YIELD LOSSES CAUSED BY SEVERAL ENDEMIC DISEASES IN QUEENSLAND

By

R.C. MAGAREY, J.I. BULL and W.A. NEILSEN
BSES, Tully

rmagarey@bses.org.au

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Abstract

Only limited sugarcane disease yield loss data have been generated in Queensland, or indeed around the world. This has meant our understanding of the effects, and importance, of diseases on productivity has been partial at best. With disease resistance a major form of disease control, objective data are needed to determine the level of resistance needed to maximise yield while, at the same time, minimising losses resulting from the effects of disease. In the past 18 months, studies were initiated to relate the level of disease yield loss of clones in plant breeding trials to yield. This paper describes research with yellow spot, orange rust and Pachymetra root rot in northern and central Queensland. Losses are shown to be very large (with orange rust in central Queensland causing as much as a 40% yield reduction). This study provides some of the first data on disease-associated yield losses with some diseases. Implications of the results are discussed as well as the potential for extension of the work.

Introduction

Research into disease-associated yield losses in sugar industries around the world has been very limited. When a disease epiphytotic occurs, losses are well understood—they are very large! Less understood are the effects of endemic disease occurring at lower incidence. Endemic diseases tend to be variable in intensity and it is often more difficult to discover their effects, both from a methodology point of view and because access to funding in these circumstances in usually restricted.

On the other hand, there is a great need to understand more about the effects of endemic diseases (Magarey and Croft, 1998) since most are controlled through the use of resistant varieties. This control comes at a cost – the loss of high yielding but susceptible varieties. If yield losses were better quantified, the optimum level of resistance needed in varieties to maximise yielding ability (while minimising disease-associated losses) could be incorporated into commercial varieties and profits for cane farmers maximised.

In recent times, the final stage trials of the BSES plant breeding program (stage 3) have been used to assess losses from endemic diseases (Magarey *et al.*, 2002a) with large losses reported in some trials caused by orange rust, yellow spot and Pachymetra root rot in northern Queensland. In this paper, further research into the losses caused by yellow spot, orange rust and Pachymetra root rot are reported for northern and central Queensland. The effect of the diseases on first ratoon, as

well as plant crops, is highlighted. The potential for further gathering of information is also assessed.

Materials and methods

The method for using breeding trials to quantify disease-associated yield losses has been outlined previously (Magarey *et al.*, 2002a) but is detailed briefly again here.

Yield assessment trials

In the cane-breeding program, BSES conducts Final Assessment Trials (FATs) on a range of soil types and in different environments, for promising clones in the plant improvement program. During the selection process, clones are screened for yield using performance data gathered in replicated small plots (four rows x 10 m) in commercial fields. FATs contain over 80 clones, plus a range of current commercial cultivars that provide a commercial reference point for selection of elite clones.

FATs are planted at 4–6 sites in each major cane-growing district of Queensland (northern, Herbert, Burdekin, central, and southern—only northern and central Queensland trials are considered in this paper). Two replicates each of test clones and current commercial standard clones are included at each site. Data for yield were obtained for each clone from each trial. Table 1 includes details of the trials included in studies reported in this paper.

Table 1—FAT trial locations in the northern and central district included in yield loss assessments for Pachymetra root rot, yellow spot and orange rust.

District	Year of trial planting	Mill area	Farmer
Northern	1998	Mulgrave	Johnson
		Mulgrave	McGuigan
		Babinda	Hanley
		South Johnstone	Riero
		Tully	Tully BSES
	1999	Mulgrave	Johnson
		Mulgrave	McGuigan
		Babinda	Hanley
		South Johnstone	Riero
		Tully	Tully BSES
Central	1998	Plane Creek	Bella
		Marian	Pullen
		Pleystowe	Walker
		Farleigh	Wright
	1999	Plane Creek	Adams
		Pleystowe	Breadsell
		Proserpine	Plemenuk
		Marian	Pullen
		Racecourse	Williams
		Farleigh	Woodman
	2000	Plane Creek	Callander
		Marian	Cappello
		Pleystowe	Jones
		Racecourse	Schmidtke
		Racecourse	Williams
		Farleigh	Woodman

Relating resistance to yield

Clones in FATs possess varying levels of resistance to endemic diseases, ranging from very resistant to very susceptible. By assessing the disease resistance of all clones, assigning ratings on a one to nine scale, then averaging the yield of clones with the same resistance rating, the relationship between resistance and yield in the presence of a disease can be assessed. Strong relationships have been found between disease and yield using this method (Magarey *et al.*, 2002a).

