THE AUSTRALIAN SUGAR CANE ORANGE RUST EPIPHYTOTIC

By

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Abstract

Research into orange rust (caused by Puccinia kuehni) was urgently conducted in 2000 and 2001 in order to minimise the effect of this once minor leaf disease on sugarcane yields in Australia. Losses from the disease exploded in 2000 leading to one of the worst epiphyticos in the history of the Australian industry. Research addressed fungicidal control in experiments located in the central Queensland region. Several chemicals with activity against rust pathogens were tested and the most effective and economic application schedules identified. Good fungicide control was provided by the fungicide tebuconazole (Folicur®) and extensive commercial spraying was undertaken in some 2001 crops. Fungicide and breeding trials were used to estimate yield losses caused by the disease; losses were as high as 38–40% in the years 2000 and 2001. With the down-turn in sugar prices, and the cultivation of more resistant varieties, commercial application of fungicide was limited in 2002 and 2003. Commercial cultivars and promising clones were screened for disease resistance and a high level of resistance was found both in parent canes and seedlings in the BSES selection program. Assistance was provided to industry to change from the susceptible Q124 to more resistant commercial varieties. An Orange Rust Task Force helped growers find planting material of alternative varieties, decide which new varieties to accelerate and assisted in obtaining emergency registration for a commercial fungicide application. The effect of weather conditions on disease occurrence was also investigated so that industry could be notified when weather conditions were conducive for disease development. This assisted with decisions related to fungicide application. The disease may still be seen but is at much lower levels. Susceptible clones are still being discarded from the breeding program, and disease levels in varieties with moderate resistance are being monitored. The orange rust epiphytotic illustrates again that sugar industries should never become too reliant on one variety but should have a mixture of varieties to protect against disease outbreaks. Even minor endemic diseases may develop into major disease outbreaks and threaten the existence of an entire industry.

Introduction

Orange rust is caused by the fungal pathogen Puccinia Kuehni (W. Kruger) E.J. Butler (Magarey, 2000). Known from the Pacific-rim countries such as Papua New Guinea, Indonesia, Philippines and Australia, the disease had for many years occurred at low levels in Australian crops (Ryan and Egan, 1989). Only a very few varieties were affected, and at such low levels that very few people noticed the disease.

All this changed in January 2000 when the most widely grown Australian variety, Q124, comprising 45% of the Australian crop, started to display rust-like symptoms in the central Queensland cane-growing region. Brown (common) rust had been widespread on some varieties in Queensland but the symptoms on Q124 did not match the description of this disease. Specimens sent to BSES pathologists and to fungal taxonomists confirmed that the disease symptoms were caused by P. kuehni. The disease was soon after identified in most cane-growing areas (Magarey et al., 2001a). The disease greatly exacerbated
the effect of poor weather on crop yields; the next few seasons saw some of the lowest yielding crops in Queensland, especially in central Queensland where Q124 comprised 85% of the district's crop in 2000 (Magarey et al., 2002; 2004b).

This paper reviews the effect of the epiphytotic on yields, specifically in central Queensland, and the research undertaken to control the disease through fungicides and the introduction of resistant varieties.

Yield losses

Historical losses

Previous outbreaks of the disease have been noted but some of these were early in the development of the industry and it is difficult to be certain that *Puccinia kuehnii* was the cause of the crop losses. Ryan and Egan (1989) suggest orange rust is of only minor economic importance in the countries where it has been present for an extended period and suggest it rarely reaches epidemic proportions. North (1915) noted one of these sporadic events in Fiji where the disease rendered some Hawaiian canes economically useless. These reports were rare.

Overall crop effects

Production in the central district of Queensland plummeted in the 2000 season compared to that in the previous four to five seasons. This was not totally due to the effects of orange rust; weather conditions were less than ideal for crop growth in the 2000 growing season. This is illustrated by the average yields over all varieties for the 1994–1998 seasons (BSES unpublished data). In the Mackay area, yields averaged 99.1 tonnes cane/ha while, in the 2000 season, the figure was 56.1 tonnes cane/ha. To identify the effects of orange rust, the average yield of all resistant varieties comprising more than 2% (by area) in each of the 1996 and 1997 seasons (Mackay district mills) was compared with the average yield of Q124 in the same mill areas and years – with the comparison also made for the 2000 season when orange rust was prevalent. These data are illustrated in Table 1.

