FINAL REPORT – COVER PAGE

Project Title:

Overcoming constraints to high yield and CCS in large and lodged cane crops

Project reference number:

SRDC CTA030

Research organizations

CSIRO Plant Industry; James Cook University

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Funding statement:

This research was supported by SRDC and by the research organizations from the period 1 July 1997 to 30 June 2001.

Confidentiality statement

This report contains no confidential information. The results have largely been published. However, media releases and publication of the results on web sites etc that attribute the authors and their affiliation should be cleared with their respective organizations prior to release. In particular, appendices 6 & 7 contain unpublished data that should not be cited without permission of Gurmit Singh and Shaun Lisson (CSIRO CSE, Indooroopilly)

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Executive summary

Past research indicates that large sugarcane crops (that usually also happen to be lodged) experience a slowdown in growth during winter, well before harvest (Muchow et al. 1996). The project examined factors affecting the growth of crops in both the dry (irrigated) and wet tropics and aimed to interpret and explain the effects of the identified factors on net growth and death processes as well as on the stalk and sucker dynamics, cane yield and CCS. Treatments included installation of bamboo scaffolding to prevent crop lodging, and a late ratooning of the crop so that a physiologically young crop would be growing into the winter ripening period. Experiments were conducted over two seasons (1997-1998 & 1998-1999) in commercial fields in areas where large crops may experience substantial lodging under different environmental conditions (Burdekin and Tully). Four or five sequential harvests were taken to determine if and when growth slowdown occurred and to separate the effects of crop age, season and lodging.

By installing scaffolding to prevent lodging, we eliminated the growth 'slowdown' in three experiments to confirm that lodging and stalk death is part of the explanation. In both the wet and dry (irrigated) tropics, lodging of sugarcane significantly decreased both cane yield and fresh commercial cane sugar content (CCS). Prevention of lodging increased fresh cane yield by 11 - 15 %, CCS by 3 - 12 % and sugar yield by 15 - 35 % at the final harvest in August/September. The rate of increase in CCS in lodged cane was reduced following lodging, although CCS recovered by harvest to be similar to that of erect cane. While death of stalks was confirmed as a major component of the effect of lodging there was also a reduced weight and sugar content of live stalks. Dead and rat damaged stalks had CCS levels that were regularly less than 50% of sound live stalks. In the dry tropics, where cane is irrigated and grows under high radiation, sugar yield was 40 t/ha with scaffolding installed. The increased yield (compared to 35 t/ha in lodged cane) was due to both the survival of an extra 0.8 stalks/m^2 and increased accumulation of sugar in live stalks. These experimental results have been published in two conference papers and in an upcoming issue of the Australian Journal of Agricultural Research (early 2003).

Additional work was undertaken during this project in conjunction with the CRC for Sustainable Sugar Production to modify the APSIM-Sugar model to improve its ability to simulate the effects of lodging. Using experiments in the SRDC CTA028 project, we also demonstrated that substantial genotypic variation for propensity to lodge, utilizing equipment to apply a constant physical force on stalks at 1.5m high. The results of the lodging and genetic sampling research were used in another SRDC project (CTA041) as part of the calculations in the whole-of-industry variety impacts report. That report demonstrated that to improve whole-of-industry outcomes using new cane varieties, it would be desirable to raise lodging tolerance higher up the list of desirable traits in both the selection and release criteria for new cultivars. Apart from conducting a survey of the extent of crop lodging in susceptible districts, the most pressing research need is to better characterize the genetic variation in lodging and its relationship to sugar yields and to develop methods to screen efficiently for cultivars that have a reduced propensity to lodge.

LETTER: Aug 30 2002

Sugar Research and Development Corporation
PO Box 12050
Brisbane (Elizabeth St)
Qld 4002
Australia

Attn: Robert Troedson

cc: P. Jackson, G. Singh, R. Lawn, B. Messer, G. Bonnett, J. Manners

Ref: *SRDC Project CTA030 Overcoming constraints to high yield and CCS in large and lodged cane crops. Report - Milestone #7 REVISED FINAL REPORT*

Dear Robert:

Please find enclosed a revised version of the final report for CTA030, in accordance with your request to reformat the report in accordance with current SRDC requirements.

I have included the original letter and paper as submitted in January 2002. However, I have not resubmitted the CD containing all of the papers and results data that was submitted to you at that time.