Resistance assessment

Three diseases (Pachymetra root rot, yellow spot and orange rust) were considered in northern Queensland FATs and one disease (orange rust) in central Queensland.

Pachymetra resistance screening

All clones in northern Queensland FATs are routinely screened at the Tully Sugar Experiment Station. Briefly, clones are grown from single bud cuttings and planted into *Pachymetra*-infested (>20 000 spores per kg of mix) potting mix. The plants are transferred to an air-conditioned bench maintaining the soil temperatures at 25–30ºC. After 12 weeks, plants are removed from the bench and the amount of root disease assessed, based on a 1–5 grading score, which is converted to a 1–9 resistance scale (1 = resistant, 9 = susceptible).

Yellow spot

A single FAT at South Johnstone was accessed in order to assign resistance ratings to clones. When yellow spot was at near maximum level, a team of assessors rated disease levels in all clones in the trial. Percent leaf areas diseased in the same leaf in the canopy of each clone was assessed and resistance ratings assigned (Magarey *et al.*, 2002a).

Orange rust

A similar method was employed as for yellow spot. As the two diseases tend to occur at the same time of year, the two diseases were assessed during the same inspection at South Johnstone, while inspections in central Queensland were undertaken toward the end of the wet season.

New indices

In order to more easily understand the resistance level needed to minimise losses, two new indices have been proposed (Magarey and Bull, 2002). These indices were calculated from the combined, and averaged, data from all trials planted in the same year within a district. Mean figures were calculated for each crop class.

Resistance Index (RI)

This is the average resistance rating calculated from all members of a breeding population – whether they be unselected clones, parents or commercial varieties (Magarey and Bull, 2002). It expresses a measure of the level of resistance within the population (but no measure of variability). The range of the index is between 1 (highly resistant) and 9 (highly susceptible). A high value indicates vulnerability of the whole population to disease while a low value, the reverse.

A value for the *RI* of clones included in the FAT trials was calculated.

Yield loss resistance index (YLRI)

This is a term to be used in association with resistance x yield loss analyses. It is calculated as the level of resistance (in breeding trial yield loss assessments) where yields are a given % below those in one-rated (the most resistant) clones; a sub-script on the abbreviated name denoting the % yield loss (Magarey and Bull, 2002).

For example, $\boldsymbol{YLRI_5}$ will mean that, at that level of resistance, yields are 5% lower than those in one rated clones. As a further example, if the $YLRI_5$ were calculated as 4.5, this would mean any clone with a resistance rating of 4.5 would have yielded exactly 5% less (a 5% yield loss) compared to the most resistant (one rated) clones. A sub-script of 10 will mean 10% lower, 15 will mean 15% lower.

If on the other hand, the $YLRI_5$ value was 9.0, this would imply even highly susceptible clones (with a resistance rating of nine) yielded only 5% lower than the most resistant clones.

The YLRI index therefore provides an instant guide as to the level of resistance needed in clones to keep disease-associated yield losses at a certain level. $\boldsymbol{YLRI_5}$ indices were calculated for each disease in each of the FAT trials included in the study and the mean for each region (average of all trials) included in Table 1

Yield loss estimates

Yield loss assessments were also calculated for each disease in each FAT series using the regression relating resistance and yield. As mentioned above, data from all FATs planted in the same year were pooled and average figures calculated.

The average yield for one-rated canes was compared to the average yield of nine rated canes and the difference expressed as a percentage of the maximum yield (yield of the one-rated canes).

Results

There were variable and generally non-significant effects of the three diseases on sugar content in each trial. Effects on tonnes cane and tonnes sugar per hectare are highlighted in the data reported here.

