BUREAU OF SUGAR EXPERIMENT STATIONS

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Final Report - SRDC Project BS172S

Part II - A Review of Yield Losses Caused by Australian and Selected Exotic Sugarcane Diseases

by

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EXECUTIVE SUMMARY

Yield loss studies of Australian endemic diseases, and those exotic diseases posing the greatest threat to production in Australia, are reviewed. There is a need for much research, particularly in relating disease intensity with yield and in investigating the effect of varietal resistance on this relationship. It is suggested that initial studies begin with yellow spot and rust, and should include sugarcane bacilliform virus and yellow leaf syndrome when techniques for handling these diseases improve. Priorities for further research should be reviewed at the conclusion of the initial yield loss research. The effect of the important exotic disease, smut, has been well researched overseas.

1.0 INTRODUCTION

Sugarcane diseases have had a big impact on the Australian sugar industry. An outbreak of gumming disease in the 1890s was an important contributing factor to the establishment of the Bureau of Sugar Experiment Stations (BSES). Epiphytotics of major diseases, such as Fiji, downy mildew, and RSD have caused substantial yield losses through the 1900s. Though research has led to generally good control, diseases have an ongoing influence in the industry, by affecting crop growth and the selection of resistant commercial varieties in the plant improvement program.

In considering the effect of a disease on our industry, four factors should be evaluated:

(1) the ability of the disease to reduce plant growth;
(2) the severity of the disease;
(3) the distribution of the disease and;
(4) the susceptibility of varieties being grown. Some of the factors obviously interact; resistant varieties usually show a decreased disease severity compared to susceptibles, with a smaller growth reduction.

In yield loss studies, it is important that the relationship between disease severity and yield loss be investigated. Disease incidence data gathered in surveys can then be related to yield loss and the importance of a disease to a district, or the industry, assessed.

Of the different types, systemic diseases (invading the whole plant) usually have the greatest ability to reduce plant growth, while diseases affecting only specific parts (eg the leaf blade) tend to have more minor effects, though this is not always the case. A number of sugar cane diseases occur in Australia, and the most important of these (based on known yield effects and occurrence) are listed below:-

Table 1: Diseases of major importance to the Australian sugar industry

Disease	Causal Agent	Type of Disease
Fiji	Virus	Systemic
sugarcane mosaic		Systemic
leaf scald	Bacterium	Systemic
ratoon stunting		Systemic
red rot	Fungus	Non-systemic
rust		Non-systemic
pineapple		Non-systemic
yellow spot		Non-systemic
Pachymetra root rot		Non-systemic
Chlorotic streak	Unknown	Systemic

Several exotic diseases pose a considerable threat to our industry, would reduce productivity, and lead to the discard of a significant amount of germplasm if they were introduced. The most important of these are listed in Table 2.

Table 2: Exotic diseases posing the greatest threat to the Australian industry

Disease	Causal Agent	Type of Disease
smut	Fungus	Systemic
downy mildew		Systemic
gumming	Bacterium	Systemic
white leaf/grassy shoot	Phytoplasma	Systemic
Ramu stunt	Viral	Systemic

This review focuses primarily on the questions - what is the potential for yield loss and how does this vary with disease severity? Also reviewed is how do yield losses vary with varietal susceptibility - this is important since much of the disease incidence in Australian crops occurs in varieties of intermediate resistance (not highly susceptible ones).

For the diseases occurring in Australia, a brief review of overseas yield loss data is included. It is important to note that the magnitude of any losses will be affected by environmental conditions, and losses in Australia may be either less or greater than those reported in other countries. Some diseases are uniquely Australian (striate mosaic, dwarf and Pachymetra root rot) and yield loss estimates rely wholly on Australian research.

It is only as all the factors mentioned are considered can the importance of a disease to an industry be assessed, and priorities for disease control established. As far as is known, this is the first specific review of the losses caused by Australian sugarcane diseases.

2.0 AUSTRALIAN DISEASES

2.1 Those causing plant death in susceptible varieties

2.1.1 Fiji Disease

Fiji disease, caused by a virus in the Reoviridae group, is one of the most important sugarcane diseases in Australia. The disease is transmitted by an insect (*Perkinsiella saccharicida*) and occurs in central and southern Queensland, and northern New South Wales. It has caused extensive yield losses in susceptible varieties and can easily lead to failed ratoons. Epiphytotics have occurred in Australia in the 1935-1950 and the 1970-1985 periods. Because of its severe effects, only varieties with adequate resistance are released for commercial production in affected districts.

Yield Loss Estimates

Cottrell-Dormer (1927) recorded losses of 5% (plant cane), 13% (first ratoon), and 20% (second and third ratoons) in D1135 in the Beenleigh district. In one diseased field, 53% of stools were diseased and stunted (May period). Egan and Ryan (1986) suggest that yield losses with Fiji disease are a function of percentage infection, disease severity, varietal tolerance, and length of time since infection, and that yield losses can be predicted up to two years in advance. Losses are greater when infection occurs early in the crop cycle, and when disease intensity is such that many stalks in the one stool become infected simultaneously. In the Bundaberg epiphytotic of the 1970s, Turner and Churchward (1977) suggested there was a 1% yield reduction for every 3% diseased stools, with negligible losses below 15-20% diseased stools. This ratio was too conservative for the very severe infections that occurred later during the epiphytotic (Egan and Ryan, 1986). Egan and Ryan (1986) used an adjusted 1:3 ratio, based on local knowledge, to predict yield losses in Bundaberg. Actual yield losses in the epiphytotic are outlined in Table 2. Losses were estimated at 5-7% of the district crop during this period (Egan, Ryan and Francki, 1989).

Table 3: Yield losses in the Bundaberg district caused by Fiji disease in the epiphytotic of the 1970s (Egan and Ryan, 1986).

Year	1975	1976	1977	1978	1979
Tonnes lost	1,500	10,000	35,000	55,000	11,500

2.1.2 Leaf Scald

Leaf scald is a systemic bacterial disease caused by *Xanthomonas albilineans*. The disease readily kills crops of highly susceptible varieties. As a consequence, extensive clonal resistance screening occurs in the BSES plant improvement program, with the discard of germplasm, to ensure that commercial yield losses are minimised. The disease is endemic in many districts and causes greater losses when crops are water stressed. Under good growing conditions, crops may show reduced symptom development and minimal losses.

Yield Loss Estimates

No study has been conducted relating disease severity to yield. Various comments have been made suggesting significant yield losses occur, (eg Egan (1971) reported that outbreaks in the early 1900s caused heavy losses in highly susceptible varieties) but data is lacking.

