BSES Limited

SUGARCANE SMUT YIELD-LOSS ESTIMATES – EASTERN AUSTRALIA 2006

RESPONSES TO QUESTIONS RAISED BY THE CONSULTATIVE COMMITTEE ON EMERGENCY PLANT PESTS

by

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SUMMARY

- The rationale for refined estimates of expected losses due to sugarcane smut in eastern Australia is presented.
- The initial advice to ABARE that the yield-loss estimates in the 1998 ABARE report were appropriate was made without having sufficient time available to gather full expert opinion and without a full understanding of the epidemiology of the incursion in the Bundaberg-Childers area.
- Yield losses from smut in eastern Australia will depend on:
  - the susceptibility of sugarcane varieties in commercial production in each area;
  - crop class;
  - the disease pressure dictated by the inoculum load and conduciveness of environmental conditions for infection;
  - whether the source of the infection is systemically infected planting material or secondary wind-borne infection; and
  - the date of arrival and rate of spread of the disease within and between sugarcane production regions.
- Evidence from epidemiological studies indicates that the date of entry of the disease in Bundaberg-Childers was 2004.
- In Bundaberg-Childers, varieties such as Q205$^{\Phi}$ are as susceptible, or perhaps more susceptible, than were Q117 and NCo310 in the Ord River Irrigation Area (ORIA).
- In general, Australian commercial varieties are highly susceptible to the disease.
- There is no evidence of ‘breakdown’ in the resistance levels of resistant varieties under high disease pressures – intermediate varieties will show increased disease levels and some yield loss under high inoculum levels.
- All studies show increased disease levels in older crops – these in turn produce more inoculum.
- Areas such as the Burdekin, drier areas of northern Queensland, and Proserpine-Mackay-Sarina have environments highly conducive to the disease – infection levels, rate of spread and inoculum levels will be higher in these areas than currently being experienced in the Bundaberg-Childers area.
- Systemically infected planting material will disseminate the disease more rapidly in the short term than will wind-borne infection, i.e. severe levels of infection will occur more rapidly in infested fields in outbreak areas or in areas that are in relatively close proximity.
- These observations support our conclusions that, in the absence of a co-ordinated response to the disease incursion, the incidence of smut will expand rapidly in Bundaberg-Childers and disease outbreaks will occur rapidly in other cane-growing areas.
- The disease is likely to impact differently in other areas because of different environments and access to propagation material of resistant varieties. The most severe impact will occur in the Burdekin and Proserpine-Mackay-Sarina regions (47% of production in eastern Australia).
- The above factors have guided our estimates of yield loss to the disease in each production area of eastern Australia.

1.0 Introduction

This document has been prepared by BSES scientists with extensive experience with sugarcane smut. It is based on our reviews of published literature and first-hand experience with smut in the Ord River Irrigation Area and Childers-Bundaberg regions of Australia. While reference to the published literature has been an important component of this analysis, our experience in the Ord River Irrigation Area (ORIA) has been used as the most appropriate basis for developing yield-loss estimates, because it is the only situation where we have direct experience with Australian varieties under commercial conditions. Additionally, leading sugarcane scientists in other countries, who have first-hand experience of smut, its effects and its control, have been consulted to ensure the accuracy of these forecasts.

2.0 Yield losses from sugarcane smut

Yield losses from smut in eastern Australia depend on:

- the susceptibility of sugarcane varieties in commercial production;
- crop class;
- the disease pressure dictated by the inoculum load and conduciveness of environmental conditions for infection;
- whether the source of the infection is systemically infected planting material or secondary wind-borne infection; and
- the time of arrival and rate of spread of the disease within and between sugarcane production regions.

2.1 Correlation between smut incidence and yield loss

Here we summarise and interpret published yield loss data and introduce how yield loss estimates were derived based on our experience in the ORIA.