Yield loss resistance indices ($\boldsymbol{YLRI_5}$)

Yield loss resistance indices for each disease in each series of FAT trials are detailed in Table 2.

Table 2—Yield loss resistance indices (***YLRI*$_5$**) for each disease, crop class and district and the resistance index (***RI***) for each set of clones in each FAT trial.

District	FAT series	Disease	Crop class	Yield parameter		Resistance index
				Tonnes cane	Tonnes sugar	
				$YLRI_5$	$YLRI_5$	
Northern	1998	Pachymetra	P	4.6	4.1	5.0
			1R	3.5	3.3	
			Mean	***4.1***	***3.7***	
	1999	Pachymetra	P	4.5	6.7	3.7
			1R	3.9	4.3	
			Mean	***4.2***	***5.5***	
		Yellow spot	P	3.2	4.1	6.0
			1R	2.8	3.1	
			Mean	***3.0***	***3.6***	
		Orange rust	P	Ns	5.0	2.2
			1R	3.8	4.4	
			Mean	***3.8***	***4.7***	
Central	1998	Orange rust	P	4.3	4.0	2.9
			1R	2.9	2.8	
			2R	Ns	Ns	
			Mean	***3.6***	***3.9***	
	1999	Orange rust	P	2.1	2.0	3.1
			1R	4.2	5.9	
			Mean	***3.2***	***4.0***	
	2000	Orange rust	P	3.5	3.1	2.5
	Overall mean			***3.4***	***3.6***	***2.8***

Yield losses caused by each disease

Northern Queensland

The yield losses attributed to each disease are detailed in Table 3. Of the diseases in northern trials, yellow spot was the most important in the seasons studied (2000–2001). Pachymetra root rot and orange rust each caused between 10–20% yield loss in most of the FAT trials.

Central Queensland

In central Queensland, data are available from three trial series but only for orange rust. These are very interesting and suggest an association between orange rust and yield even in the 1999 season, one year before the disease was noticed in crops of Q124. Data from the 1999-plant series suggests that the disease was having a severe effect in the 2000 season but a lesser effect in 1999 and 2001.

Table 3—Percent yield losses attributed to Pachymetra root rot, yellow spot and orange rust in FAT trials in northern and central Queensland (comparison of yields in the most resistant vs most susceptible canes).

District	FAT series	Disease	Crop class	Yield parameter	
				Tonnes cane % loss	**Tonnes sugar** % loss
Northern	1998	Pachymetra	P	11.0	12.8
			1R	15.9	17.2
			Mean	***13.5***	***15.0***
	1999	Pachymetra	P	11.5	7.0
			1R	10.9	12.3
			Mean	***11.2***	***9.7***
		Yellow spot	P	18.3	12.8
			1R	22.3	19.2
			Mean	***20.3***	***16.0***
		Orange rust	P	Ns	10.0
			1R	14.4	11.8
			Mean	***7.2***	***10.9***
Central	1998	Orange rust	P	12.3	13.2
			1R	20.8	22.3
			2R	Ns	Ns
			Mean	***11.0***	***11.8***
	1999	Orange rust	P	38.1	40.9
			1R	12.7	8.1
			Mean	***25.4***	***24.5***
	2000	Orange rust	P	16.0	18.9
	Overall mean *(orange rust)*			***16.7***	***17.2***

Discussion

The data summarised and presented here reflect calculations from 28 trials, over 1–3 harvests and the weighing of nearly 9000 individual plots of cane.

Local sugar industry staff in the central district have indicated they, and some farmers, believe that orange rust was present in at least part of the central district before 2000 (unpublished information). The analyses reported here suggest there was a relationship between clonal orange rust resistance and yield in the 1999 harvest.

Data from breeding trials (not reported individually here) in the region show that the trials in the Racecourse and Pleystowe area were the ones where the relationship between orange rust and yield was significant in 1999, while in Plane Creek and Proserpine trials, there was no relationship between orange rust and yield in that year. However, by 2000 (and since), there have been strong relationships between orange rust and yield in all FATs in all central district trials and in many other districts around Queensland.