Sincerely,

Dr. Scott Chapman
Crop Adaptation Scientist

LETTER: Jan 31 2002

Sugar Research and Development Corporation
PO Box 12050
Brisbane (Elizabeth St)
Qld 4002
Australia

Attn: Robert Troedson

cc: P. Jackson, G. Singh, R. Lawn, B. Messer, G. Bonnett, J. Manners

Ref: *SRDC Project CTA030 Overcoming constraints to high yield and CCS in large and lodged cane crops. Report - Milestone #7*

Dear Robert:

The milestone 7 report (final report) comprises a paper (submitted to AJAR for publication) that contains most of the results from this research project. These are summarized in the abstract of the paper. We have included an appendix (ZIP file) of chapters from Gurmit Singh's incomplete Ph.D. In particular, the chapters 1 and 2 are quite useful summaries of the prior research in this area. However, until the PhD is submitted, we request that permission be sought from Gurmit and myself before distributing this information further. Where there are any conflicts between the new paper and the draft thesis, the paper should be considered as the more up-to-date and therefore, reliable, source. Two papers published by the Australian Society of Sugar Cane Technologists were provided in previous reports and have been included in the ZIP file. Our results, perhaps due to the use of the low-suckering variety Q158 conflict with those of Hurney and Berding (2000) at the same locations in the Tully region (see the journal paper). These data (i.e. from our trials and those of Hurney et al) may be worthy of further joint investigation.

In addition, we enclose a CD containing the full set of field data from which the data in the paper have been extracted as well as the documentation and reports submitted to SRDC throughout this project. Please also note that Gurmit has supplied his field data to Di Prestwidge so that it is available to industry researchers via the SugarBag database. Given Gurmit's departure in November 2000, we have not further advanced the work on genetic variation for lodging resistance that was initiated outside the project milestones. The quantification of genetic variation for lodging that was carried out by this project and reported in milestone #6 has been incorporated into the dataset being collected in CTA028 and will be reported there in the future. Our current conclusions with respect to project objective 3 are that there are indeed prospects to improve tolerance to lodging via plant improvement.

Thank you for supporting this research. We have had the opportunity to undertake some novel field studies in sugarcane and to clearly establish some of the effects of lodging that until now have been largely speculative.

Sincerely,

Dr. Scott Chapman
Crop Adaptation Scientist

Background

Past research indicates that large sugarcane crops (that usually also happen to be lodged) experience a slowdown in growth during winter, well before harvest (Muchow et al. 1996). This occurred where environmental conditions, fertility and irrigation appeared to be favourable to produce tonnage 25 to 40% higher than were observed, i.e. farmers may have been foregoing substantial income. However, it is not known whether environmental factors and/or lodging are the cause. If we understood the causal factors and the mechanisms that slowed overall growth, then a management or breeding solution may become apparent. For example, if lodging were determined to be a factor, then breeding for lodging resistance might be practical, particularly given that current procedures in early-generation selection bias selection toward taller varieties that may be more susceptible to lodging.

It is also known that well-grown crops of sugarcane in the wet tropics frequently have low mill CCS. An industry analysis by Leslie and Wilson (1997) suggested that a declining trend in CCS in the wet tropics was associated with several factors that increase the extraneous matter (EM) delivery to the mills, including lodging, suckering and stalk deterioration. Sugarcane suckers are shoots that appear late in the growing season, when other tillers have already produced a large amount of millable cane. In one-year crops, such as those in far-north Queensland, suckers are harvested along with mature stalks, and due to their short period of growth, are low in sugar content. The project examined the growth of crops in both the dry (irrigated) and wet tropics.

There are several possible explanations for the slowdown in yield accumulation:

1. Loss of above-ground biomass has occurred due to death and rotting of stalks (part of canopy) or via increased canopy respiration (whole canopy);
2. Potential canopy photosynthesis is decreased directly by the environment (temperature?) or in relation to changes in crop development (maturation?) or the growth of storage volume in stalks.

One other alternative is that part of the 'missing' biomass was stored in underground parts that had not been recovered in experiment harvests and which will be measured in this project. To identify the causes of this slowdown in growth we need to separate the interacting 'factors' of lodging, season and crop size/age and consider the effects at different 'levels' of analysis, i.e. for the crop overall and for components or parts of the crop (stalk age classes etc.). Once this is done and the mechanism of the slow-down has been explained, potential genetic and/or management solutions can be recommended.

An improved understanding of the processes occurring would also improve the usefulness of crop simulation models to estimate growth of high-yielding crops for applications such as yield forecasting and for generalising experience over regions and seasons. The proposal is directed towards SRDC objectives in both programs 1 and 2, aiming to increase yields via both genetic and management means, depending on which avenue appears to be most suited.

Muchow, R. C., Wood, A. W. and Robertson, M. J. (1995). Does stalk death set the yield ceiling in high yielding sugarcane crops? *Proc. Aust. Soc. Sugar Cane Technol.*, 17: 142 - 148.

Wilson, G.L. and Leslie, J.K. (1997). Productivity trends in sugarcane in the wet tropics. *Proc. Aust. Soc. Sugar Cane Techno*l. 19:21-29.