2.1.1 Published literature

Two types of yield-loss estimate exist in the literature:

- Simple reports of yield loss at one level of smut infection at one point in time – these are useful for validating the predictions from models of yield loss over time;
- Relationships between percent-infected plants and yield loss that allow prediction of losses over time – these are more appropriate to the development of predictive models of yield loss.

Simple reports of yield loss at one point in time presumably refer to the maximum loss before responses to the incursion had effect. Examples are:

- Anon. (1979) reported a 92% yield loss from 90% infected stalks in South Africa.
- Hoy et al. (1986) reported a 54% yield loss at 60% infected stalks in Louisiana.
- Glaz et al. (1989) reported 30% yield loss from 10% infected stalks in Florida.
- Akalach (1996) reported 90% infection in a susceptible variety 2 years after detection in Morocco.

- Bailey (pers. comm. RA Bailey, 13 August 2006) has commented that in the Nchalo district of southern Malawi, he estimated yield losses from smut in variety NCo310 in the late 1970s-early 1980s as approximately 40%. On that estate, variety NCo310 was totally infected (i.e. all plants), resulting in mean yields of approximately 80 tonnes cane/ha/year, compared with more than 120 tonnes when this variety was first planted.
- Whittle (1982) estimated maximum losses from the disease in plant and first-ratoon crops in Guyana at 26%.

In published studies from overseas, the relationship between percent-infected plants and yield loss due to smut varies markedly, depending on the variety and the environment in which the research was conducted (Table 1).

Table 1 Relationship between percent yield loss from sugarcane smut and percent-infected plants as reported from overseas research

Country	% loss for each 1% increase in infected plants		Reference
	Range (number of varieties)	Average	
Brazil	0.10-1.00 (136)	0.67	Anon. (1993), Copersucar Ann. Rept. 1992/93
USA – Florida	0.61 (1)	0.61	Irey (1986), Proc. Am. Soc. Sugar Cane Technol. 6:32-36
India	0.48 (1)	0.48	Padmanaban et al. (1988), Indian Phytopathology 41:367-369
Mean		0.59	

For estimating potential yield losses in eastern Australia, we have used the average of these reports, namely 6% yield loss for each 10% increase in percent-infected plants. This is close to the estimate of 5% yield loss for each 10% increase in percent-infected plants that has been used in southern Africa since the 1980s (pers. comm. RA Bailey, 13 August 2006).

Yield losses are also influenced by:

- Crop class (plant crop or successive ratoon crops);
- Whether the infection is from systemically infected planting material, or secondary wind-borne infection.

Crop class - Chona (1956) reported yield losses of 70% loss in ratoon crops, compared to 29% loss in plant crops. Similarly, Whittle (1982) reported from Guyana that losses in a plant and first ratoon crop were estimated with disease levels of 28%. We interpret these data as indicating that subject to variety and environment, losses greater than 28% are highly likely at higher disease levels and in older crop classes.

Infection source - Losses are usually greater when systemically infected planting material is used to establish new crops (Lee-Lovick 1978).

These are considered below in the context of the epidemiology studies conducted to date in the Bundaberg-Childers area.

2.1.2 Yield-loss estimation from Australian data and experience

We derived estimates of potential yield losses from correlations between smut infection and yield loss. A wide range of other methods for estimating yield loss are available, but we have concentrated on estimates between percent loss and percent-infected plants, because these can be extended easily to any situation.

The only information that is available on Australian varieties under commercial conditions comes from observations made in the ORIA.

The following quotations are relevant to interpret the epidemiology and disease progression in the ORIA and serve as a key reference point for defining what we expect to observe in eastern Australia.