It seems possible that the disease first appeared in the Racecourse-Pleystowe area and spread to the surrounding districts within 12 months causing large losses in the 2000 harvested crop. The failure to detect orange rust in 1999 probably resulted from the assumption that the leaf disease

observed in the Mackay area in 1999 was caused by yellow spot (the main variety growing there at the time, Q124, is highly susceptible to yellow spot).

Indications are that little detailed examination of symptoms occurred in 1999; closer scrutiny of leaves only occurred in 2000 when orange rust became very severe across the district. Identifications then revealed the presence of orange rust (Magarey *et al.*, 2001).

The data show how severe orange rust was in the 2000 crop. Losses in tonnes cane/ha and tonnes sugar/ha were as high as 40% in central Queensland. It is no wonder the local industry suffered very large losses with the highly susceptible Q124 dominating the commercial variety scene. Losses in the 1999 and 2001 harvests were less, between 10 and 20% and it is likely these are closer to the longer-term average losses that will result from this disease. Weather information for the period 1996–2001 from Cairns, Townsville, Mackay and Brisbane has been analysed for suitability for orange rust spore germination and these suggest that the 2000 calendar year was the most suitable of these years for spore germination (Magarey, R.C., unpublished data).

Orange rust yield loss data averaged over all trials suggest loss figures are slightly lower than those reported by Magarey *et al.* (2002b) who used fungicides in the central district to estimate the effect of the disease in crops of the susceptible Q124. They reported losses of between 30% and 40% in two trials with Q124. The reason for the lower yield losses in the current study is not known but could be related to local weather and agronomic conditions at the trial sites.

Resistance index figures for clones in the central district suggest that in most years, average losses caused by orange rust in clones in breeding trials would be 5% or less. However, it should be noted that, in the 2000 season, average losses were above 5% in clones in FATs. It could be argued there is a need for higher levels of resistance in the breeding population to reduce the effects of the disease in years of severe disease such as this one. Only longer-term data can substantiate whether current levels of resistance are sufficient to keep losses at minimal levels over an extended period.

In the northern area, of the three diseases studied, yellow spot caused the highest average yield losses, being particularly severe in the 2001 crop harvest. Sugar losses were between 13% and 19%. Pachymetra root rot and orange rust caused lower sugar losses in the northern area (between 10% and 17%), and this is consistent with previous published research using this type of analysis (Magarey *et al.*, 2002a).

The level of resistance for each disease in clones in breeding trials (the ‘breeding strategy’) appeared to be of varying suitability. With yellow spot, it is very clear that on average in the years studied, clones in FATs are suffering more than 5% yield loss from the disease. There is a need to re-think the breeding strategy based on these figures. The strategy for Pachymetra root rot and orange rust on the other hand seems to ensure that losses will usually be 5% or less. The $YLRI_5$ data show how the suitability of the breeding strategy varies year by year with variability in weather conditions (favourability for the disease) and changes in *RI* according to the resistance of clones in a particular series in the breeding program. As with orange rust in the central district, data from much longer-term studies are needed to determine the optimal level of resistance in clones progressing through the breeding program.

The results from this study are part of on-going research that will lead to understanding the longer-term effects of endemic diseases on yield throughout Queensland. So far studies have been limited to three diseases in two districts of Queensland. It is planned to undertake this research in each district (northern, Herbert, Burdekin, central and southern) and to assess the effects of

Pachymetra root rot, brown rust and orange rust (and yellow spot in selected districts). Other diseases may be analysed in this fashion depending on their occurrence and severity. Eventually, when sufficient data are on hand, and after a number of years of analyses, it should be possible to understand the following:

- The average effect of an endemic disease on yield in each district/region.
- Variation in yield effects in P, 1R and 2R. It is quite likely for instance that leaf diseases such as brown rust will affect plant crops more than ratoon crops due to the susceptibility of lush leaf growth in plant crops.
- Variation in yield loss with weather conditions and the timing of the wet season.
- The level of resistance needed to minimise yield losses.

There seems little doubt that much better quantitative data can now be obtained to ensure optimisation of breeding strategies and the minimisation of the effects of endemic diseases on commercial sugarcane yields.

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