G 3. ADDRESSING FACTORY NEEDS IN CANE VARIETY SELECTION

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Abstract

Cane fibre content has increased over the past ten years. Some of that increase can be attributed to new varieties selected for release.

This paper reviews the existing methods for quantifying the fibre characteristics of a variety, including fibre content and fibre quality measurements – shear strength, impact resistance and short fibre content. The variety selection process is presented and it is reported that fibre content has zero weighting in the current selection index.

An updated variety selection approach is proposed, potentially replacing the existing selection process relating to fibre. This alternative approach involves the use of a more complex mill area level model that accounts for harvesting, transport and processing equipment, taking into account capacity, efficiency and operational impacts, along with the end use for the bagasse. The approach will ultimately determine a net economic value for the variety. The methodology lends itself to a determination of the fibre properties that have a significant impact on the economic value so that variety tests can better target the critical properties.

A low-pressure compression test is proposed as a good test to provide an assessment of the impact of a variety on milling capacity. NIR methodology is proposed as a technology to lead to a more rapid assessment of fibre properties, and hence the opportunity to more comprehensively test for fibre impacts at an earlier stage of variety development.

Introduction

There is a rigorous and well defined process in place that manages the selection and release of new varieties in each region. Australian sugarcane variety breeding programs consist of four main stages, from seedlings through to propagation for release. During the second and third trial stages, varieties are assessed for disease resistance, sugar quality, fibre content, CCS and tonnes of cane produced (Cox *et al.*, 2000). Variety performance characteristics are weighted according to their economic importance in each regional area and incorporated into a relative Economic Genetic Value (rEGV). In calculating rEGV, traits are weighted on the basis of their economic benefit over the whole sugar production process, from harvesting to marketing (Wei *et al.*, 2008). This value allows plant breeders to select clones on the basis of their overall economic benefit for the whole of the Australian sugarcane industry, in comparison to the average performance of standard commercial varieties (Wei *et al.* 2008).

Fibre content was originally given a negative weighting in the Sugar Research Australia (SRA) selection index (Wei *et al.*, 2006). Since 2010, fibre content has had a zero weighting in the selection index. Only the most advanced varieties are tested for fibre quality characteristics, prior to release. Although the process is well defined, there is a regular need to review the methodology to ensure that it meets the needs of each region. The current methodology has seen some criticism that it does not adequately reflect the costs of processing in the factory. While high fibre is desirable in some mill areas that have adequate processing capacity and can benefit from the fibre in terms of cogeneration income or steam supply, high fibre in other mill areas is a processing rate limitation and/or causes a bagasse disposal problem (Kent, 2007).

This paper sets out to review the emphasis placed on fibre content and fibre qualities in variety selection and the impact of these factors on factory income and factory costs. Revisions to the current process and methodology are proposed to better match industry income and production costs.

Trends in fibre content

Figure 1 shows cane fibre content trends across six mill areas over the past 10 years. Average cane fibre content has increased in all six mill areas. Of course, variety selection is only one contributing factor towards fibre content level. Trash content in cane supply can be influenced by harvesting practices, such as green harvesting, topping height and fan speed (Jones, 2004; Pope *et al.*, 2004), or wet weather conditions at harvest (Ridge and Norris, 2000). Seasonal effects on the percentage of arrowing (Rao and Kumar, 2003), side-shooting and lodging (Ridge and Norris, 2000) can also contribute to fibre levels.