Overseas Research: Shepherd (1928) noted yield reductions of the order of 10% in a highly susceptible variety in Mauritius. Hutchinson and Robertson (1953) suggested lower yields were a result of reduced growth in infected stalks, a reduction in millable stalks per stool, and failed ratooning. Juice quality parameters are also affected by the disease, with a lowering of brix, pol and purity (Ricaud and Ryan, 1989). Hoy and Grisham (1994) studied yield components in leaf scald infected fields in Louisiana. They selected 7.5m, single-row plots in four commercial fields and related disease incidence to number of millable stalks, weight of cane per plot, and sucrose content. With disease incidence averaging around 5-30,000 symptomatic stalks per ha, leaf scald affected stalk weight (diseased vs asymptomatic) in only one of four fields, juice purity in three, and % sucrose in all four fields. A regression of sugar yield with the number of symptomatic stalk/ha yielded a relationship with low r^2 values.

2.1.3 Red Rot

Red rot is a stalk rot caused by the fungus *Glomerella tucumanensis*. Stressed (drought or flood), or over-mature, crops are susceptible to the disease. In susceptible varieties, stalk and crop death can be rapid, and total loss can result if the crop is not rapidly harvested. The disease may occur in all districts but is seen more frequently in the drier areas. Clones are screened for resistance late in the plant improvement program to ensure highly susceptible varieties are not released to industry.

Yield loss estimates

Bell (1928) estimated the effect of the disease on M1900 Seedling (Sarina) and EK28 (Kalamia) and noted ccs losses of 4.0 and 5.3 units respectively. Other effects on juice parameters are given in Table 4. No data on crop weights were reported.

Table 4: The effect of red rot on juice quality parameters in M1900 and EK28

Variety: Quality parameter	Healthy	M1900 Diseased	% Reduction	Healthy	EK28 Diseased	% Reduction
Brix	24.0	21.0	**12.5**	23.2	20.8	**10.3**
Sucrose	22.4	18.1	**19.2**	21.3	16.0	**24.9**
CCS	17.7	13.7	**22.6**	16.1	10.8	**32.9**
Glucose	0.3	0.7	**+133.3**	0.5	2.5	**+400.0**
Purity	93.2	86.3	**7.4**	91.6	77.0	**15.9**

Deleterious effects on purity and reducing sugars affect sucrose manufacture. No other Australian yield loss studies have been published. A number of observations support the fact that the disease is able to cause substantial losses in susceptible varieties.

Overseas Research: Singh and Singh (1989) suggest that losses from red rot result from deterioration of seedcane and stubble, death of individual stalks or stools, reduction in sucrose content and juice purity, and resultant problems in processing. Death of infected shoots or stalks, arising from locally infected setts or from later stalk infection, may occur at any time. The magnitude of the losses depends on climatic conditions, crop management, and varietal susceptibility (Singh and Singh, 1989). Reductions in sucrose content may reach 50% (Abbott, 1938).

2.1.4 Pineapple Disease

Pineapple disease is a disease of the planting material caused by the fungus *Ceratocystis paradoxa*. It can cause complete failure in crop establishment. Substantial replanting costs are incurred through additional cultivation, fertiliser, insecticide and in employing field hands or contract planters. It occurs in all districts in Queensland and must be regarded as a major disease. Most farmers regularly apply a preventative fungicide at planting worth > $1m annually.

Yield Loss Estimates

No specific yield loss experiments have been conducted, but yield effects could be calculated on reduced stool numbers per hectare up to a threshold where plough out and replanting was necessary.

Some fields have been replanted three times in an attempt to establish a crop (Story, 1952).

2.1.5 Striate Mosaic

This disease is thought to be caused by a virus belonging to the Carlavirus group (Choi and Randles pers. comm.) and appears to have a soil-borne vector. It is restricted to the Burdekin district affecting up to 120 ha annually. Stools of susceptible varieties are usually killed by the disease leading to localised severe losses and failed ratoons.

Yield Loss Estimates

The relationship between disease intensity and yield has not been investigated, though plant infection usually leads to no millable cane and ultimately stool death. Hughes (1964) cites a crop of Pindar which cut 132 t/ha as plant cane and was expected to cut 33 t/ha in first ratoon, a 75% reduction in yield (compared to plant cane).

2.1.6 Dwarf

Dwarf is a minor disease of sugarcane occurring in the central district of Queensland. Very few reports of the disease have occurred in recent years. It is thought to be caused by a virus though no causal agent has been assigned.

Dwarf is capable of causing complete plant death in susceptible varieties (McDougall, 1946). Losses are greater in poorly drained, low lying areas, and spread is greatest in hot wet weather.

Yield Loss Estimates

The relationship between disease intensity and yield has not been established.

2.2 Diseases not usually causing plant death

2.2.1 Ratoon Stunting Disease (RSD)

RSD is a systemic, highly infectious bacterial disease, caused by *Clavibacter xyli* s. sp. *xyli*., which has no external symptoms besides reduced growth. As a result, the disease was not recognised until the summer of 1944 when healthy and diseased Q28 growing in the Mackay district provided such a contrast in growth that investigations into the cause of the difference were initiated. Research by Mr David Steindl, a BSES pathologist, showed the disease was transmissible, and he with Graham Hughes laid the foundations for a great deal of our knowledge of the disease today. RSD occurs in all canegrowing districts in Australia (except the Ord River), and much of the general disease control activities undertaken are aimed at controlling this disease.

Yield loss estimates

Because of the nature of the disease, yield loss studies have been a cornerstone of RSD research with the main focus on the yield difference between healthy and diseased cane. Recently, the development of a serological assay (EB-EIA) has made it feasible to relate bacterial numbers in diseased stalks to varietal susceptibility and yield loss, but only preliminary studies have been conducted so far.

Water stress affects the magnitude of yield losses which under irrigation, are significantly reduced. This has led to variation in the effects of the disease between years and between districts with greater severity in drier, rainfed districts. Typical effects of the disease on yield are detailed by Hughes (1958) in Table 5.

Table 5: Typical yield losses caused by RSD in plant, first and second ratoon crops (Hughes, 1958)

VARIETY	DISEASE STATUS	CROP STATUS (Yield = ton cane/acre)			
		Plant	1R	2R	% Yield Loss
NCo310	Healthy	34.7	31.6	34.4	
	Diseased	28.3	26.8	30.4	**15.1**
POJ2878	Healthy	30.7	20.7	25.3	
	Diseased	26.3	18.2	19.8	**16.2**
PINDAR	Healthy	25.1	30.6	27.3	
	Diseased	21.9	25.6	21.6	**16.7**
Q47	Healthy	37.1	32.8	10.2	
	Diseased	30.6	24.9	7.1	**21.8**
Q56	Healthy	30.7	22.4	21.0	
	Diseased	31.0	19.9	16.9	**8.5**
Q57	Healthy	38.0	40.2	37.9	
	Diseased	34.7	35.6	33.5	**10.6**
SJ4	Healthy	34.5	42.7	35.6	
	Diseased	23.6	33.4	30.7	**22.3**
Trojan	Healthy	37.0	20.4	23.8	
	Diseased	29.6	18.0	18.4	**18.7**
Vidar	Healthy	39.2	22.4	24.8	
	Diseased	35.0	17.5	17.6	**18.9**

Results from other yield loss studies are included in Appendices 1 and 2.