<table>
<thead>
<tr>
<th>Seasons</th>
<th>Relative performance</th>
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<tbody>
<tr>
<td></td>
<td>Q124</td>
</tr>
<tr>
<td>1996–1997</td>
<td>100.0</td>
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<tr>
<td>2000</td>
<td>100.0</td>
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<tr>
<td>Difference</td>
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These data suggest a 22% reduction in the performance of Q124 in tonnes cane production. Losses in sugar content (CCS) of up to 2 units were also noted.

Breeding trial estimates

The relationship between the resistance of clones in breeding trials and the average yield of those clones of the same resistance rating was investigated using regression analyses (Magarey et al., 2003; 2004a; 2004b). The effect of the disease on yield was quantified over the 1999–2002 period. Data from breeding trials suggested that:

- Orange rust caused losses in the 1999 season in some parts of the Mackay district, before the disease had been recognised. These were of the order of 10% (Magarey et al., 2004a). In that year, diseased Q124 canopies were attributed to yellow spot (caused by *Mycovellosiella koepkei* (W. Krüger) Deighton) but no confirmation of symptoms was made. This illustrates the importance of looking closely at diseased leaves to confirm the diagnosis.

- Losses in the 2000 season in breeding trials in the Mackay district averaged 38% (Magarey et al., 2004a), confirming the very large effect of the disease in that year. In the 2000 March–May period, the entire Mackay crop appeared brown when viewed from the air, except for isolated plantings of resistant varieties. With 85% of the Mackay crop comprised of the now susceptible Q124, it was not surprising the district effect was large. Losses in other parts of Queensland were lower (around 15% in northern Queensland; Magarey et al., 2003). Total industry losses were also lower in other districts because of the lower percentage of Q124 and the higher proportion of resistant varieties grown.
• Losses in subsequent seasons in breeding trials were lower than in 2000 but still significant. This is attributed to less conducive weather conditions for orange rust (Magarey et al., 2004a).

**Fungicide estimates**
Fungicide research using the susceptible Q124 provided an estimate of the losses directly attributable to the disease. Magarey et al. (2002) compared the best fungicide control treatments with unsprayed control plots and losses were around 40% (tonnes cane/ha) in some trials. There is no doubt the disease can dramatically affect yield in susceptible varieties. Experiments conducted in 2002 suggested lesser responses (Staier et al., 2003). This was believed to be related to disease development occurring later in the growing season. In 2001, weather conditions led to high disease levels during the rapid growth period (mid-late summer); in 2002, the disease didn’t reach high levels until after this period. Sugar levels were reduced in 2002 since diseased crop canopies could not function efficiently during the period when the crop normally matures (Staier et al., 2003).

**Economic effects**
The economic effect of the orange rust outbreak was colossal; the whole industry, especially the central Queensland area, was affected — individual cane farmers, harvesting contractors, factories and the consequent effects reached into local communities.

**Farmers**
Reduced yields and lost production meant individual farmers suffered considerable financial stress (Magarey et al., 2001b). The cost of replanting to replace the susceptible varieties was an added burden to growers with many growers having to take out loans to be able to afford to replant large areas of their farms. Lost yield (tonnes cane/ha) alone is estimated to have cost the central Queensland industry between US$35–70 million in the 2000 season.

**Sugar factories**
Orange rust-affected crops of Q124 contained much lower fibre levels than normal resulting in low fuel supplies for the sugar factories in the 2000 season. This increased manufacturing costs because of the need to purchase additional fuel. Profits were significantly reduced for sugar manufacturers because of lower tonnages processed. The low yields resulted in the temporary closure of one mill in the central district.