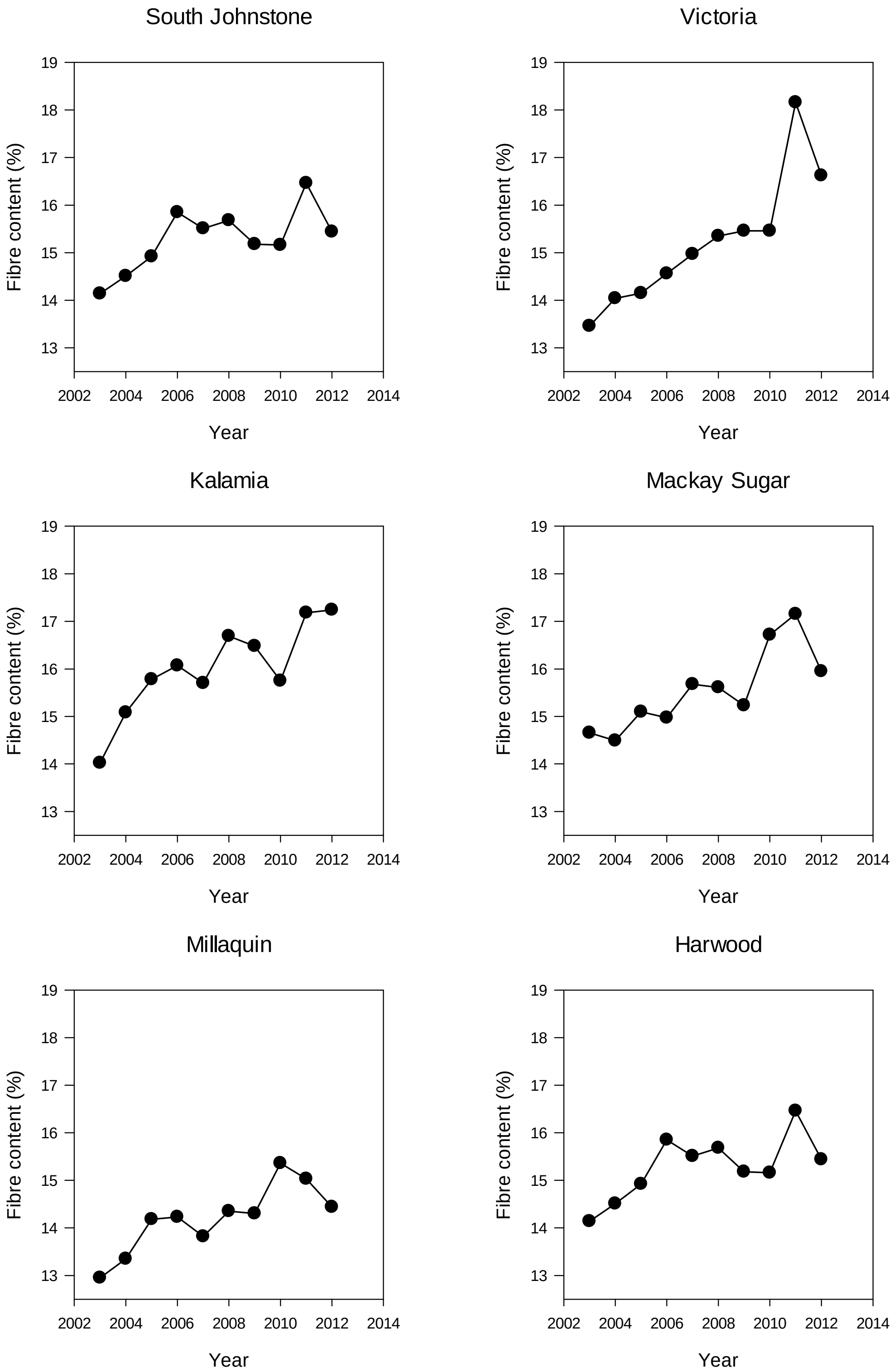

Fig. 1—Cane fibre content trends (2003 – 2012) for six mill areas

To gain an indication of the contribution of variety to fibre content at the factory, each variety was assigned a single regional cane fibre content value, based on fibre content measurements made by SRA for that variety in variety trials. The fibre content for each year was weighted according to each variety's proportion of the harvested crop for a mill to give an estimate of cane fibre content. The estimated fibre contents based on regional variety trial data are compared to the actual mill fibre contents for South Johnstone and Millaquin factories in Figure 2. In both cases, variety does appear to have had an impact on the measured fibre content at the factory, since the variety trial data and factory measurements both increase over the period.