2.2.2 Mosaic (SCMV)

Sugarcane mosaic is caused by an aphid-transmitted virus and has occurred in most regions of Queensland. It is favoured by cooler climates and accordingly is of greater significance in southern Queensland. The disease leads to reduced growth but rarely to complete loss of millable cane. Varieties in the final stage of the plant improvement program are screened for resistance.

Yield Loss Estimates

Kelly (1926) recorded a 50% loss in weight in diseased vs. healthy stools of the varieties Shahjahanpur 10, Gingila, and M1900 seedling. He suggested 40% was a more average figure. In an experiment conducted at Proserpine, Bell (1930) planted 40 healthy and 40 diseased setts and grew the cane under dry conditions. Yield differences of 75% (HQ426) and 50% (M1900 seedling) resulted in the plant crop.

Jones (1988) reported on yield loss studies conducted in the Isis mill area in southern Queensland in 1987. The weight of millable cane in diseased and healthy stools of three susceptible varieties was compared. The following average results were obtained from two commercial fields (Table 6):-

Table 6: The effect of mosaic on yield (diseased vs. healthy stools) in three varieties in the Isis district

Variety	Average % Yield Loss
Q103	51
Q137	41
Q95	25

Isis Cane Protection and Productivity Board (CPPB) staff compared the weights of diseased and healthy stalks and found the following average losses (Table 7) (Jones, 1988).

Table 7: Weight of diseased vs. healthy stalks in crops of three varieties in the Isis district

Variety	Average % Loss in Stalk Weight
Q103	36
Q137	32
Q95	19

It should be noted that the way these studies were undertaken did not account for crop compensation effects. Jones (1988) suggests that for each 10% increase in disease level, the following crop losses result (Table 8):

Table 8: Disease intensity effect on yield in three varieties (Jones, 1988)

Variety	Crop Loss/10% Disease Level (t cane/ha)
Q103	5.0
Q137	5.0
Q95	2.5

Assuming average yields of around 80t cane/ha, this would lead to maximum losses of around 60% (Q103, Q137) and 30% (Q95).

Overseas Research: Bailey and Fox (1987) investigated the effect of strain D on the yield of the varieties N12 and NCo376 in Natal. Yield reductions in recoverable sugar of up to 30% and 42% occurred in N12 and NCo376 respectively. Losses resulted from a reduction in stalk mass and stalk number but not from a reduction in sugar content (Bailey and Fox, 1987).

Summers (1943) reported yield reductions of up to 17% in Co290 and 33% in Co281 though this varied with the strain of the pathogen (Koike and Gillaspie, 1989). The yield of CP44-101 was reduced by 17% (plant cane), 31% (first ratoon), and 50% (second ratoon) with sugarcane mosaic strain H (Abbott, 1960). Other workers suggest that significant losses occur when disease levels reach 50% (Koike, 1977). Combinations of mosaic with other diseases often reduce growth more than their additive effects (Koike and Gillaspie, 1989); this has been also noted with RSD (Steib and Chilton, 1967, Koike, 1977), and Pythium root rot (Koike and Yang, 1971).

2.2.3 Chlorotic Streak

Chlorotic streak is a disease of widespread occurrence but unknown etiology. First recognised in 1929, research has failed to identify a causal agent though limited evidence points to a virus (Egan, 1989).

Transmission occurs via planting material and by flood water. The disease is favoured by high rainfall and/or poor drainage and the incidence is affected by the weather conditions during the previous year. Up to 50,000 ha may be diseased annually in Australia.

Yield loss estimates

Early yield loss studies were conducted before RSD was recognised and Egan (1989) suggests that the data from these early experiments should be treated with caution. Egan (1962) reported that under wet conditions, chlorotic streak reduced germination; reductions of 10, 16, and 22% were recorded in Q66, Q67, and Pindar respectively. Yield data from this trial are summarised in Table 9.

Table 9: The effect of chlorotic streak on the yield of Q66, Q67 and Pindar in northern Queensland (% loss vs. healthy control)

Crop\Variety	**Q66**	**Q67**	**Pindar**
Plant	18	27	28
First Ratoon	23	23	10

The Herbert River district suffers relatively high disease levels and district-wide losses of 16% in the 1981 season were reported by Symington and Kaupilla (1982). In the early 1980s, a series of paired disease-free and diseased cane plots was planted in the Herbert River district and yield data compared. Data were recorded for plant, first and second ratoon crops in the varieties Triton and Cassius. Multiple-regression analysis suggested a

0.24% yield loss for each 1% of stools displaying disease symptoms (Nielsen et al, 1986) implying a maximum yield loss of 24%. The magnitude of such losses will vary according to the resistance/tolerance of the variety.

2.2.4 Common Rust

Common rust, caused by *Puccinia melanocephala*, was first seen in Australia in 1978 and occurs every year in all sugarcane growing districts in Queensland and New South Wales. The disease is favoured by cool nights (with dews) and warm days, and for this reason occurs predominantly during the October - December period. In severe cases, affected leaves show little green leaf tissue and the crop exhibits a general brown appearance. Control is achieved through varietal resistance.

Yield loss estimates

Australian data on yield losses are based on field trials conducted in 1982-1984 by Taylor, Croft and Ryan (1985) in northern (Mourilyan) and southern (Isis) districts. The trial design was a split-plot with fungicide treated/untreated as the main plots, and varieties [Q87, Q90, Q108, Q110 and 70S77 (Isis), and 71A123, Q90, Q105, Q107 and Q113 (Mourilyan)] as subplots. These varieties represented a range in resistance to the disease. Disease control was achieved by the application of oxycarboxin at approximately 9-day intervals using overhead spray equipment. Treatments were initiated during the tillering growth stage and ceased when it became impossible to move an interrow tractor through the maturing crop (March in Mourilyan, June at Isis). Disease severity was assessed during the course of the experiments by estimating leaf areas affected. At Isis, the level of disease in Q87 was assessed immediately after each spray application by selecting 10 stalks from the untreated plots and estimating leaf areas affected in the first 5-7 fully expanded leaves. The disease levels in other varieties were subjectively compared to the disease in Q87 on a 0-100 scale. At Mourilyan, disease levels were assessed at the peak of disease incidence (November 1982) by estimating percent leaf area affected in 10 stalks in each plot (first seven fully expanded leaves). The results from this research have been reworked to reflect the relationship between yield losses (tonnes cane/ha, tonnes sugar/ha) and varietal resistance (figures 1 and 2).