**Harvesting contractors**
Lower yields meant diminished returns for harvesting contractors since they are normally paid on a fixed price per tonne of sugarcane harvested. Variable costs such as for fuel and maintenance remained the same since a similar area was harvested. This translated to increased costs per harvested tonne resulting in losses for most operators.

**Control**
There was an extremely urgent need to implement remedial action because of the large and very challenging economic losses caused by the disease. The central Queensland industry quickly established an ‘Orange Rust Task Force’ (ORTF) to speed district actions to minimise the effect of the disease on industry.

The task force met regularly to discuss proposed actions and contained representatives from cane farmers, sugar factories, agri-business, research and extension agencies and farmer representative bodies. The ORTF assisted growers to locate planting material of alternative varieties, decide which new varieties to accelerate and assisted in obtaining registration for commercial fungicide application. This group helped formulate rapid response mechanisms. The local media were also kept up to date with developments.

**Varietal resistance**
Varietal resistance is the cornerstone of disease control in the Australian sugar industry and indeed around the world. One of the first tasks in the control program was to assess the resistance of clones in the selection program and evaluate resistance in the population of parents used in crosses to generate new seedlings. Varieties were screened using leaf area estimation, as described by Magarey et al. (2003).

In brief, a leaf mid-placed in the canopy was selected and the area affected by pustule development in the mid-section of this leaf was estimated by two assessors. Four leaves were assessed per clone per replicate and the results averaged in selection trials. Parent cane resistance was assessed using an individual plot of each parent; because there were so many parents, further replication was impossible. Resistance ratings were applied using Q124 as the susceptible standard.
Fortunately, excellent resistance was identified – with most clones possessing satisfactory resistance (Magarey et al., 2001a). This is illustrated in Figure 1.

![Graph](chart.png)

**Fig. 1**—The number of parent varieties x disease level in an assessment of the resistance of parent canes at BSES Meringa in early 2001.

With the plant breeding program possessing some highly resistant, high-yielding clones, and with some already commercial varieties resistant to the disease, one of the priorities of the ORTF was to accelerate the release of the new resistant varieties, and to enable large quantities of the already released resistant commercial varieties to be distributed to farmers for replanting operations. New varieties released more rapidly were Q170 and Q190, while quantities of the resistant Q157 were transported from the Herbert River, around 420 km to the north, to the Mackay area for propagation. It was important that adequate quarantine precautions and strict sanitation were observed during this period to avoid other disease issues. Additional hot water treatment of the already commercial resistant varieties, Q135 and Q138, was undertaken early on in the disease epiphytotic. This enabled these varieties to be planted more widely in the Mackay district.

The local sugar manufacturer (Mackay Sugar Limited) developed a loan scheme enabling farmers to borrow money to undertake replanting operations to encourage and assist growers having no or little cash flow that were faced with replanting crops with resistant varieties. A considerable proportion of the Mackay district (25%) was replanted in 2001; this accelerated replanting continued over the following years. Some old ratoons were used as plant sources, but there was no noticeable increase in RSD levels due to careful inspections coupled with ELISA detection technology. Some previously 'second choice' varieties were planted until planting material of the new varieties was increased. In some instances this resulted in below-average yielding crops, but in other cases, it highlighted the value of previously underutilised varieties such as Q135 and Q138. This rapid replanting operation and change over of commercial varieties, was no doubt a telling factor in the rapid control of the disease.

More than 70 international varieties have been rated for orange rust susceptibility but only a few have been rated as susceptible. The susceptible international varieties are NCo310, RB72-454, SP72-4728 and R84-0472. RB72-454 has been a major cane in Brazil and orange rust must be considered an important quarantine risk for countries where orange rust does not yet occur.