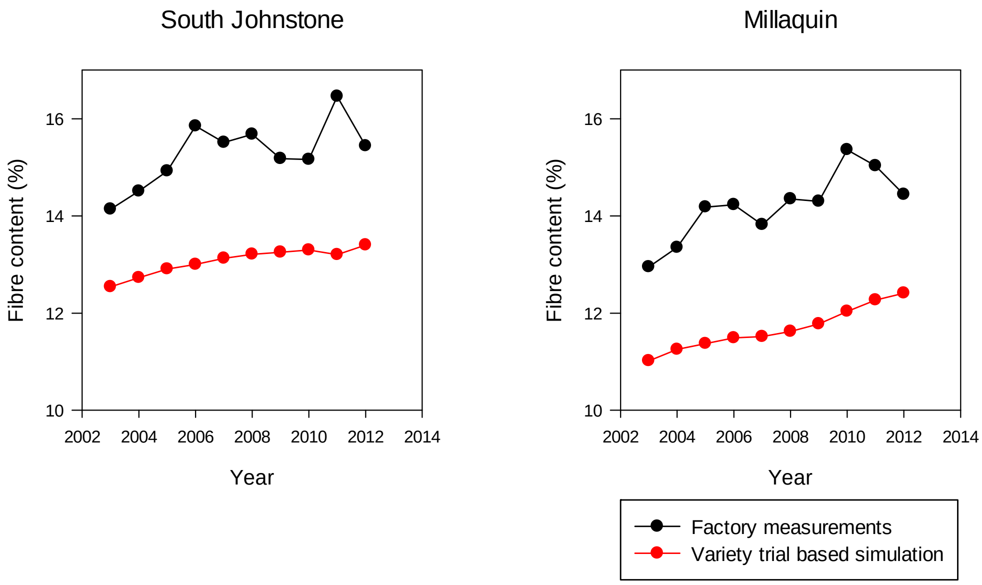

Fig. 2—Comparison of actual fibre content against fibre content estimated from SRA variety trial data.

Current selection methodology

Quantifying fibre content

Prior to 2008, only select variety trials were sampled for fibre analysis due to the time required to process samples using the conventional bag method (Method 4 of Bureau of Sugar Experiment Stations, 2001). Near infra-red (NIR) spectroscopy is now used at the Meringa, Ayr, Mackay and Bundaberg centres in Queensland to analyse fibre content, as well as brix and polarimeter readings. SpectraCane™ is the automated NIR-based system used in the SRA selection programs. It is capable of efficiently analysing a wider range of cane quality components (Berding and Marston, 2010). Every tenth sample through SpectraCane™ is automatically saved and processed through the conventional laboratory where juice is squeezed from the shredded cane using a hydraulic press. The remaining fibre is then dried and weighed to calculate the fibre content. At the end of each harvesting season, SpectraCane™ is re-calibrated against the conventional laboratory data. The 2012 fibre calibration, based on data collected from 2008 to 2012, had a root mean standard error of cross validation (RMSECV) of 0.78 and an R-squared value of 0.89.

Assessing fibre quality

Three main tests were established by BSES Limited and Sugar Research Limited for the measurement of cane fibre quality. These measurements are used to identify whether or not a variety is likely to cause mill handling (handleability) problems. Prior to fibre quality analysis, cane material is prepared using a hammer mill. Figure 3 shows the fibre quality measurement equipment.

A standard weight of shredded cane is compressed between two nailed boards which are then pulled across one another in opposite directions. The kilogram force (ranging from 0 – 50) required to shear the block of cane is referred to as shear strength. This measurement is used as an indication of the ease of conveying shredded cane for a given variety (Brotherton *et al.*, 1986).

The impact resistance test is used to measure the energy absorbed by a core sample of cane, during shear fracture by impact. A 10 mm core internode sample is placed within an anvil, and then a pendulum is swung into the core sample after being released from a horizontal position. The cosine of the highest angle reached by the pendulum is recorded. Impact resistance relates to the density of vascular bundles within the internode (Brotherton *et al.*, 1986).

Short fibre content, also referred to as pith content (Brotherton *et al.*, 1986), is measured during fibre quality analysis by tumbling one kilogram of shredded cane in a 12 mm^2 wire cage for 90 seconds. The short fibres are then collected from a tray underneath the tumbler cage and weighed.