In the original data analysis, a yield difference of over 30% occurred between sprayed and unsprayed plots of the most highly susceptible variety at Mourilyan (Q105) and Isis (70577) but the results were not statistically significant. This was attributed, in part, to the split-plot trial design. Data from these trials are included in Appendix 3.

The reworked data (Figures 1 and 2) show considerable variation, but tend to confirm that large losses occur when highly susceptible varieties are grown. Varieties of intermediate resistance appear to suffer much lower yield losses.

Rust appeared to affect stalk populations (leading to less stalks) but had little effect on ccs.

Figure 1: % losses in cane yield caused by rust in trials at Mourilyan (right) and Isis (left). Variation in disease intensity was generated by varietal resistance.

Figure 2: % losses in sugar yield caused by rust in trials conducted at Mourilyan (right) and Isis (left)

Overseas Research: Comstock *et al.* (1992) compared the yields of inoculated and uninoculated plots of B4362 (susceptible), CP 78-1247 (intermediate) and CP70-1133 (resistant) in Florida. Th disease occurred early in the cropping period and reduced plant biomass significantly in B4362 (16.4% reduction) but not in the other varieties. Yield losses were a result of a decrease in stalk number. They found that inoculated and uninoculated cane grew at a similar rate when the disease subsided; there were no compensatory growth increases in inoculated plots (Comstock *et al.* 1992).

Bernard (1980) suggests yield losses vary according to environmental conditions and have been estimated at 10-20% under good growing conditions and up to 50% where the disease has been severe (Esquivel, 1980, Purdy *et al,* 1983). The Cuban industry suffered an estimated loss of one million tonnes sugar in the 1978-79 season when 40% of the area was planted to the susceptible variety B4362 (Egan, 1989).

2.2.5 Pachymetra root rot

A uniquely Australian disease, Pachymetra root rot was first seen in 1967 in the Babinda mill area. The causal agent, *Pachymetra chaunorhiza*, was isolated in 1981 and described in 1989. The disease occurs in northern, Herbert, and central districts with a restricted distribution in the Bundaberg area (Magarey et al, 1997). The pathogen causes a soft flaccid rot of the large roots (Magarey, 1986) leading to a poor and inadequate root system and reduced growth. Loss of anchorage leads to increased levels of stool tipping, reduced plant populations in ratoons, and excess soil in the cane supply.

Yield loss estimates

Pachymetra root rot is one of the diseases where disease intensity has been related to yield. Magarey (1989) developed a soil assay for the disease, while Croft (1989) has shown that resistance to the disease is present in Australian sugarcane germplasm. Accordingly, a plant improvement trial site was located, the former plots tagged, and the different varieties ploughed out. Pachymetra inoculum densities were then quantified, and the site replanted with a susceptible variety (Q90). At the harvest of the plant and ratoon crops, the yield in each former plot was related to Pachymetra inoculum density in the same plot and the relationship between yield and inoculum density investigated. In both plant and first ratoon crop, a highly significant relationship was found (Figures 3 and 4), with maximum yield losses estimated at 30-40% in both plant and ratoon crops (Magarey, 1994). The disease has a significant effect on variety selection in northern Queensland and consideration is given to the disease in the choice of parent canes.

Figure 3: The relationship between Pachymetra chaunorhiza soil inoculum density and yield in plant cane (Q90) at Miriwinni

Figure 4: The relationship between Pachymetra chaunorhiza soil inoculum density and yield in a first ratoon crop (Q90) at Miriwini

2.2.6 Yellow Spot

Yellow spot is a fungal disease of the leaf blade caused by *Mycovellosiella koepkei*. The disease was first observed in Australia in 1950. It is favoured by warm, humid conditions typical of those on the wet tropical coast during the wet season. Up to 50,000 ha may be affected annually. No specific resistance screening is incorporated into the plant improvement program.

Yield Loss Estimates

The only research into yellow spot associated yield losses in Australia has been undertaken by Egan (1960, 1972, 1973). Some of this research aimed at developing a fungicide application program to provide disease-free controls in yield loss studies. Trials conducted in 1971-72 showed that benomyl applied at 560 g/ha every three weeks during the disease epiphytotic could reduce disease levels by 60 percent (based on total canopy leaf areas). Under these circumstances, yellow spot reduced ccs early in the harvest season by 2.0 ccs units in the susceptible Q91. This was considered a conservative estimate of the effects of yellow spot because some disease remained in treated plots. Stalk sampling during the course of these trials made yield data unreliable and losses in cane tonnages were not reported. Egan (1973) indicated stalk thicknesses appeared to be reduced by the disease in these trials. Yield loss data on yellow spot have never been published in Australia.

Overseas Research: Ricaud (1974) used the fungicide benomyl to control yellow spot over three seasons in the variety B3337. He suggested a conservative estimate of yield losses was 10-15%. He also found an inverse relationship between the effect on sucrose content in early harvests and on cane yield in late harvest; yellow spot principally reduced sugar content early, and biomass later in the season (Ricaud, 1974). Ricaud *et al* (1980) studied the effect of yellow spot on yield in susceptible varieties, one of which flowered profusely while the other remained vegetative. A greater yield loss was recorded in the flowering cane in July (23.0% sucrose loss vs. 11.3%). Losses in Mauritius in the susceptible variety Saipan 17 were of the order of 10-15% in commercial fields in the early 1980s (Ricaud and Autrey, 1989a). Autrey, Ricaud, Sullivan, and Dhayan (1983) suggest that a given level of infection may not result in the same yield loss in different areas. Ricaud and Autrey (1989a) suggest a loss of 15% of leaf area in the variety Saipan 17 was the threshold at which yield losses occurred.

2.2.7 Red Stripe/Top Rot

Red stripe/top rot is a bacterial disease affecting individual leaves (red stripe) or the growing point (top rot). It is caused by *Burkholdia rubrilineans*, and occurs in the wet season as crops make rapid growth. Yield losses are generally considered minor and no varietal resistance screening is undertaken. The disease may occur in all districts in Queensland.

Yield Loss Estimates

Bell (1932) injected stalks with the bacterium to simulate infection levels of 0, 10, and 20% diseased stalks. The experiment was established at Mundoo in northern Queensland in the variety Badila (?). Yield losses of 4.8 and 14.0% occurred respectively (10 and 20% diseased stalks). It should be noted that losses will vary greatly depending on occurrence during the growing season (Bell, 1933). Late planted crops (spring) suffer greater yield losses than those planted earlier because higher stalk populations are present during the wet season when conditions are ideal for disease development.

2.2.8 Eye Spot

Eye spot is a fungal disease (*Bipolaris sacchari*) of the leaf blade and may occur in all sugarcane districts but is favoured by cooler climates. Australian commercial varieties are usually resistant to the disease and it is rarely sighted.

Yield Loss Estimates

No yield loss experiments have been undertaken.