**Fungicides**

A commercial fungicide spray program has only been exploited once in sugarcane around the world; this was with the control of yellow spot (caused by *Mycovellosoidea koepkei*) in Mauritius in the 1970s (Autrey et al., 1983). A number of fungicides were tested for control efficacy for *P. kuehni* in initial experiments in Mackay during growth of the 2001 crop (Magarey et al., 2002). Of these, the commercially most promising appeared to be tebuconazole (‘Folicur®, a triazole fungicide) and mancozeb (a
dithiocarbamate). Propiconazole (‘Tilt®’, ‘Bumper®’ or ‘Aurora®’) was also tested along with cyproconazole (‘Alto®”). Cyproconazole proved the most active of the fungicides, but for several reasons the chemical was not initially registered. Tebuconazole, and temporarily mancozeb, were registered with the Australian National Registration Authority (NRA) with ‘emergency use permits’ and this allowed farmers to apply fungicide to crops of Q124 in the 2001 and 2002 growing seasons. The recommended spray schedule included two sprays of the systemic tebuconazole spaced at two-weekly intervals (two sprays only), early in the disease development cycle. Reasonable control was achieved if applications were made at the right time. The strategy was to spray Q124 only and to use fungicide control as an interim measure until more resistant varieties could be planted. Relatively high world sugar prices in 2001 enabled economic fungicide application, but a decline in prices in 2002 ruled out widespread fungicide application in the 2002 crop. Application was largely restricted to the central and southern Queensland districts. More than 30 000 ha of crops was sprayed in 2001 (some crops were sprayed twice) in the central Queensland area.

Disease prediction and monitoring

Disease prediction was assisted by laboratory studies into the conditions needed for spore germination in P. kuehni. These conditions were compared to environmental information collected from several weather stations in the area (Staier et al., 2004) and used to calculate the number of hours where conditions were favourable for spore germination. There appeared to be good agreement between hours of ‘conducive conditions’ and disease development in the field (Staier et al., 2004). It was recognised that details on spore germination alone were insufficient to fully predict all aspects of orange rust development, but the substituted model provided an adequate assessment as to when the disease would occur.

Disease prediction was important in the Mackay district when farmers were considering the application of fungicide. Knowledge of the level of disease in the district, coupled with predictions of disease development, enabled better fungicide application decision-making. Monitoring sites were established throughout the Mackay area and the results published in the local newspapers.

Current situation

Losses due to orange rust are less in recent years since the area planted to the susceptible Q124 now represents around 24% of the Mackay (Central) district crop (down from 85%) and conditions have not been so favourable to disease development. Conditions for disease development in the 2004 crop have been more favourable, but the greatest threat to yield in the Central district in the last couple of years has been drought. Orange rust remains a disease of concern from a breeding perspective in the Australian industry. Each year 5–10% of varieties are discarded because of orange rust susceptibility and restrictions are in place on the use of orange rust susceptible parent varieties. Orange rust has now assumed generally minor status again from a cane farmer’s perspective, as the proportion of the crop planted to susceptible varieties has been reduced. A result is the almost zero commercial use of fungicides in Queensland. However, the 25% of the Australian crop planted to susceptible varieties is still suffering significant yield losses.

Discussion

Orange rust has played ‘second fiddle’ to brown rust in disease research in many industries around the world. Having rarely caused industry devastation, the Australian experience was something new and resulted in the gathering of much new information on P. kuehni.

The recent epiphytotic again illustrates the potential for even minor diseases to create industry havoc and financial catastrophes. It also again emphasises the fact that, when a single variety becomes dominant, it almost inevitably succumbs to a disease outbreak. In Queensland, this has been seen with epiphytotics in a number of major varieties; Q50 was widely grown in the Mackay area until sugarcane mosaic spread rapidly in the variety; Q63 was also very popular in the Mackay and Burdekin districts until leaf scald caused crop losses; Q90 was very widely grown in northern Queensland until Pachymetra root rot caused disastrous yield losses, and NCo310 was widely grown in the Bundaberg area until a Fiji leaf gall epiphytotic caused large and financially very damaging losses.