Fig. 3—Equipment used to measure fibre quality components; a) hammer mill for cane preparation, b) impact resistance, c) shear strength and d) short fibre content.

A variety may be termed a ‘soft’ cane if it has a low impact resistance (<0.3) or low shear strength (<10). A variety may be referred to as a ‘hard’ cane, if it has a high impact resistance (>0.8) or high shear strength (>38). These values are used as a guide to whether or not a variety will be difficult to handle with equipment typical of an Australian sugar factory. Within these limits, a variety is considered safe for processing. Figure 4 demonstrates the varying fibre quality of four released cane varieties and the safe ranges for each measurement.

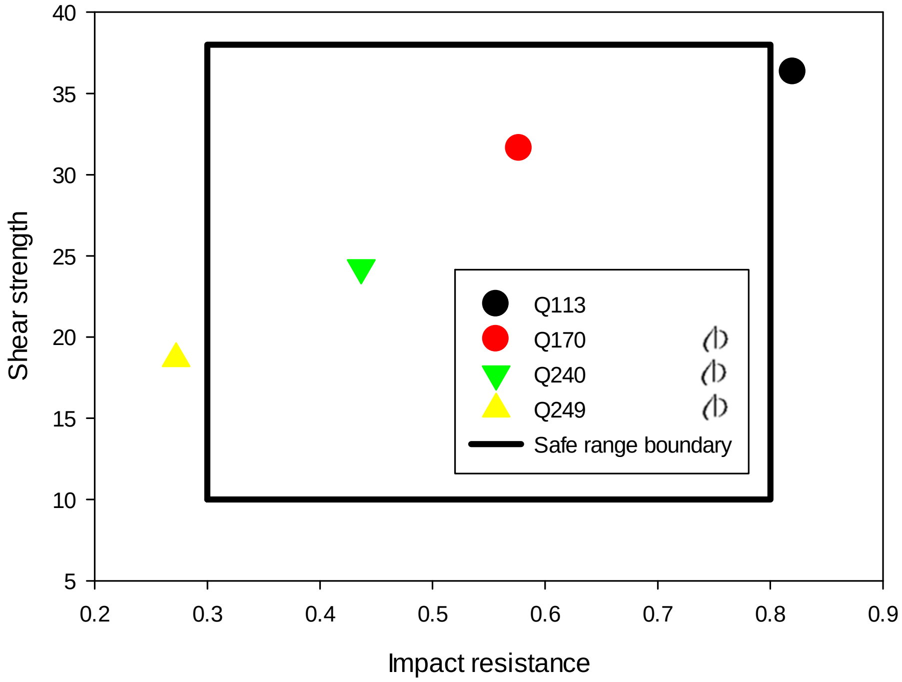

Fig. 4—Mean impact resistance and shear strength of four released cane varieties. Q170 and Q240 fall into the safe range for both parameters.

The fibre quality of new varieties is tested only in the final two years prior to release due to the expense of the sampling procedure. If a variety exceeds the safe ranges for either measurement (Figure 4), then it is usually monitored closely during the first few years of production and shredding and milling equipment may be adjusted to ensure efficient handling of the cane (Brotherton *et al.*, 1986).

Use of fibre tests in variety selection

Australian sugarcane variety breeding programs consist of several stages. Canes are assessed for sugar content, fibre content and tonnes of cane produced at all variety trial stages. During the later stages of the selection program clones are also tested for resistance to major diseases, sugar quality and fibre quality.

The rEGV is a selection tool used to assess the potential economic benefit of a clone for the whole of the Australian sugarcane industry (Wei *et al.*, 2008). This value provides information to breeders and technicians about which individuals should be selected as parents for crossing, which clones to advance to the next stage of the selection process, and which clones should be released for commercial production. This value is calculated relative to the average of standard commercial varieties (assigned a value of 10) and incorporates both the genetic value and economic value of multiple traits, including tonnes of cane per hectare (TCH), commercial cane sugar (CCS), fibre content and disease ratings. While TCH, CCS, and fibre content (plus appearance grade in the northern program) are assessed from field trials, resistance to important diseases is generally evaluated in screening trials specifically established for this purpose.