Objectives

1. Determine what factor(s) cause large and lodged crops to slow down production of biomass and sucrose well before time of harvest, even when environmental conditions appear to be suitable for high growth rates. This potentially large foregone yield is currently 'unnoticed' in the industry.
2. Interpret and explain the effects of the identified factors on net growth and death processes as well as on the stalk and sucker dynamics, cane yield and CCS.
3. Determine whether the identified constraints to yield will be best addressed via breeding and/or management options. In particular, if lodging is found to be an important constraint, alternative methods of selecting varieties for high-yielding environments may be appropriate and would be discussed with plant breeders in BSES.

Methodology

Description/Plan

The project was focussed around an SRDC sponsored post-graduate student (Gurmit Singh) at JCU co-supervised by Prof R.J. Lawn (JCU) and CSIRO scientists. The first task was to research the literature and SugarBag database and analyse data from high-yielding trials that have/have not experienced substantial lodging. Experiments were conducted over two seasons (1997-1998 & 1998-1999) in commercial fields in areas where large crops may experience substantial lodging under different environmental conditions (Burdekin and Tully). Treatments were imposed to prevent lodging and determine whether was a factor in causing the differences in growth. Other treatments included planting late so that the crop age going into winter is much younger than for the normal planting dates. Four or five sequential harvests were taken to determine if and when growth slowdown occurred and to separate the effects of crop age, season and lodging. In addition to observations of stalk size, stalk number and crop biomass components (including below-ground), measurements aimed to distinguish between the processes of stem breakage/bending and root lodging.
Analysis of these data aimed to determine the factor(s) and some possible mechanisms(s) by which growth slowdown occurs. Once this was done, the Ph.D. developed to use crop growth simulation modelling to examine in more detail the mechanisms behind the slowdown and their impact across different production environments. Apart from typical trial costs, the field trials themselves required a high degree of technical supervision and frequent observation as well as extra costs associated with the construction of scaffolding to impose non-lodging treatments. For example, more than 4 linear kilometres of bamboo was cut to build the scaffolding in all of the experiments.

Relationships/Linkages

The research built on some significant findings of SRDC-funded research in physiology (Muchow et al.). We also aimed to provide new information to improve models of sugarcane growth that did not separate these confounding effects. The issue of genetic variation in crop respiration was previously addressed by UQ11S, and would have been a useful starting point should this be suggested as a factor (it wasn't!). The project was centered around a Ph.D at the CRC for Sustainable Sugar Production. No direct or indirect environmental impacts resulted from this research.

At the time of the submission of this report, Gurmit Singh had not submitted the final version of the PhD. Under supervision of Prof. Lawn, he was continuing to work on the writing up of the thesis, having taken a job in Sydney as of September 2000.

Additional work beyond project specifications

All experimentation was completed in accordance with the project milestones. Given that progress and the assisted resources of the joint CRC project, we undertook two additional activities during the life of the project:

- With the assistance of Shaun Lisson (CRC Sugar) used the experimental data to develop a modification of the APSIM-Sugar module to account for lodging effects. Also used the model to re-interpret the results of the Burdekin experiment to determine if there was a slight water stress effect in the experiment near the end of the season.
- Used the CTA028 project to undertake a pilot assessment of genetic variation in lodging propensity.

The methods and preliminary results of these additional activities are given in the appendices.