In the Australian orange rust outbreak, commercial application of fungicide for sugarcane leaf disease control occurred for only the second time on a world basis. Though the economics of fungicide application was not fully researched at the time, a large area was treated in central Queensland. This no doubt provided some satisfaction to farmers in that they were able to do something to control the disease and produce a crop at a time of high world sugar prices. Varietal resistance has provided a stable long-term economic control option, as with almost all other sugarcane diseases.
Losses from the disease were large. Independent estimates put losses in the 2000 season at around 40% in susceptible varieties. Losses were lower but still significant in later seasons where the disease severity was reduced, or where the timing of disease incidence meant that the crop had already grown before the disease peaked. There is also strong evidence that the low yields of 2000 were not entirely due to orange rust; even the yield of resistant varieties was well below normal yields.

The future possibility for other orange rust outbreaks has diminished considerably with the reduced plantings of susceptible canes. The reason for the recent epiphytotic was thought to be a change in the strain of the pathogen (Magarey et al., 2002). A further change in strain is considered unlikely for two reasons: (i). There is no variety currently as dominant as was Q124 in the Australian sugar industry; i.e. the germplasm base is more diverse; (ii). the pathogen does not have a history of rapid mutation, so the chances of a new strain developing appear small. Research in strain characterisation is continuing.

The Australian breeding program is now routinely taking into account orange rust resistance in parent canes used in the crossing program. The resistance of parents is assessed each year and entered into the plant breeding database. This is used when crosses between parents are selected. The resistance of individual clones in the selection program is also assessed in each region of Queensland and highly susceptible clones discarded. The resistance of the current commercial varieties is generally high and only a small number show any degree of susceptibility to the disease. However, there are still some crops of Q124 in districts where it was widely grown, but on much less area than before the orange rust outbreak.

Though the epiphytotic has now largely passed, it is hoped the effects will not be forgotten and that strategies will be employed by cane farmers to eliminate the possibility of future losses from such a disease outbreak. If history provides a guide, this may not occur.

Conclusions

Orange rust caused extensive losses to the Australian sugar industry in the year 2000. Rapid control was achieved through industry-wide cooperation in the replacement of susceptible varieties with resistant canes, through the acceleration of high yielding resistant canes in the breeding program, and the selective use of fungicides in crops of the susceptible Q124.

REFERENCES


North, D.S. (1915). Extracts from recent reports by Mr D.S. North on control of diseases and pests at the mills. C.S.R. Co. Ltd, N.S.W.


ÉPIDÉMIE DE LA ROUILLE ORANGETE EN AUSTRALIE

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MOTS CLÉS: Mesure de Lutte, Effets Economiques, Fongicides, Puccinia kuehnii, Résistance Variétale, Pertes de Rendements.

Résumé

La recherche sur la rouille orangée (causée par *Puccinia kuehnii*) a été mise en place en urgence en 2000 et 2001 afin de réduire au minimum l’effet de cette maladie, précédemment considérée comme mineure, sur le rendement de la canne à sucre en Australie. Des pertes dues à la maladie ont explosé en 2000 menant à une des plus sévères épidémies dans l’histoire de l’industrie sucrière australienne. La recherche fut axée sur des mesures de lutte fongiques avec la mise en place des essais situés dans la région centrale du Queensland. Plusieurs produits chimiques, actifs contre les agents pathogènes de la rouille, ont été évalués et les plus efficaces ainsi que les fréquences d’applications les plus économiques ont été identifiées. Un effet efficace a été obtenu avec le fongicide tébuconazole ("Folicur") et des pulvérisations extensives à l’échelle industrielle ont été entreprises en 2001. Des parcelles traitées aux fongicides et des essais variétaux ont été utilisés pour estimer les pertes de rendement causées par la maladie, les pertes étaient aussi fortes que 38-40% en 2000 et 2001. Avec la baisse dans le prix du sucre, et la culture de variétés plus résistantes, l’application commerciale du fongicide a été moins importante en 2002 et 2003. Les variétés commerciales et prometteuses ont été criblées pour la résistance à la maladie et un niveau élevé de résistance a été observé dans les parents et les plantules issues des graines dans le programme de sélection du BSES. Une assistance a été fournie à l’industrie sucrière pour l’adoption des variétés plus résistantes pour le remplacement de la variété Q124. Le Comité de la rouille orangée a aidé les planteurs à trouver le matériel de plantation des variétés alternatives, choisir les nouvelles variétés à exploiter et aider à obtenir l’homologation urgente de fongicides pour des applications industrielles. L’effet des conditions climatiques sur l’incidence de la maladie a été également étudié de sorte que l’industrie pourrait être prévenue en avance quand les conditions climatiques sont favorables pour le développement de la maladie. Cela a aidé à prendre une décision sur le moment de l’application du fongicide. La maladie peut encore être observée, mais à des niveaux bien plus bas qu’autrefois. Les variétés sensibles sont rejetées dans le programme de sélection et le niveau de la maladie dans les variétés avec une résistance modérée est surveillé. L’épidémie de la rouille orangée démontre encore une fois que l’industrie sucrière ne devrait jamais devenir trop dépendante d’une seule variété, mais devrait cultiver une gamme de variétés afin de se protéger contre les épidémies. Même les maladies endémiques mineures peuvent se développer en maladies importantes et menacer l’existence d’une industrie entière.
LA EPIDEMIÓGENA DE LA ROYA NARANJA DE LA CAÑA DE AZÚCAR AUSTRALIANA