- *"At the time of smut's arrival here, NCo310 was a major variety, and very susceptible to smut. NCo310 would not produce second ratoons in the presence of smut - 100% loss in practical terms. Similarly, Q117 was just getting going commercially here and was looking very promising - it would not produce first ratoons in the presence of smut - again 100% loss. We have trouble maintaining NCo310 and Q117 here for use as standards in our smut trials." (Bill Webb,* Western Australian Agriculture and Food / BSES extension officer with 35 years experience in sugarcane RD&E)
- *"Assuming no very rapid spread of smut beyond what current meagre data suggest, there are unlikely to be any direct yield losses in NCo310 and Q117 in the 1999 and 2000 crops. Brian Egan, August 1998: [This report is illustrative of how wrong predictions can be when based on inadequate information.]*
- *There has been an explosive increase in % smut infection in Q117 since the initial inspections in 1998. Well-grown plant cane in late 1998 is now showing lots of symptoms in most stools. (Brian Egan, April 1999).*
- *The smut situation has deteriorated markedly. We can be quite certain now, one year after initial detection, that Q117 becomes very heavily infected over a short period, will collapse in yield even in first ratoons, and can produce enormous inoculum pressure. Part of the well grown plant block was ratooned as an experiment, produced only masses of grassy shoots with no normal shoots, and was ploughed out. Yield loss 100%in the first ratoon. (Brian Egan, August 1999).*
- *NCo310 smut incidence increased considerably but most blocks will yield reasonably in 2000. (Yields subsequently collapsed, i.e. it lasted 1 year longer than Q117). (Brian Egan, 2000).*

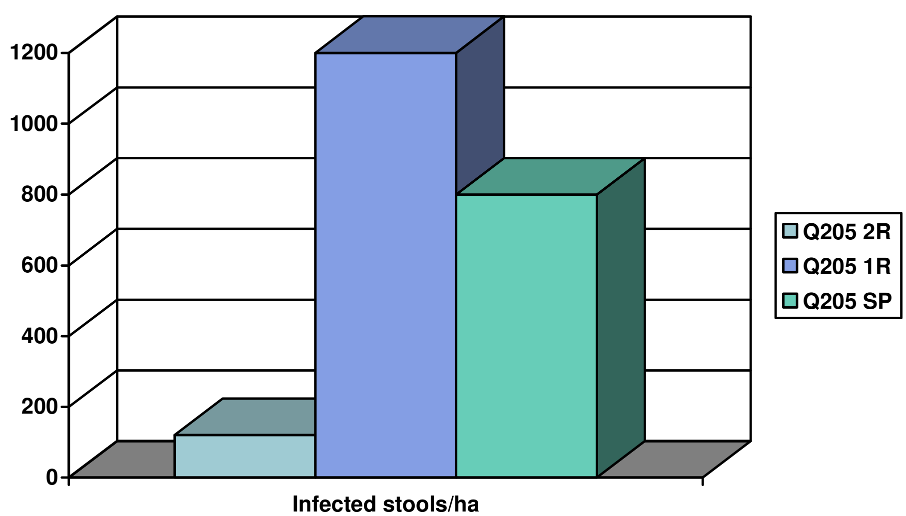
The variety Q117 comprises 5% of the Burdekin crop, but of greater concern is that Q117 and NCo310 were used extensively as parents before the heightened smut risk and feature prominently in the parentage of many Australian commercial varieties. Experience in the Ord suggests that almost all varieties with Q117 as a parent have a similar reaction to Q117.

Our estimates are also strongly influenced by observations on Australian varieties in smut-resistance screening trials in Indonesia and ORIA (Croft et al. 2000; Engelke et al. 2001). In these trials, most Australian varieties suffer severe yield loss or even total loss in the first-ratoon crop (second year of growth). For example, Engelke et al. (2001) reported that the sugarcane varieties introduced to the ORIA in 1999 had heavy natural infection pressure from the time they were planted in July 1999, and many showed smut infection within 1 year. For example, Q141 was 100% infected and badly affected within 7 months of introduction, while others such as Q154, Q165[Φ] and Q179[Φ] were 100% diseased within a year.

We also have observations on our varieties from many countries and, in nearly all cases, they report that many of our varieties are far too susceptible to smut to be considered for commercial production. For example, Brazil has never commercialised an Australian variety despite an active, on-going exchange program (pers. comm. Dr Bill Burnquist, CTC Centre, Brazil, 11 August 2006). Similarly, no Australian variety has ever been released for commercial production in South Africa, with susceptibility to smut being one of the main reasons (pers. comm. RA Bailey, 13 August 2006).