Project milestones

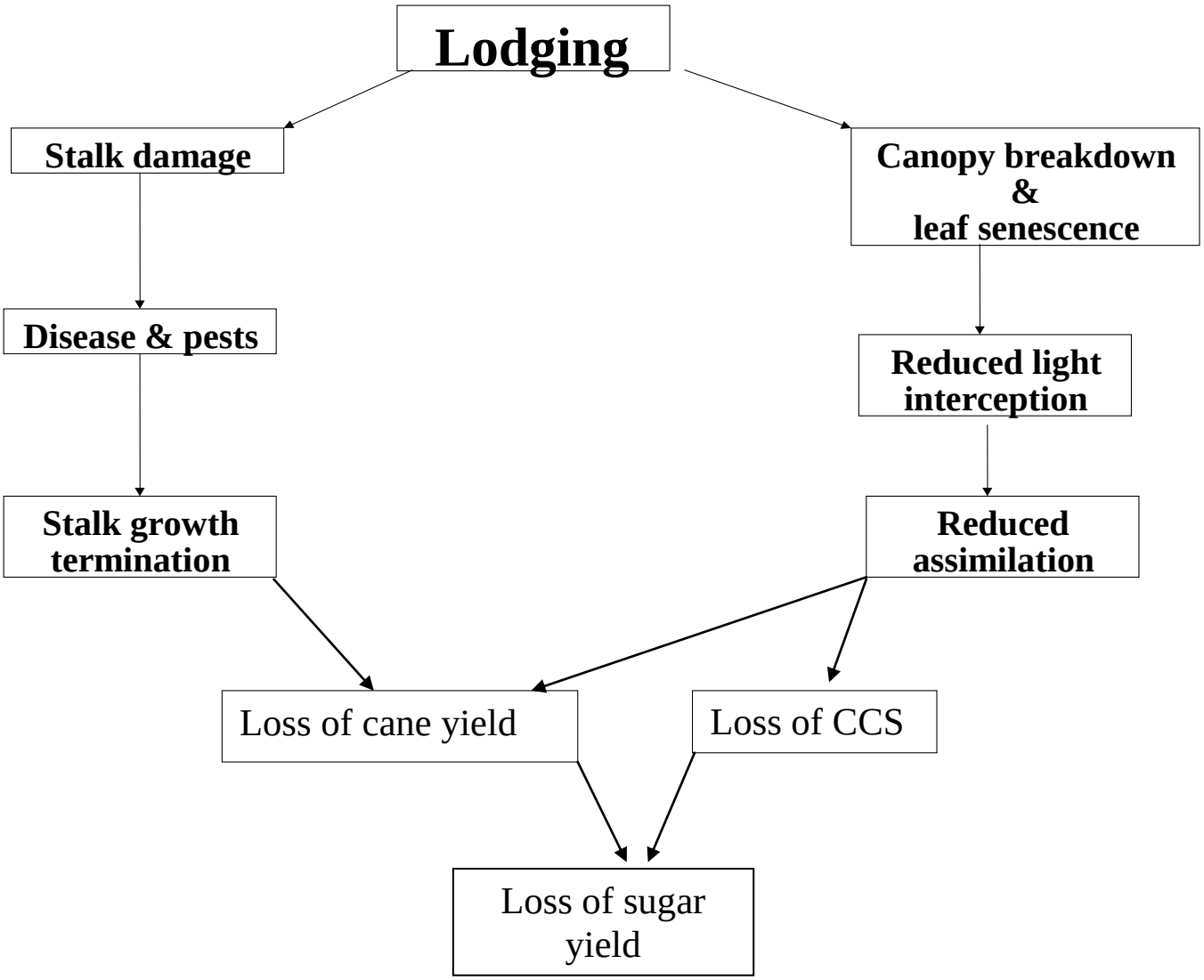
Date	Milestone	Description
1/07/1997	1	Signing of agreement. **Achievement** Agreement signed to satisfaction of all parties.
1/03/1998	2	Obtain capital items and plant first crop. **Achievement** Equipment purchased. Student appointed. Literature review completed to satisfaction of JCU requirements for Ph.D.
1/09/1998	3	Plant crop cycle harvested and all measurements taken. **Achievement** Preliminary analysis of plant crop data completed and objectives set for ratoon crop.
1/06/1999	4	Complete analysis of the plant crop results for a mid-term review. **Achievement** Mid-term report to SRDC on significance of lodging, crop age and season on plant crop yields in Burdekin and Tully. Submit conference paper for ASSCT.
31/01/2000	5	Preliminary analysis of second season of data. **Achievement** Preliminary report on second season of results. Set objectives and prepare work plan for the final season of study.
31/07/2000	6	Integration of results of the field experiments. **Achievement** Submit scientific manuscript(s) on results of field program.
1/09/2002	7.6	Submission of final report

Achievement
Final report accepted by SRDC

Results

The results of this research are reported briefly here as modified versions of the milestone reports (3 to 6). In the appendices, there are additional results in the form of three published papers and in two unpublished reports on simulation of lodging and genetic variation for the trait.

Lodging was found to be the major cause of yield loss in these irrigated and wet-tropics trials (cf. slowdown in biomass accumulation or seasonal effects). The figure below is used in the papers and particularly in Gurmit Singh's PhD as the basis of his interpretation of the effects of lodging on sugar yield, via both decreases in cane yield and CCS.



Milestone 3

The first trials (1997/98) were planted prior to the start of the funding for the project. Three sites (Ayr, Feluga and Euramo) were planted, the latter two in the Wet Tropics being planted on the same sites as the SRDC BSES project examining N and variety effects on CCS (Hurney and Berding). Following the failure of the Ayr trial (due to a cane beetle infestation – see milestone 2 report), we removed the bamboo scaffolding from the site for re-use in the 1998/99 trials.

Crop growth was not as greatly hampered in any of the treatments as we expected. It seems that the warm winter (>2°C cf. 30 year average) contributed to this continuation of growth. However, we were able to show, for the first time we believe, that lodging per se can reduce cane and sugar yields compared to a crop which has not been allowed to fall.

New plant crop trials were established in 1998/99 at one of the Tully sites (Feluga) and in the Burdekin. We decided to concentrate on one site in Tully, to make the workload more manageable, and enable more detailed measurements at a single location. The Burdekin site was chosen after extensive consultation with BSES about likely cane grub infestation problems etc. and will be protected as well as possible using all available methods. The site chosen last year had not had cane grubs in the last 10 years, but we believe that the new site will be even more isolated.

Results were written up and interpreted for a paper in ASSCT April 1999 (see appendix). At this stage of the second season of study, we believe that the original results are likely to be confirmed. In the most recent harvest (within the last month) this season, at both sites, the CCS of the lodged treatment was between 1 and 2.2 units below that of the control (scaffolded) treatments. There was no repeat of the problems with cane grub experienced in the Burdekin 1997/98 trial.