The main effect of the disease is to reduce the sugar content (ccs) of the harvested crop. Observations by McAleese (1976) suggest the disease caused a drop of 4 units in one commercial crop, and that a drop of 2 units was common in the susceptible variety Q101 in the northern epiphytotic of the 1970s. Some fields of Q101 were so badly affected that the crops were condemned by the local sugar mill (ccs < 7.0, Anon, 1976).

Overseas Research: A 33% yield loss resulting from eye spot has been reported (Osada and Flores, 1968). In an epiphytotic in H109 in Hawaii in the 1920s, stalk diameter and internode length were reduced (Lee, 1926).

2.2.9 Yellow Leaf Syndrome (YLS)

Yellow leaf syndrome is a recently recognised disease of uncertain etiology. It is characterised by the yellowing of leaf mid-ribs and the adjacent leaf blade, a symptom which is accentuated by various stresses, and crop maturity. Research conducted in several countries suggests a luteo virus is associated with these symptoms (Brazil, USA, Australia) while recent research in the UK and South Africa links a phytoplasma with this disease. Transmission studies and additional survey work are needed to clarify the situation.

Yield Loss Estimates

As the disease has only recently been recognised, little yield loss research has been conducted. In Brazil, it has been suggested that in one susceptible variety, a 50% yield loss resulted from the disease.

2.2.10 Sugarcane Bacilliform Virus (SCBV)

Also recognised only recently, SCBV has poor symptom definition and appears to have a minimal impact on plant growth, though this is uncertain. The disease has a wide distribution around the world but is not thought to be present in wild *Saccharum* spp. in the centre of origin (PNG, Jones, pers. comm.). Virus titre is highest in *S. officinarum* clones and shows variable intensity in commercial hybrid varieties (Braithwaite, pers. comm.)

Yield Loss Estimates

Little yield loss research has been undertaken with SCBV. A contributing reason is the difficulty in obtaining healthy and diseased material for comparison. Lockhart and Autrey (1988) linked SCBV with declining yields in Mex 57-473 in Morocco. Comstock and Lockhart (1996) recently reported on the effect of SCBV on the biomass production of three varieties in Florida. They found a mixed response to infection with increased yield with SCBV inoculation in the variety (CL61-620) and decreased yield in CL65-357 (up to 20%). Further research is needed.

3.0 EXOTIC DISEASES

Exotic diseases pose a considerable threat to sustained high productivity in the Australian sugar industry. The sugar industry world-wide has a history of crises caused by the introduction of major diseases to sugarcane production areas. One of the most important of these has been sugarcane smut.

3.1 Smut

Sugarcane smut, caused by *Ustilago scitaminea*, was first recognised in the late 1800s on the African continent. It is a systemic fungal disease which gains entry to the plant via the infection of buds. As a systemic disease, it changes the growth habit of diseased plants leading to a grassy-type growth habit, the production of a terminal whip-like structure, and reduced yield. Dispersal is via wind-blown spores or planting material. Dispersal episodes have occurred through the 1900s with the last major event in the late 1970s when sugarcane production areas in central and north America, Hawaii, and Indonesia were invaded. Reduced productivity, and the discard of valuable germplasm resulted. The only production areas free of smut are Australia, PNG and Fiji.

Yield Loss Estimates

Bailey (1979) in South Africa reported losses of 17 and 22% in the varieties NCo376 and Nco310, Antoine (1961) reported yield losses of >50% and Lee-Lovick (1978) up to 73%.

In contrast to many sugarcane diseases, the relationship between disease intensity and yield has been well studied with sugarcane smut. Irey (1986), using the variety CL65-260, measured both disease intensity and yield in 24 plots. Using multiple regression analysis, he showed a significant relationship between yield and % stalks infected or % stools infected.

Hoy et al (1986) also investigated yield losses, by delineating single row plots in established cane fields and relating disease intensity to yield. Assessments were made in three plant cane fields, and one second ratoon field of CP73-351. The relationship between smut and yield was described using multiple regression analysis. They attributed yield losses to a reduction in the number of healthy millable stalks; smut infection led to stalk death.

In Brazil, studies using a number of varieties suggested a 0.67% yield loss for each 1% stools showing disease (Anon. 1993). Padmanaban et al (1988) related disease intensity and yield and stated that a total crop loss resulted from above 80% stools infected. The equations relating smut disease intensity to yield in each of these studies is detailed in Table 10.

Table 10: The relationship between smut disease intensity and yield in various studies around the world

Equation relating disease and yield	Author (s)
Tonne cane/ha = 108.18 - 0.66 (% stools infected) r = -0.52, P = 0.009	Irey, 1986
Tonnes sugar/ha = 12.11 - 0.04 (% stalks infected) : early harvest r = -0.54, P = 0.007	Irey, 1986
Tonnes sugar/ha = 11.72 - 0.05 (% stalks infected) : late harvest r = -0.60, P = 0.002	Irey, 1986
Estimated tons cane/ha = 77.01 - 0.66 (% stalks infected) : plant cane $r^2 = 0.60$	Hoy, *et al,* 1986
Estimated tons cane/ha = 81.22 - 0.69 (% stalks infected) : second ratoon $r^2 = 0.79$	Hoy *et al,* 1986
Yield loss (%) = 0.67 (% stools infected) - 0.438 r = 0.97	Anon., 1993
Expected yield (kg/plot) = 193.2 - 4.78 (% diseased stools) r = -0.77	Padmanaban *et al,* 1988

James (1973) suggested smut led to a decrease in the number of millable stalks, and a decrease in stalk diameter. No reduction in sucrose content was noted in his studies. However some researchers report an effect of smut on juice purity (Ferreira and Comstock, 1989). There is no doubt the disease has a major effect on cane yield in susceptible varieties.

3.2 Downy Mildew (DM)

DM is a systemic fungal disease caused by *Peronosclerospora sacchari*. In the first half of the 20th century, it was one of the major diseases affecting sugarcane in Australia. The selection of resistant commercial varieties, coupled with strict regulations, led to the eradication of the disease, with the last known diseased field occurring in the Bundaberg district in 1957.

In highly susceptible varieties, DM can cause severe stunting leading to greatly reduced yields. The disease is present in PNG and other countries around the rim of the western Pacific and is a major disease in these areas.

Yield loss estimates

No yield loss studies were conducted on DM in Australia, and the relationship between disease severity and yield was not established. As with some other diseases, casual observations confirmed that the disease could cause substantial losses.