The effect of planting systemically infected planting material has been seen on one of the heavily infested premises in Childers. We believe that infected cane was planted out in both 2004 and 2005. The level of disease in the original infested block (now second ratoon, 2R), the 2004-plant (now first ratoon, 1R), and the 2005-plant blocks (SP) are shown in Figure 1. The dramatic increase in infection in field-planted systemically infected planted material can be seen in this case. The second-ratoon block has a concentrated patch of infection in the area where it is thought that the plants were taken to plant the first-ratoon blocks.

Fig. 1 Smut in different crops of Q205



2.2 Rate of spread and disease incidence in commercial fields

2.2.1 Published literature

Estimates of yield loss over time will depend on the rate of spread and build-up of the disease. These factors are also strongly influenced by variety and environment and, therefore, it is difficult to extrapolate from one country or region to another. The disease is favoured by hot dry climates. Infection is favoured by temperatures of 24-34℃ (Bock 1964), and spore survival declines as soil-moisture content increases (Andreis 1980).

It is difficult to obtain good data on disease build-up over time in overseas countries, because management strategies confound the picture. In all overseas countries, highly susceptible varieties suffered severely and they have been replaced rapidly with resistant varieties.

2.2.2 Rate of spread and disease incidence from Australian data and experience

The spread and build up of smut in the ORIA in susceptible varieties was rapid. The estimated date of the initial incursion in the ORIA was 1996 and, by the end of 1999, all crops of Q117 were 100% infected (Engelke et al. 2001). All crops of the variety NCo310 were 100% infected by 2000. In summary, susceptible varieties were 100% infected 3-4 years after the arrival of smut.

Table 2 gives a similarity index for the match for maximum and minimum temperatures and annual rainfall for Queensland locations with those of Kununurra. [Data derived from CLIMEX and represent an index only – they are not percentages. Indexes of >30 usually indicate biological limitations].

The ORIA has a similar climate to the Burdekin region (PQA3) in Queensland – see Table 2, particularly minimum temperature and rainfall. In our yield-loss estimates, we considered that the rate of spread and build up of the disease in susceptible varieties in PQA3 would be similar, but slightly slower, than in the ORIA. Similarly, we considered the rate of spread in PQA5 to be similar to that in Florida (Miami has climate matches with Bundaberg of 80, 50 and 70 for maximum temperature, minimum temperature and rainfall, respectively). We combined these estimates of disease spread and the average yield loss for all varieties from the overseas reports in Table 1 to give the estimated yield loss over time. We believe that this is a very conservative estimate for this region, considering that 3-4 years after entry of smut in the ORIA the two susceptible varieties suffered effectively 100% yield loss.

Table 2 Matches of climatic parameters with those of Kununurra (CLIMEX)

Area	Location	Maximum temperature	Minimum temperature	Annual rainfall
PQA2	Mareeba	39	48	87
	Innisfail	32	74	20
	Ingham	40	65	36
PQA3	Bowen	37	86	81
PQA4	Mackay (Te Kowai)	32	49	47
PQA5	Bundaberg	25	42	77
PQA6	Maryborough	28	37	69
NSW	Murwillumbah	24	32	47

In the other regions of eastern Australia, we considered the environmental differences for each region and modified the expected rate of spread and build–up. We took into consideration the experience in the ORIA and the spread in the Childers/Bundaberg region

(PQA5), where we believe that, within 2 years, the disease has spread from the original infection to 57 farms and that, in 5 farms, the disease has already reached a level where yield losses are being experienced. If the containment program is not implemented, this spread and disease build-up will escalate dramatically in the coming seasons.

Table 3 summarises the times of arrival and detection and the predicted yield loss in susceptible varieties in the absence of the Response Plan activities.