The economic value (or weighting) of a trait included in the rEGV represents the economic benefit of that trait over the entire sugar production process (Wei *et al.*, 2008). For example, an increase in TCH will have a positive effect in the amount of sugar produced, but will also have a negative effect by increasing harvesting and transportation costs. Such factors were considered in the establishment of these weightings by consultation with experienced industry representatives (Wei *et al.*, 2006). Weightings for each trait vary between the six major sugarcane plant breeding regions (North, Herbert, Burdekin, Central, South and NSW) due to different operational procedures, available resources and cost structures.

For the small number of promising clones reaching the penultimate selection stage, fibre quality (shear strength, impact reading and % short fibre) is also measured. Currently, fibre quality is not included as part of the rEGV, and this information is used independently to select and recommend a variety for release.

The need for a new process

The effect of fibre on the economics of sugarcane and sugar production is complex.

Considering first the income generated from fibre, Kent (2010) confirmed that, as per Bureau of Sugar Experiment Stations (1984), approximately 95% of the fibre in cane ends up in bagasse. Kent (2007) reported that the value of bagasse (and hence fibre) is highly dependent of the use of the bagasse. In some factories, excess bagasse has no use and hence has a negative benefit due to the need for its disposal. In other factories, excess bagasse can be used for cogeneration to provide additional income from exported electricity. In yet other factories, excess bagasse can be used to replace other, purchased fuels such as coal and so reduces fuel costs. In the future, diversification options such as feedstock and biofuel production may considerably change the value of bagasse.

The costs of processing fibre are also not straightforward. In terms of the overall process economics, there are two main considerations.

Firstly, there is an impact on capacity. Assuming the same CCS yield per hectare (and hence essentially the same sugar production), the factory must maintain the same CCS rate through the factory to maintain the same season length. If the fibre to CCS ratio in the cane increases, a higher cane fibre rate is required. The higher cane rate has an impact on harvesting, transport, cane receival and cane preparation processes. The higher cane fibre rate has an impact on extraction processes. If there is not sufficient capacity within these systems, there is a need for either capital investment to gain that capacity or an increase in season length.

Secondly, there is an impact on process efficiency that is at least partially accounted for by the CCS measurement (since CCS depends on fibre content). Higher fibre content in the cane results in greater pol loss in bagasse (Mason *et al.*, 1983).

Apart from these bigger picture issues, fibre has an impact on operational efficiency within the factory. The study of Mason *et al.* (1983) found that varieties with low fibre contents had a porridge-like consistency that caused mill feeding problems. Brotherton *et al.* (1986) continued the work of Mason *et al.* (1983) and reported that handling problems, such as the mill feeding difficulties reported by Mason *et al.* (1983), were experienced when processing some varieties and that these problems could not be detected through fibre content measurement alone. This need to identify handling characteristics led to the development of the shear strength, impact resistance and short fibre tests described above.

The fibre characteristics of a variety cannot simply be considered in isolation, either. Jones *et al.* (2002) reported that variation in cane and fibre rate caused interruptions to sugarcane processing due to periodic overflowing of mill feed chutes, juice tanks and bagasse conveyors. These interruptions increase processing costs, reduce process efficiency and extend the season. Factory control systems need to be well designed to reduce the impact of these variations.

To ensure the selection and release of the 'best' varieties, the selection process should consider these issues. There is a need for a more holistic model of sugarcane and sugar production that encompasses these income, capacity, efficiency and operational aspects.

Concept for a new process

Introductory remarks

Following on from the discussion in the previous section, it is clear that the impact of the fibre characteristics of a new variety on the overall economics of sugarcane and sugar production will vary from one mill area to another, depending on the available harvesting, transport and processing equipment. Consequently, it is proposed that a model that takes this equipment into account is required to holistically evaluate the impact of a variety on a mill area.

The discussion in the previous section indicates that a suitable model should take into account:

- end uses of the fibre, to quantify the income to be generated
- capacity of the available equipment to assess the capital investment and/or season length costs
- process efficiency, to determine the impact on income from sugar and other products
- handleability, to put a cost on interruptions to the process.