Milestone 5

Results from the second season of study were written up and interpreted for a paper, ASSCT May 2000, in appendix 1. These results were consistent with the findings from the first season of study:

1. Lodging was found as a major constraint to high yields and CCS in both the dry and wet tropical environments due to consistently large negative impact on the crop growth, sucrose accumulation and sugar yields. Prevention of lodging increased cane yield by 11-19% and sugar yield by 15 -35% depending upon the timing/nature/extent and number of lodging events.
2. While death of stalks was confirmed as a major component of the effect of lodging there was again reduced weight and sugar content of the live stalks. This was associated with reduced light interception by the canopy of those stalks. While dead and rat damaged stalks were of lower weight that live stalks, their CCS levels were normally less than 50% of sound live stalks.
3. The losses from lodging could be much more considering the harvesting and extraneous matter problems. This issue needs to be addressed either through improved variety selection program or better crop management or a combination of both.

Comments on an improved sampling methodology for lodged conditions

Due to our interest in the fate of cane stalks where lodging occurs, we employed an additional methodology to that used/recommended by the CRC guidelines for

minimum datasets. The standard approach in quadrat sampling is to enter the plot area and sample plants from a given amount of land area, usually 4 rows x 2.5m. In our trials, all harvest areas were marked out (using flagging tape and marking pegs) at the same time in Feb-April, before lodging occurred. Stalks with >1m millable cane were counted at that time, and during subsequent harvests all of these stalks were accounted for as live or dead. In some previous experiments, researchers have reported decreases in total stalk number during the later part (say 8-12 months after planting) of the season even after most millable sections of stalks were >1m. Based on our observations and the experience of researchers in the CSR breeding program, we do not believe that stalks can die and decompose in the time periods between lodging and harvest, even 6-7 months after severe lodging in the wet tropics. While the previous researchers indeed found that stalk death increased, the net loss of stalks they reported is difficult to explain, other than as a function of sampling variation.

This project has been supported each year by additional funding from the CRC for Sustainable Sugar Production and by JCU with a Ph.D. scholarship for Gurmit Singh. Related projects include one supervised by BSES (Alan Hurney and Nils Berding) and another CRC Sugar project investigating suckering (Graham Bonnett, CSIRO Tropical Agriculture and Barry Salter, Ph.D. student, CRC). In the recently-completed SRDC project into the "whole of industry" impact of new varieties, Jackson and colleagues found that lodging was an important trait economically compared with other traits currently selected for (cane yield and whole-stalk CCS). That study used data collected within CTA030 on which to base some assumptions. It was concluded that the value of incorporation of lodging propensity in a selection index in breeding programs should be assessed.

Milestone 6

Results from the second series of experiments were presented at ASSCT May 2000 by Gurmit Singh and at the CRC for Sugar review on July 18 2000.
In the milestone 5, we proposed to undertake some investigative field work into the genetic variation for lodging resistance. A work plan was detailed in that milestone. While this was additional work beyond the original research proposal, we decided to get a start in this area as we believe that we already have sufficient evidence of the effects of lodging on cane and sugar yield. The main aim of these measurements, utilizing current trials in the GxE project (CTA028) was to try to relate variation in lodging propensity scored at harvest with a quantitative measure of lodging taken earlier in the season.
This work is reported in the appendix.

Outputs

The main outputs from this proposal were information, published as media releases, in conferences, scientific journals (see appendix) and CRC and SRDC milestone/annual reports. As the experiments were run on-farm and involved some 'interesting' treatments, the on-site field days to present and discuss the research with local growers were well-attended and attracted substantial attention, including an article in Sugarcane magazine.

Popular media reports

- Time for lodged cane to stand up and be counted. Australian Sugarcane, Oct-Nov 1998 p23.
- Upright cane produces more sugar. Australian Canegrower, Nov 9, 1998, p16.
- Erect cane has 18% higher sugar yield. Tablelander (Atherton), Nov 3, 1998, p25.
- Upright cane produces more sugar. Queensland Farmer, March 1999, p14.
- Overcoming the high cost of lodging. Australian Sugarcane, Dec-Jan 1999-2000. p13.
- Other local reports in 98/99 were in "Bush Telegraph (Mackay)", "Courier Mail" and the "The Observer (Home Hill)".

Field days

April 2, 1998: a small field visit was held at the Tully site for all participants in the Sugar CRC Program 3. This research is in part funded under sub-program 3.3.
July 1998: a field day was conducted at the Feluga site to demonstrate the treatments and their effects to CRC and other scientists

Expected Outcomes

Given the findings of the industry project CTA041, the major outcome of this research is the accurate quantification of the effect of lodging in several 'well-grown' crops and an increased awareness of the issue. The project demonstrated that a 1 year 40 t/ha sugar crop could be grown in the Burdekin, given the prevention of lodging. These results have been well discussed in industry fora and, together with the results of the whole of industry project, have led to an increase in the value placed on lodging tolerance in the breeding programs. While increased tolerance to lodging has made substantial impacts in cereals such as wheat and maize, it is not yet clear how much lodging tolerance can be increased through the breeding of sugarcane.