Husmillo (1982) in the Philippines investigated the relationship between disease intensity and yield caused by the closely related downy mildew pathogen *Peronosclerospora philippinensis*. Mixtures of healthy and diseased setts were planted to create disease intensities ranging from 0 (treated with metalaxyl) to 85% infection (stool or stalk infection was not specified). Maximum losses in tonnes cane was 37.5% and in tonnes sugar/ha, 58.1%. Sugar content was not affected except at the highest disease level. The equations relating yield to disease intensity are:-

Y (tonnes cane/ha) = 168.15 -0.90 X (disease intensity) r = -0.96

Y (*Ps/ha) = 250.72 - 1.99 X (disease intensity) r = -0.94

*Ps = picul/sugar (a picul = 63.25kg)

Yield loss studies with *P. sacchari,* following a similar method, are current at Ramu Sugar in PNG.

3.3 Gumming

Gumming is a systemic bacterial disease caused by *Xanthomonas campestris* pv. *vasculorum*. It was the first sugarcane disease recorded in the literature (Ricaud and Autrey, 1989) when described by Dranert in 1869 in Brazil. The disease has caused substantial losses in a number of countries, including Australia, and is considered a major disease. Control has been achieved through varietal resistance, with several countries (Australia, Brazil, Fiji and the West Indies) conducting successful eradication campaigns.

Yield loss estimates

The disease was last seen in Australia in 1947. Epiphytotics caused substantial losses early in the history of the Australian industry but specific yield loss research was never conducted in this country. However North (1935) reported yield reductions of 30-40% (cane tonnage) and 9-17% (sugar content) occurred in New South Wales in the 1893-1899 period. Recent research in Mauritius (Ricaud and Autrey, 1989) has shown that significant losses may occur in current commercial hybrids. Systemic infection in the susceptible M377/56, showing severe symptoms resulted in a 19.5% reduction in sugar yields compared to lightly diseased cane. In other experiments, yield reductions of up to 45% were recorded in the same variety in healthy vs. diseased material. Gumming disease has a further debilitating effect in that the gum produced in stalks may severely disrupt sugar manufacture in the milling process (Hughes, 1961).

3.4 Ramu Stunt

Ramu stunt is one of several recently recognised diseases occurring in Papua New Guinea. It is thought to be a systemic viral disease (Kuniata *et al.* 1994) transmitted by the planthopper *Eumetopina* spp, though some evidence suggests a phytoplasma as the cause (Jones and Cronje, pers. comm.) The disease has been seen in commercial canes on the estate of Ramu Sugar Ltd, Gusap and in surrounding chewing (*S. officinarum*) and wild canes (*S. robustum*).

Yield loss estimates

No yield loss studies have been undertaken. The disease was first recognised in 1986 when 90% of the estate of Ramu Sugar was planted to the susceptible variety Ragnar. Infection by Ramu stunt contributed substantially to a reduction in crop from the original estimate of 360,000 t cane to the actual harvest result of around 120,000t (Eastwood 1990). The disease usually leads to plant death in susceptible clones.

3.5 White leaf/Grassy shoot

White leaf and grassy shoot diseases occur in south Asia (India, Bangladesh, Malaysia, Nepal, Pakistan, Sri Lanka, Sudan, Thailand, Taiwan) and are caused by phytoplasmas. The two diseases show some variation in symptom expression though stunting and leaf chlorosis are common. Transmission of the diseases is via insects and planting material. White leaf has been a disease of major importance in Thailand.

Yield loss estimates

Little data on yield losses has been published. Rishi and Chen (1989) suggest grassy shoot can cause severe losses, especially when diseased planting material is used. Chuang-Yang and Ling (1963) reported a 74% loss in cane yield with white leaf disease, and a 30% loss in sugar content.

4.0 DISCUSSION

It is clear from this review that the data on yield losses caused by Australian diseases are incomplete and considerable research is needed. A summary is detailed in Table 6.

Table 6: Types of yield loss research conducted with important Australian and exotic diseases

Australian Research

Disease	Disease intensity vs. yield	Healthy vs. diseased comparison	Effect of varietal resistance on losses
Fiji	✓	✓	x
Leaf scald	x	x	x
Mosaic	✓	✓	✓/x
rsd	x	✓✓	✓
red rot	x	x	x
chlorotic streak	✓	✓	x
common rust	x	✓	✓
yellow spot	x	x	x
red stripe/top rot	x	✓	x
eye spot	x	x	x
striate mosaic	x	x	x
Pachymetra root rot	✓	✓	x
dwarf	x	x	x
yellow leaf	x	x	x
Bacilliform virus	x	x	x

Overseas Research

Disease	Disease intensity vs. yield	Healthy vs. diseased comparison	Effect of varietal resistance on losses
Smut	✓✓	✓✓	x
downy mildew	✓	x	x
gumming	x	✓	x
white leaf/grassy shoot	x	✓	x
Ramu stunt	x	x	x

x = no research conducted ✓= some research conducted ✓✓ = much research conducted

With some diseases, it could be argued that a comparison of healthy vs. diseased cane yields is unnecessary (eg leaf scald, striate mosaic and dwarf) since the disease usually kills infected highly susceptible plants. While this is true, the types of losses suffered by these varieties in the field, with high natural levels of infection, could be useful information - particularly for leaf scald.

For estimating yield losses in commercial crops, it is important that two types of yield loss studies are undertaken. (1) relating disease intensity to yield; (2) relating yield losses to varietal susceptibility. Disease intensity investigations have been undertaken with Fiji, mosaic, chlorotic streak, and Pachymetra root rot and this has provided a guide as to yield losses occurring with a particular disease intensity. There are a number of diseases where this relationship has never been investigated, some examples are rust, yellow spot and leaf scald. Even with those where disease intensity vs. yield has been studied, little research has been directed toward investigating how varietal susceptibility influences this relationship. There are two outcomes which naturally result from this lack of knowledge:-

(a) **An inability to predict yield losses:** it is almost impossible to accurately predict yield losses caused by disease in the Australian sugar industry based on disease incidence data.

(b) **Uncertainty in varietal selection strategies:** it is very difficult to assign rejection values for disease susceptibility for clones in the plant improvement program (production of new varieties). Varieties are usually discarded if it is considered that significant yield losses would occur under field conditions. If the relationship between susceptibility and yield losses is largely unknown, then the setting of thresholds for susceptibility has an unsure footing. Current thresholds have been set intuitively based on field observations, and though providing perhaps reasonable guidance, their accuracy remains questionable. The discard of germplasm is a major cost to industry; some quantitative data should be gathered to confirm intuitive decisions.

In considering the effect of a disease on yield, and particularly when using overseas data on diseases endemic in Australia, the issue of pathogen variability (strains) is most important. Though pathogen variability is limited in Australia, considerable variability occurs around the world. This is evidenced with mosaic disease where up to 13 species of the poty virus have been distinguished. Though all infect sugarcane, the strains have been classified as either sugarcane mosaic virus, sorghum mosaic virus or johnsongrass mosaic virus (Tosic *et al*, 1990). Losses will vary according to which virus is causing the disease. Strains have also been reported for the pathogens associated with the following diseases: common rust, leaf scald, smut, downy mildew and gumming. Yield loss studies should take account of this variation.