While some complexity in the model is likely to be required, it is important that the input parameters for mill area inputs can be readily measured and that the variety tests are simple and economical to perform.

Some thoughts on model development

Techniques to quantify bagasse production reported by Kent (2010) and techniques to quantify the value of bagasse reported by Kent (2007) could form the basis of the component of the model to measure income from fibre.

Supply chain models such as those reported by Thorburn *et al.* (2006) may be of use in defining the harvest and transport requirements for a system that can then be compared against the number of units (harvesters, cane bins, locomotives, trucks) available. Cane receival capacity can be readily assessed by considering the tipping cycle and the number of tonnes tipped each cycle. Cane preparation capacity can be determined using models presented by Cullen (1986) and Cullen and McKay (1992). Milling capacity can be determined using mill feeding (Kent, 2004) and mill setting (Russell and Murry, 1968) models.

The main impact of fibre on process efficiency is through the extraction parameter. A model such as that reported by Thaval and Kent (2012) could achieve that purpose.

Handleability costs require an estimate of the amount of resulting lost time. While mills can estimate the cost of lost time, estimating the amount of lost time is not simple and has not yet been undertaken.

Some thoughts on variety tests to be conducted

The fibre content measurementis without doubt the most useful measurement of the impact of fibre on a mill area. This measurement could form the basis of the fibre income, capacity of harvesting, transport, cane receival and cane preparation systems and process efficiency models.

The existing shear strength, impact resistance and short fibre tests have been shown to be suitable for measuring the handleability properties (Brotherton *et al.*, 1986).

Probably the biggest weakness in the existing regime of tests is a test to assess the impact of a variety on milling capacity. While fibre content is an important parameter for this purpose, fibre compressibility is also important (Kent, 2004).

In 2012, Queensland University of Technology tested three varieties of energy cane with fibre contents from 14% to 22%. To determine the compressibility, a compression test was performed (Figure 5). The compression characteristics can be readily converted into a feed chute exit compaction (Murry and Hutchinson, 1958) which is directly proportional to capacity. Figure 6 compares the compression characteristics of the three energy cane varieties to measurements made in Australian factories in the late 1990s. One of those varieties had compression characteristics quite different to the others and consequently could be expected to process at a different fibre rate than most varieties.