Future Research Needs

We note that the effects of lodging on sugar yield in commercial crops can well be expected to be greater than what we observed here, as the lodging events that we experienced were relatively 'gentle'. To the extent that lodging is related to plant size, it may be the case that the effects of lodging are lessened in crops grown in narrow rows or other configurations, and in crops where nitrogen and water supply are managed to be less abundant than in our experiments. With these points and the outcomes in mind, the clearest future research needs are:

1. to establish the approximate degree of impact of lodging in susceptible districts. Satellite and aerial imagery could assist in this task, and potentially be used to assess the degrees of losses due to lodging

2. determine whether useful genetic variation in lodging exists and can be selected for in sugarcane breeding programs.

Recommendations

Our main recommendations are to try to utilize another current research project, CTA028, to attempt to partially answer point 2 of the future research needs (we have already begun this effort). In the final report to CTA033, the authors detailed the research that would be required to effectively incorporate other breeding traits like suckering and lodging tolerance into the breeding programs. As to developing the research related to point 1, it would be useful to engage with systems researchers to determine whether the simulation research and/or remote sensing methods can be incorporated into their assessments of district yields. Presentation of our results would be a useful contribution to a larger meeting that is examining methods to estimate district yields.

LIST of APPENDICES Publications, press releases and reports

1. CSIRO press release Oct 27, 1998
2. Singh, G., Chapman, S.C., Jackson, P.A. and Lawn, R.J. (1999). Yield accumulation in sugarcane under wet tropical conditions – effect of lodging and crop age. Proc. Aust. Soc. Sugar Cane Technol., 21: 241-245. (Gurmit Singh was awarded the best student paper prize at the ASSCT meetings in Townsville in April 1999 for the above paper)
3. Singh, G., Chapman, S.C., Jackson, P.A. and Lawn, R.J. (2000). 'Lodging' -a major constraint to high yield and CCS in the wet and dry tropics. Proc. Aust. Soc. Sugar Cane Technol., 22: 315 - 321.
4. Singh, G., Chapman, S.C., Jackson, P.A. and Lawn, R.L. (2002). Lodging reduces sucrose accumulation of sugarcane in the wet and dry tropics. Australian Journal of Agricultural Research (accepted, in press)
5. Report on field work to assess genetic variation in lodging propensity
6. Chapter 5 of Singh thesis: Simulation modeling studies
7. Report on Gurmit Singh's trial simulations (by Shaun Lisson, CRC for Sustainable Sugar Production, May 2000)

APPENDIX 1 CSIRO PRESS RELEASE

http://www.csiro.au/news/mediarel/mr1998/mr98253.html:

UPRIGHT SUGARCANE PRODUCES MORE SUGAR

Cane that remains erect has an 18% higher sugar yield than cane that has fallen over in the canefields, a CSIRO experiment has found.

According to scientists working at the CSIRO's Davies Laboratory in Townsville, the problems with harvesting fallen sugarcane plants, or lodged cane as it is called, are well known. But the effects of lodging on crop growth and the commercial sugar content of cane stalks was an unknown factor.

"Lodging is very common in well grown sugarcane following wind or rain," explained Dr Phillip Jackson.

"This year, lodging was widespread throughout Queensland with the unusually wet conditions experienced. Apart from directly reducing sugar yield, lodging makes harvesting difficult as harvesters cannot remove the tops from the cane before it is cut - this means extra leaves and trash in the cane bins that are sent to the mill, reducing the sugar concentration in harvested cane. This leads to higher transport and milling costs per unit of sugar produced, reducing industry profitability."

And according to Dr Jackson, when lodging occurs, it is usually the better grown cane that lodges first.

"This has tended to cloud the issue over whether lodging has an adverse effect on sugar yield. In fact, lodging is expected by many growers as an indication that their crop has grown well," he said.

These issues led to a Sugar Research and Development Corporation sponsored collaborative research project between CSIRO Tropical Agriculture, CSR Ltd and the CRC for Sustainable Sugar Production in which the effects of lodging on yields and sugar content was investigated in a field experiment in the Tully region.

"One treatment used in these experiments involved the erection of 2 kilometres of bamboo scaffolding to stop the cane from lodging," explained Gurmit Singh, a Ph.D. student who conducted the experiments.

"This allowed a direct comparison between lodged and erect cane growing under exactly the same conditions. Obviously, growers will not be erecting scaffolding in their fields, but the research has shown that genetic or management approaches to stop the cane from lodging would be useful."