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PALABRAS CLAVES: Control, Efectos Económicos, Fungicidas, Puccinia kuehnii, Resistencia de la Variedad, Pérdidas de la Producción.

Resumen

DE URGENCIA se realizaron investigaciones con la roya naranja \( (Puccinia kuehnii) \) entre 2000 y 2001, para minimizar el efecto de esta enfermedad que alguna vez fue de poca importancia y evitar que afectara las producciones de la caña de azúcar en Australia. Las pérdidas de la enfermedad fueron explosivas durante el 2000, considerándose una de las peores epifitotas de la historia de la industria australiana. La investigación se relacionó con el control químico en experimentos localizados en la región central de Queensland. Varios productos químicos que mostraban actividad contra las royas fueron evaluados, identificándose los más eficaces y económicos. Un buen control se logró con el fungicida tebuconazol (Folicur), tomándose la decisión de realizar aplicaciones extensivas en los cultivos del 2001. De acuerdo con los ensayos con fungicidas y el uso de variedades resistentes, se pudo estimar las pérdidas causadas en la producción por la enfermedad tan alta como 38-40\%, en los años 2000 y 2001. Con el descenso en los precios del azúcar, y el aumento en el cultivo de variedades resistentes, el uso del fungicida se redujo en el 2002 y 2003. Tanto las variedades comerciales como los clones avanzados fueron evaluados en su resistencia a la enfermedad, encontrándose altos niveles de resistencia entre los progenitores así como en la progenie, dentro del programa de selección del BSES. Se colaboró con la industria para que cambiara la variedad Q124 susceptible por variedades comerciales más resistentes. Un grupo ayudó a los cultivadores a encontrar material para siembra de variedades alternativas, a decidir qué nuevas variedades se debían multiplicar rápidamente y obtener registro de emergencia para la aplicación comercial del fungicida. El efecto de las condiciones atmosféricas en la incidencia de la enfermedad también se estudió de modo que la industria pudiera ser notificada cuándo las condiciones atmosféricas eran aportadas para el desarrollo de la enfermedad, lo cual ayudó en las decisiones sobre el uso del fungicida. La enfermedad todavía se encuentra presente pero está en niveles de incidencia muy bajos. Los clones susceptibles todavía se están descartando en el programa de mejoramiento, y los niveles de la enfermedad en variedades con resistencia moderada se están supervisando. La epifitota de la roya naranja ilustra una vez más que las industrias de azúcar nunca deben depender de solo una variedad pero deben tener diferentes variedades que la protejan contra las epidemias de enfermedades. Más aún, las enfermedades endémicas de menor importancia pueden convertirse en epidemias importantes y amenazar la existencia de una industria entera.