Fig. 5—A compression apparatus

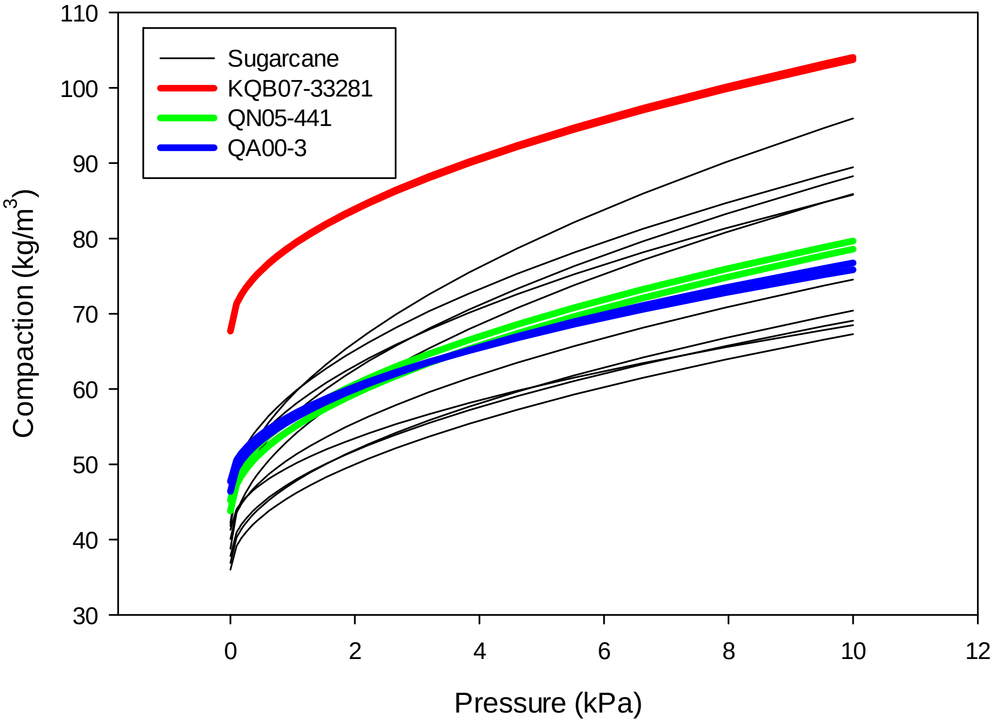

Fig. 6—Compression characteristics of three energy cane varieties compared against factory sugarcane supplies

If bagasse is to be used for other value adding opportunities in the future, it may be necessary to consider measurements of fibre components such as cellulose, hemicellulose and lignin (O'Shea *et al.*, 2010).

Conducting fibre tests efficiently

The fibre quality and compression tests described above are time-consuming and costly to perform. It is also sometimes difficult to determine the shearing point of a cane mat and inaccuracies can occur particularly at extreme ends of the range

(Brotherton *et al.*, 1986). A more efficient, safer and more consistent method of measuring fibre quality components is required.

In 2012, 35 cane samples were sourced from BSES Limited propagation and trial plots at Meringa, Tully, Ayr, Bundaberg and Condong (Table 1). Cane stalks were processed using both the conventional fibre quality procedures and also using NIR. This procedure was repeated in 2013, with a further 51 samples (Table 1). Calibration results based on a total of 86 samples from all regions are shown in Table 2. Initial calibrations between the two methods indicated a level of positive correlation for all three components. Further testing is required in order to build a more robust prediction model.

Table 1 – Number of whole-stalk samples assessed using both NIR and conventional fibre quality assay methods in 2012 and 2013.

Region	2012	2013	Total
Burdekin	3	6	9
Central	8		8
Herbert	6	22	28
New South Wales	13	6	19
Northern		5	5
Southern	5	12	17
Total	35	51	86

Table 2 – Prediction of fibre quality components using NIR spectroscopy, calibrated against conventional assay methods.

Variable	N	Min	Max	Mean	r2	SD	RMSECV
Impact Resistance	86	0.36	0.80	0.54	0.39	0.09	0.12
Shear Strength	86	18.39	34.35	27.02	0.41	3.24	3.88
Short Fibre	86	37.47	70.28	54.81	0.56	6.63	5.93
Fibre Content	86	11.79	16.05	14.32	0.44	0.97	1.10

The ability to accurately predict fibre quality components using NIR is largely dependent on the accuracy of reference methods. A large number of samples (400+) must therefore be measured, in order to establish a usable prediction model for fibre quality components, with future validation required. The repeatability of the reference methods must also be established.

Conclusions

Cane fibre content in factory cane supplies has increased significantly over the past ten years. At least part of the increase in cane fibre content can be attributed to cane varieties. Cane fibre content does not feature strongly in the variety selection process and so there has been little selection pressure in the variety selection process to alter it.

The impact of cane fibre content on the overall economics of sugarcane and sugar production is quite variable and depends largely on the available harvesting, transport and processing equipment, along with the end use for the bagasse. As a consequence, a favourable variety (from a fibre point of view) in one mill area will not necessarily be favourable in another.

A more detailed approach to variety selection that more completely takes into account the major cost and benefit impacts is proposed. The approach is based on the development and use of a more comprehensive mill area model that accounts for the income from the resulting bagasse, the impact on equipment capacity and season length, sugar and other products income and handleability impacts. Once this model is developed, sensitivity analysis can determine which variety traits have the most impact on profitability and appropriate variety tests can be chosen. The existing cane fibre content and at least some of the various fibre quality measurements will be most likely required. A compressibility test to measure milling capacity impacts also may be important.

Although this paper has focussed on cane fibre characteristics, this same methodology could be applied to other variety traits. There is expected to be benefits to be gained by considering all traits in a holistic fashion rather than each trait individually to obtain a mill area value for a variety.

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