Table 3 Predicted yield losses (%) in susceptible varieties without a containment program

Year	PQA2	PQA3	PQA4	PQA5	PQA6	NSW
2006				Detection	Detection	
2007		Arrival	Arrival	5	2	
2008	Arrival	Detection	Detection	10	5	Arrival
2009	Detection	5		25	10	Detection
2010		10	5	40	30	
2011	5	30	10	60	60	5
2012	8	60	30			15
2013	23		60			30
2014	40					

The following interpretation of the relative conduciveness of each region to smut build-up was applied to our estimates of expected yield losses in each region.

PQA2 (Wet Tropics, Atherton Tablelands, Herbert Valley – 34.3% of production) – This is a highly variable tropical region with both hot-dry climates, which will be favourable for smut spread and build-up, and super-wet tropical regions, which will be less favourable for the disease. We estimate that the disease would reach this region in 2 years (2008) if there is no containment program and spread would be on average less than experienced in the ORIA and less than that predicted in PQA3. However, there will be parts of this region, such as the Atherton Tablelands and the drier parts of the Herbert, Mulgrave and Mossman mill areas, that will suffer losses similar to those in the ORIA.

PQA3 (Burdekin Valley – 22.0% of production) – Similar hot dry climate to the ORIA and requiring full irrigation. Smut spread and yield losses are likely to be similar to the ORIA, and we are conservative in estimating that the losses will be slightly lower than the actual losses experienced in the ORIA. We estimate that smut would arrive and be causing economic losses by 2009 if action is not taken to contain it within the proposed Control Area.

PQA4 (Proserpine, Mackay, Sarina – 25.7% of production) – PQA4 has a generally dry climate, which requires full to supplementary irrigation. Winters are slightly cooler than in PQAs 2 and 3. It has a similar climate to the northern sugarcane areas of South Africa where smut can cause serious yield losses in susceptible varieties. We estimate that, without a containment program, the disease would reach this region in 1 year (2007) and would spread and build-up at a slower rate than in the ORIA, but at a faster rate than in the cooler PQA5.

PQA5 (Bundaberg, Childers – 9% of production) – Smut has been present in this region for 2 years and has already spread to 57 farms. Yield losses are currently restricted to five heavily infested farms, but are likely to increase rapidly if there is no containment program. Disease spread will be slower than in the ORIA, because of the cooler climate in this region. We have predicted (in the absence of the Response Plan) a 5% loss in susceptible varieties in 2007, escalating to 60% by 2011 as inoculum increases and infected material is used for planting.

PQA6 (Maryborough, Rocky Point – 2.7% of production) – This area is only 30-40 km south of PQA5 and smut is likely to reach this area in 6-12 months (2006) if there is no program to contain smut to the current affected area to the north. The northern (70% of production) area of PQA6 has no effective ecological barrier to PQA5. The climatic conditions are similar to PQA5, so the progression of yield losses would be similar to those in PQA5.

NSW (Tweed, Richmond and Clarence Valleys – 6.3% of production) – NSW is the most southerly cane-growing region in Australia and has similar climatic conditions to the southern parts of the South African sugar industry. Smut is less important in that part of the South African sugar industry, but can cause some losses in highly susceptible varieties. We estimate that smut would take 2 years to spread to this region, the region would suffer lower losses, and losses would take longer to be expressed.

3.0 Answers to Specific Questions posed by CCEPP

3.1 International yield comparisons

Question:
Why are yield losses (at 60%) so much higher than [some] international studies suggest? Field trials in Guyana demonstrated losses in five of twenty varieties and the maximum loss was 26%. In Morocco, losses were around 11.7%, two years after detection.

The key factors determining the effect of smut are **variety susceptibility, environmental conditions** and **time since the incursion**, and it is difficult to compare the events in Guyana and Morocco with the situation in Australia. Our estimates of yield loss are based on extensive reading of the literature and the personal experience of a number of BSES scientists. It is also strongly influenced by experience in the ORIA **with Australian susceptible varieties** after the smut incursion in 1998. In the ORIA, which is not dissimilar to the drier northern parts of Queensland, total crop loss was experienced in the two susceptible varieties within 3-4 years from the estimated date of the incursion. Our observations on Australian varieties in smut-resistance screening trials in Indonesia, ORIA and reported to us from some overseas countries suggest that the estimates of losses that we have supplied to ABARE are conservative **for our environments and varieties**. The maximum losses in PQA5 are predicted 5 years after detection.