Researchers believe it is likely that the effect of lodging differs between different varieties of sugarcane.

Mr Singh and other workers at CSIRO will be conducting further field experiments in the Tully and Burdekin regions next year. Experiments are also planned to be conducted in a new special purpose 'sugarcane' glasshouse which is to be built at the Davies Laboratory next year.

The work on lodging is part of a wider effort in CSIRO and other research organisations to identify the basic limits to higher sugar yields in well managed commercial sugarcane fields.

For further information, contact Mr Gumit Singh or Dr Phillip Jackson 07 4753 8500

Commonwealth Scientific and Industrial Research Organisation
(Australia's largest scientific research organisation)

Appendix 2: Singh, G., Chapman, S.C., Jackson, P.A. and Lawn, R.J. (1999).

(photocopy of paper to be inserted here)

Appendix 5: Field work to assess genetic variation in lodging propensity

Background

From work done in 1997/1998/99 it was clear that lodging was a major constraint to CCS, cane yield, and industry profitability. There was evidence of a reduced rate of sucrose accumulation caused by lodging, but no evidence for any large slowdown associated with seasonal or crop age effects.
It is known that varieties differ greatly in propensity to lodge. Given this, and given the economic importance of lodging it is possible that lodging resistance could be used in a selection index in different stages in selection in regional sugarcane selection programs. Several basic areas of information are needed to determine if, and how, traits related to lodging resistance could be used to improve selection systems compared with present procedures.

Objectives

1. To obtain some basic information about genetic variation in lodging in order to determine if and how it should be used as a selection criteria in sugarcane selection systems. Information to be obtained will examine the following issues:

- Degree of genetic variation in lodging propensity
- Error variation and broad-sense heritability of lodging propensity
- Genetic correlations of lodging propensity with cane yield, suckering and CCS in different environments.
- Assessment of traits that could be useful predictors of lodging propensity (eg. force needed to pull cane to a certain angle, visual ratings before lodging, stalk diameter/height ratio, fibre content etc.).

2. To make recommendations on the use of lodging propensity as a selection criterion in different stages of selection, and on further work needed to determine specific procedures that should be adopted for this in core breeding programs.

Similar questions should be addressed for suckering propensity at the same time, given the frequent association between lodging and suckering.

Methods

It is proposed to utilise variety trials already established in breeding programs and other projects. The mega-GxE trials will be suitable for providing information about unselected clones. Advanced stage breeding program trials will be suitable for providing information pertaining to highly selected clones across different environments. A major advantage of using these trials is that costs of establishment and of measuring cane yield and CCS will be nil since this work is being done for other projects/programs.
Use 2 mega-GxE trials in the Herbert, 2 in the Burdekin and 2 in the Central region. Also, use 4 BSES 2nd ratoon multi-environment variety trials in the Herbert, and 4 CSR multi-environment variety trials in the Burdekin. The 2nd ratoon trials should be useful for determining if there is any relationship between ratoon performance and suckering propensity. In each trial make the following measurements at two times:

1. Measure stalk diameter, stalk height, force to pull from vertical, visual rating of lodging propensity in all plots at a stage where cane is well grown (but not yet lodged). This will vary for different trials but between February (Burdekin trials) and April would probably be best.
2. Assess degree of lodging and suckering at a time when the trial just starts to lodge, and then at harvest. It would be advantageous if the same person (BM or FZ) can be present at harvest of each trial to help ensure consistent ratings are obtained across all trials.