For most Australian diseases, current yield loss data are deficient. These include leaf scald, red rot, sugarcane mosaic, Pachymetra root rot, yellow spot, rust and chlorotic streak. Nothing is known of the effects of bacilliform virus and yellow leaf syndrome on yield.

Future yield loss studies should investigate the relationships between disease intensity and yield, and varietal resistance and yield. It is recommended that research with 2-3 diseases occur first, with on-going yield loss studies building on the methods and results gained in the initial studies.

Of the exotic diseases, sugarcane smut has been well studied and its effects on yield could be reasonably predicted. Yield loss data is lacking for DM, gumming, white leaf/grassy shoot and Ramu stunt diseases.

5.0 FURTHER RESEARCH

Further research should be directed toward relating disease intensity to yield, and assessing the influence of varietal susceptibility on losses with a number of diseases. Opportunity exists to understand the latter relationship by planting a series of paired diseased and disease-free plots of a range of varieties of differing resistance in the same experiment (similar to, but an expansion of the rust yield loss studies reported). By including 15-20 varieties, the relationship between resistance and losses could be better understood, and thresholds for variety discard refined. This will take significant resources, particularly if undertaken for the major Australian diseases, but could provide considerable returns in the long term. Such investigations would also allow better predictions of economic losses from currently gathered industry disease data. It is suggested that initial research target the diseases rust and yellow spot, with a consideration of further yield loss studies at the conclusion of these first experiments.

There is still much research needed to relate disease and yield losses in the Australian sugar industry.

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APPENDIX I

Summary of yields from various varieties in ratoon stunting disease trials harvested to the end of 1955; tons of cane per acre. (Steindl, 1956).

Variety	Crop	Yield		Loss	
		Healthy	Diseased	Tons	Percentage
Badila	Plant	58.23	57.02	1.21	2.08
"	"	33.45	32.65	0.80	2.39
"	"	37.32	32.17	5.25	14.07
"	"	25.83	25.58	0.25	0.97
"	"	36.33	37.58	-1.25	-3.44
"	Pl. Av.				3.21
"	Ratoon	30.20	27.18	3.02 *	10.00
C.P.29/116	Plant	38.24	36.73	1.51	3.95
"	"	36.68	37.74	-1.06	-2.89
"	"	42.70	38.40	4.30	10.07
"	Pl. Av.				3.71
Comus	Plant	34.98	36.18	-1.20	-3.43
"	"	49.71	51.02	-1.31	-2.64
"	"	37.15	38.65	-1.50	-4.04
"	Pl. Av.				-3.37
"	Ratoon	23.06	23.17	-0.11	-0.48
N.Co.310	Plant	34.75	28.31	6.44 §	18.53
"	"	28.75	25.33	3.42 *	11.90
"	Pl. Av.				15.22
"	Ratoon	31.58	26.78	4.80 §	15.20
P.O.J.2878	Plant	30.75	26.29	4.46 *	14.50
"	"	36.01	31.70	4.31 §	11.97
"	Pl. Av.				13.24
"	Ratoon	20.71	18.21	2.50	12.07
Pindar	Plant	25.11	21.86	3.25 *	12.94
"	"	47.88	40.87	7.01 §	14.64
"	"	49.98	49.30	0.68	1.36
"	"	41.67	35.83	5.84 §	14.01
"	"	43.48	40.75	2.73	6.28
"	"	40.65	35.25	5.40 §	13.28
"	"	37.80	34.90	2.90 §	7.67
"	"	54.28	41.84	12.44 §	22.92
"	"	49.50	48.15	1.35	2.73
"	"	34.86	32.24	2.62	7.52
"	"	38.10	37.80	0.30	0.79
"	"	31.43	26.61	4.82 §	13.34
"	"	44.96	41.90	3.06 §	6.81
"	"	33.56	31.50	2.06	6.14

Table 1 - Continued					
		Yield		Loss	
Variety	Crop	Healthy	Diseased	Tons	Percentage
"	Pl. Av.				9.32
"	Ratoon	30.63	25.64	4.99 §	16.29
"	"	44.09	32.34	11.75 §	26.65
"	"	27.43	25.07	2.36	8.60
"	"	38.01	28.48	9.53 §	25.07
"	Ratoon Av.				19.15
Q.28	Plant	28.6	17.9	10.7 §	37.4
"	"	36.0	27.3	8.3 §	23.1
"	"	30.2	23.9	6.3 §	20.9
"	"	40.1	33.1	7.0 §	17.5
"	"	37.3	33.0	4.3 *	11.5
"	Pl. Av.				22.1
"	Ratoon	27.6	9.6	18.0 §	65.2
"	"	20.5	7.5	13.0 §	63.4
"	"	17.0	10.0	7.0 §	41.2
"	"	29.6	11.4	18.2 §	61.5
"	"	30.3	10.0	20.3 §	67.0
	Ratoon Av.				59.7
Q.47	Plant	37.13	30.57	6.56 §	17.67
"	"	34.63	35.43	-0.80	-2.31
"	"	35.14	31.22	3.92§	11.16
"	Pl. Av.				8.84
Q.50	Plant	32.07	27.65	4.42 *	13.78
"	"	36.97	37.02	-0.05	-0.14
"	"	36.78	35.03	1.75	4.76
"	"	46.10	46.38	-0.28	-0.16
"	"	32.47	30.25	2.22	6.84
"	"	25.97	25.68	0.29	1.12
"	Pl. Av.				4.29
"	Ratoon	32.91	30.25	2.66 *	8.08
"	"	29.83	28.53	1.30	4.36
"	"	39.92	39.67	0.25	0.63
"	Ratoon Av.				4.36
Q.56	Plant	30.66	31.00	-0.34	-1.11
Q.57	Plant	41.95	40.55	1.40	3.34
"	"	38.04	34.72	3.32 *	8.73
"	Pl. Av.				6.04
S.J.4	Plant	30.40	30.85	-0.45	-1.48
"	"	34.52	23.59	10.93 §	31.66
"	Pl. Av.				15.09