3.2 Why have the yield-loss estimates changed?

Question:
Why have the yield loss estimates changed so much since the original ABARE analysis was completed?

The initial advice to ABARE that the yield-loss estimates in the 1998 ABARE report were appropriate was made without having sufficient time available to gather full expert opinion and without a full understanding of the epidemiology of the incursion in the Bundaberg-Childers area. It was given in the context of the assumptions in the1998 ABARE report.

The base assumptions in the 1998 ABARE report are considerably different to those used in the current ABARE analysis. The 1998 ABARE report estimated the cost of a smut incursion at $985-1480 million net present value over 20 years, which highlights the disparity in the base assumptions between the two reports. Subsequent survey results in the Bundaberg-Childers area have refined the estimate of the presumed time of entry of the disease and the extent of the incursion. Experience in commercial crops in the ORIA and smut-resistance trials there and in Indonesia has given a better understanding of the susceptibility of Australian varieties. This increased understanding has led us to revise the estimates of likely yield loss in eastern Australia.

3.3 How were the estimates derived?

Question:
Are the estimates based on sugarcane smut affecting 100% of the crop or some other percentage? In other words, does it take into account the fact that all cane stalks may not be affected at the same rate?

Our estimates are based on a combination of our estimates of disease spread and build-up and the losses that could be expected at that level of disease in the crop. The prediction of rate of spread and build up is influenced by both the experience already in the Bundaberg-Childers region and the ORIA and our understanding of the influence of environment gained from reading of the literature. We think that it likely that, with our highly susceptible varieties and environmental conditions that are relatively favourable for the development of smut, 100% plant infection will occur in many situations.

There is no evidence from the ORIA or Indonesia of ‘breakdown’ in the resistance levels of resistant varieties under high disease pressures – intermediate varieties show increased disease levels and some yield loss under high inoculum levels.

3.4 Have you assumed growers will take no action?

Question:
Does Table 1 in section 2.5 titled “Yield loss in susceptible varieties in the absence of a response” assume no action will be taken by growers in terms of mitigating against smut in the intervening years? In other words, does it take into account the fact that is expected that industry would voluntarily replace susceptible varieties within a few years? What is the base case used in the ABARE Benefit Cost Analysis?

It is stated in the explanation that ‘the table demonstrates that, in absence of any response, susceptible varieties would potentially demonstrate significant yield loss’. Need to cover percentage for when growers take action and this percentage yield loss is justified in these circumstances.

The table definitely takes into account that growers will replace susceptible varieties voluntarily when losses become severe. If this did not happen, the losses would extend for many more years.

In the absence of a containment program, growers will continue to grow susceptible varieties until losses become severe because:

1. Without assistance, growers will, for a number of years, have insufficient planting material of resistant varieties that are adapted to all conditions in the region. For example, one of the current intermediate-to-resistant varieties is limited to soils that are not conducive to pachymetra root rot. If this variety was grown on other soils, losses from this disease would be almost as great as from smut. Because sugarcane is a vegetatively propagated crop that requires large quantities (6-10 t/ha) of relatively perishable planting material (viable only for 2-3 days for billet planting or 2-3 weeks for whole-stalk planting), moving planting material long distances is difficult and expensive.

2. The susceptible varieties in the Bundaberg-Childers region are (in the absence of the disease) at least 10-20% higher yielding than currently available resistant varieties. Hence, some growers, in the absence of a containment program, will continue to grow these susceptible varieties until the losses exceed the advantage that susceptible varieties have over resistant varieties in the absence of smut. At that stage, inoculum production will be excessive and the varieties would collapse before growers could replace the crops.

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