Analyses

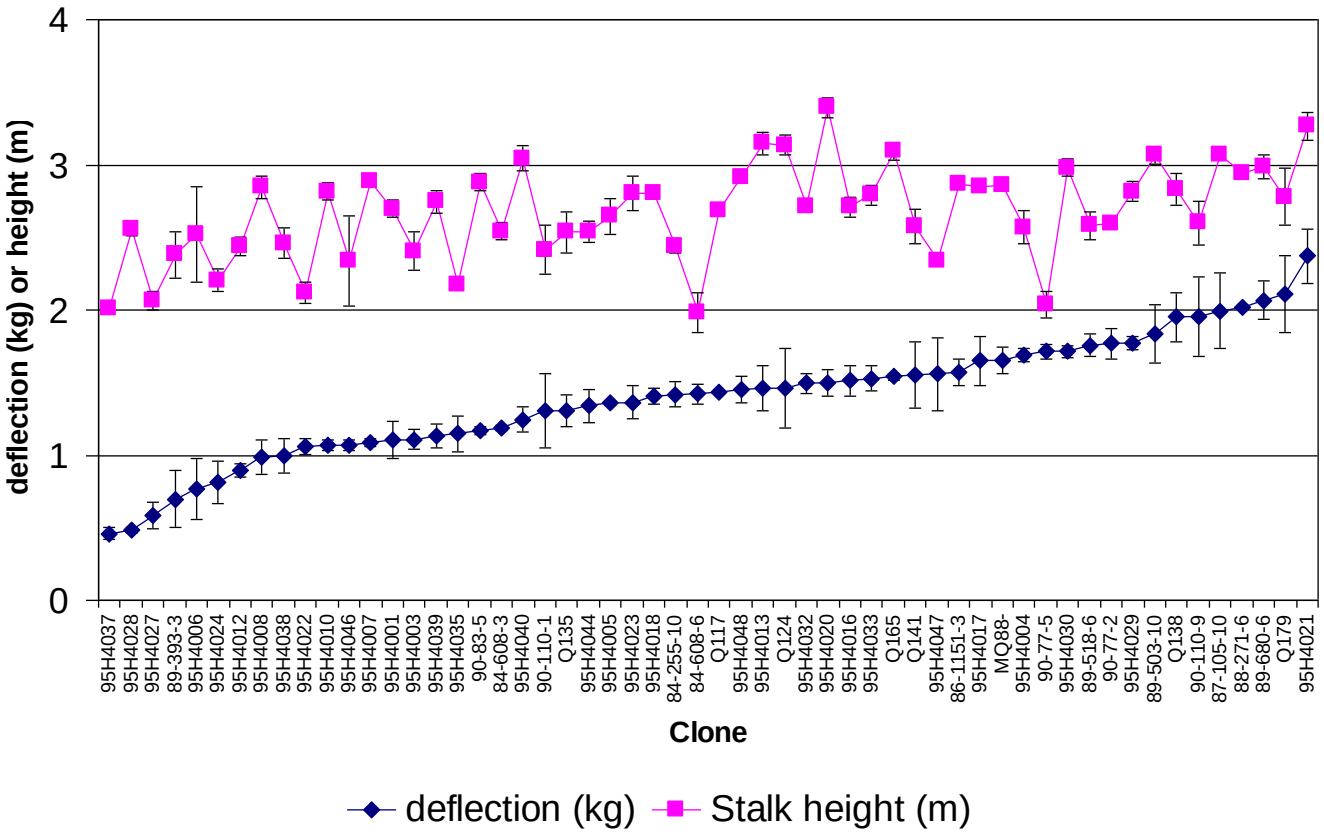
Conduct analyses of variance and covariance for all measurements made. Determine broad sense heritabilities of each and genetic correlations among the different measurements. Assess if lodging propensity is repeatable in trials and if it can be easily predicted. Determine possible optimal selection indices based on data obtained. Identify what further issues need to be addressed before making confident recommendations on selection procedures to adopt in core programs in relation to lodging and suckering propensity.

Results

After several days of field trialling, Phillip Jackson, Bill Messer, Franco Zaini and technical staff at CSIRO/CSR constructed a PVC tubing "measuring stand" consisting of a 3.5m high tube with a fixed 0.4m horizontal tube. This was held alongside a stalk in the field. A spring balance was attached to the stalk at 1.5m from the ground and the balance pulled horizontally until the stalk had been deflected by 0.2m. The balancing force required to hold the stalk at this point was registered. This method is based on similar approaches that have been used for maize. In practice, the procedure usually measured the "bending" of stalks. However, in some clones, with relatively stiff stalks, the force was sufficient to cause stool-tipping (root lodging).

In early May 2000, measurements were made on 5 stalks per plot in the central 2 rows of 4 row plots in the two CTA028 experiments in the Herbert, containing 48 random clones and six commercial clones. The data from Abergowrie are presented below. There were significant differences ($p < 0.01$) among clones. The following figure (clones ranked by deflection force) shows that there is a substantial variation in this value across the clones from 0.5 to 2 kg. This is positively correlated with stalk height (0.51), but not with stalk diameter at 1.5m

Using data from two trials in the Herbert, we found the following high positive genetic correlations (> 0.7) between either sugar or cane yield and both the cane height and the force needed to deflect the stem. The stem deflection force was highly correlated with both cane length (0.72) and diameter (0.82), though length and diameter were poorly correlated with each other (0.19). The broad sense heritabilities of stem deflection force and cane length were >0.7 while that for stem diameter was 0.66.


deflection (kg) or height (m)
4
3
2
1
0
95H4037
95H4028
95H4027
89-393-3
95H4006
95H4024
95H4012
95H4008
95H4038
95H4022
95H4010
95H4046
95H4007
95H4001
95H4003
95H4039
95H4035
90-83-5
84-608-3
95H4040
90-110-1
Q135
95H4044
95H4005
95H4023
95H4018
84-255-10
84-608-6
Q117
95H4048
95H4013
Q124
95H4032
95H4020
95H4016
95H4033
Q165
Q141
95H4047
86-1151-3
95H4017
MQ88-
95H4004
90-77-5
95H4030
89-518-6
90-77-2
95H4029
89-503-10
Q138
90-110-9
87-105-10
88-271-6
89-680-6
Q179
95H4021
Clone
deflection (kg)
Stalk height (m)