Table 1 - Continued					
		Yield		Loss	
Variety	Crop	Healthy	Diseased	Tons	Percentage
S.J.16	Plant	47.75	43.55	4.20	8.80
"	"	54.00	53.58	0.42	0.78
"	"	49.66	47.42	2.24	4.51
"	"	42.38	42.84	-0.46	-1.09
"	Pl. Av.				3.80
"	Ratoon	29.38	25.60	3.78	12.87
Trojan	Plant	37.04	29.58	7.46 §	20.14
"	"	84.65	83.99	0.66	0.78
"	"	37.56	33.44	4.12 §	10.97
"	"	45.83	34.27	11.56 §	25.22
"	"	43.25	33.42	9.83 §	22.73
"	"	31.59	26.72	4.87 §	15.42
"	"	45.32	42.18	3.14	6.93
"	"	49.97	48.08	1.89	3.78
"	"	46.71	42.74	3.97 *	8.50
"	"	25.08	25.26	-0.18	-0.72
"	"	38.57	37.13	1.44	3.73
"	"	30.95	31.20	-0.25	-0.81
"	"	24.23	19.53	4.70 §	19.40
"	"	38.01	36.54	1.47	3.87
"	"	44.21	41.77	2.44 *	5.52
"	Pl. Av.				9.70
"	Ratoon	20.38	17.96	2.42	11.87
"	"	43.07	38.77	4.30 *	9.98
"	"	17.98	14.57	3.41 §	18.97
"	"	28.58	13.86	14.72 §	51.50
"	"	29.56	19.22	10.34 §	34.98
"	Ratoon Av.				25.46
Vidar	Plant	41.45	36.35	5.10 §	12.30
"	"	39.17	35.00	4.17 §	10.65
"	"	45.50	43.30	2.20	4.84
"	Pl. Av.				9.26
"	Ratoon	22.43	17.51	4.92 §	21.93

*** Differences significant at the five per cent level.**
§ Differences significant at the one per cent level.

APPENDIX 2:

Summary of yield losses caused by RSD as reported in recently published papers (as reported in SRDC project BS172S final report).

Country Ref.	Number of Cultivars	% Cane Yield Loss							
		Plant		1st Ratoon		2nd Ratoon		Crop Cycle	Length of crop cycle
		Mean	Range	Mean	Range	Mean	Range	Mean	(yrs)
Australia (Unpublished)[a]	6	13	-8[b] to 22	21	-6 to 34			17	2
Louisiana U.S.A. (Grisham, 1991)	8	14	3 to 20	17	6 to 32	29	8 to 55	19	3
Louisiana USA (Koike, 1982)[c]	4							12	2
Louisiana USA (Koike, Gillaspie, Benda,1982)[b]	20							13	3
Natal S.Africa (Bailey & Bechet, 1986)	8	12	2 to 23	20	0 to 45	27	11 to 45	20	3
Florida USA (Dean & Davis, 1990)	4	3	-17 to 12	4	-7 to 30	7	-27 to 43	5	3
Florida USA (Irey, 1986)	2	7	6 to 7	7	6 to 8			7	2

a. Cane Protection & Productivity Board and BSES demonstration plots using current commercial varieties including Q107, Q115, Q117, Q122, Q124, Q138.
b. Negative values mean that the RSD-infected cane out-yielded the healthy can in some cultivars.
c. Data for individual crops not published.

APPENDIX 3: The effect of rust on sugarcane yield in yield loss experiments conducted in southern (Isis) and northern (Mourilyan) Queensland.

The effect of rust infection on sugar quality of 70S77, Q90, Q108, Q87 and Q110 in the Isis trial
Treated plots were sprayed with oxycarboxin

Cultivar	Refrac. brix	Spindle brix	Pol	Fibre	CCS Sept 83	Pol % juice	% sucrose (HPLC) in juice	% glucose (HPLC) in juice	% fructose (HPLC) in juice	% dry sub in juice	% True purity	% Ash in juice	Reducing sugar to ash ratio	pH of juice
70S77														
Treated	20.23	20.31	77.63	11.62	13.19	18.66	18.70	0.06	0.09	20.01	93.48	0.50	0.31	5.57
Untreated	19.77	20.50	75.42	11.75	12.42	18.11	18.18	0.06	0.06	19.48	93.35	0.50	0.25	5.58
Q90														
Treated	19.53	19.43	73.03	9.66	12.60	17.62	17.63	0.11	0.13	19.29	91.34	0.42	0.57	5.57
Untreated	19.29	19.33	72.41	9.86	12.43	17.48	17.64	0.10	0.11	19.13	92.15	0.48	0.46	5.55
Q108														
Treated	19.13	19.18	72.25	15.03	11.60	17.46	17.51	0.11	0.12	18.97	92.32	0.46	0.51	5.59
Untreated	18.64	18.69	69.73	15.20	11.08	16.88	16.96	0.12	0.14	18.47	91.83	0.50	0.52	5.55
Q87														
Treated	19.83	19.89	76.86	11.36	13.23	18.51	18.50	0.13	0.14	19.83	93.27	0.34	0.80*	5.60
Untreated	20.06	19.98	77.69	10.64	13.57	18.70	18.67	0.10	0.11	19.89	93.89	0.37	0.59*	5.61
Q110														
Treated	19.57	19.73	75.66	14.47	12.42	18.24	18.24	0.11	0.11	19.50	93.54	0.32	0.67	5.56
Untreated	20.20	19.90	78.90	13.90	13.37	19.00	19.03	0.09	0.10	20.05	94.92	0.31	0.59	5.60
LSD (0.05) #	0.97	0.91	5.07	0.83	1.19	1.16	1.14	0.03	0.05	0.94	2.27	0.14	0.20	0.12

* Means are significantly different ($p \leq 0.05$); all values are the mean of three replicates.
# Least significant difference for comparing the two treatment means for each individual cultivar.

The effect of rust infection on growth and yield of 71A123, Q90, Q105, Q107 and Q113
in the Mourilyan trial
Treated plots were sprayed with oxycarboxin

Cultivar		**Number of shoots/ha ($x10^5$) Nov 82**	**Number of stalks/ha ($x10^5$) Sept 85**	**Stalk cross sectional area (cm^2)**	**Stalk height to T.V.D. (cm)**	**Tonnes cane per hectare**	**CCS**	**Tonnes sugar per hectare**
71A123	Treated	0.906*	0.735	4.18	305.4	101.75	13.13	13.26
	Untreated	0.715*	0.684	3.78	277.2	85.86	14.56	12.47
Q90	Treated	1.181	0.830	4.51	359.0	156.27	15.63	24.40
	Untreated	1.060	0.798	4.28	354.9	130.75	15.25	19.94
Q105	Treated	1.153*	0.871*	4.08*	265.3*	109.58	16.32	17.87**
	Untreated	0.959*	0.765*	3.48*	230.3*	73.81	16.65	12.29**
Q107	Treated	1.133	0.615	6.88	365.3	157.93	14.84	23.45
	Untreated	1.071	0.589	6.64	363.4	146.09	15.18	22.18
Q113	Treated	1.171	0.928	3.76	337.1	139.86	14.98	20.97
	Untreated	1.134	0.962	4.09	331.2	136.18	14.76	20.03
LSD (0.05 #		0.139	0.070	0.44	32.1	36.26	1.83	4.51

* Means are significantly different ($p \leqq 0.05$); ** Means are significantly different ($p \leqq 0.10$); all values are the mean of three replicates.

\# Least significant difference for comparing the two treatment means for each individual cultivar.