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The effect of sugarcane rust (Puccinia melanocephala) on yield

Taylor, PWJ

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PROJECT REPORT

THE EFFECT OF SUGARCANE RUST (*Puccinia melanosephala*) ON YIELD

By

P.W.J. Taylor
B.J. Croft
C.C. Ryan

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December 1985
Bundaberg
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Growth stages of sugarcane

Stage 1: Pre-germination
Stage 2: Germination and Emergence
Stage 3: Shoot-rooting
Stage 4: Tillering
Stage 5: Stem elongation
Stage 6: Pre-maturity
Stage 7: Maturity

Diagram showing the stages of sugarcane growth.
THE EFFECT OF SUGARCANE RUST \textit{(Puccinia melanocephala)} ON YIELD

1. INTRODUCTION

Sugarcane rust caused by \textit{Puccinia melanocephala} H. & P. Syd. is an important disease of sugarcane throughout the world (Purdy, Liu and Dean, 1983). In India, the rust susceptible cultivar Co475 was withdrawn from cultivation due to yield loss in the 1950's epiphytotic (Vasudeva, 1956). Rust has caused serious yield decline in the widely grown susceptible cultivar B4362 of up to 50 per cent yield loss (Purdy et al, 1983; Scarlett, 1979, 1980) and five to 20 per cent yield loss in the cultivar N55/805 (Bailey, 1979). In South Africa, two fungicide spray trials showed potential yield losses of 15 per cent and 23 per cent in N55/805 under conditions favourable to the pathogen (Anon., 1981).

Rust was first detected in North Queensland in 1978 and quickly spread throughout all canegrowing areas (Ryan and Egan, 1979). A high proportion of commercial cultivars were susceptible to rust.

To accurately determine the effect of rust on yield, adequate control of the disease must be obtained to enable a comparison between yields of diseased and non-diseased plants of the same cultivars. Control of rust can be obtained by the application of fungicides. There have been reports on the efficacy of several fungicides to control sugarcane rust.

In South Africa, Bailey (1979) found that mancozeb fungicide gave excellent control of rust in young cane. In rust yield loss assessment studies in Jamaica, Scarlett (1980) recorded that mancozeb applied to young B4362 reduced the level of rust infection. However, he found that there was no significant increase in c.c.s. in the fungicide treated plants. Yield loss trials in South Africa showed that mancozeb had no stimulatory or phytotoxicity effect on N55/805, hence the yield increase in sprayed plots was due to the reduction in the level of rust infection (Anon., 1981). Liu (1980) noted that mancozeb, chlorothalonil and oxycarboxin also gave good control of rust.

Trials in North Queensland to screen various fungicides for the control of sugarcane rust showed that chlorothalonil and oxycarboxin were the most effective (Taylor, Croft and Ryan, 1983). Further trials were conducted to develop a spray program suitable for yield loss assessment studies. Results showed that oxycarboxin 75 per cent used at a concentration of 0.1125 per cent active ingredient and applied at nine day intervals at 1 095 L/ha was the most suitable (Taylor et al, 1983).

This report details the results obtained from two trials to assess yield loss caused by sugarcane rust and also outlines the epiphytotiology of the rust disease.
2. MATERIALS AND METHODS

Field trials to assess the effect of rust on yield were planted at Isis and at Mourilyan.

2.1 Isis trial

Trial design

The trial was planted at J. Cardillo's, Foley's Road, Farnsfield, on 11th March, 1982 in yellow podzolic soil type. The trial design was a split plot with fungicide treated and untreated as the main plots. There were three replications of each main plot and these were split into five sub-plots for the cultivars Q87, Q90, Q108, Q110 and 70977 (Appendix I). Plots of each cultivar consisted of four rows, 15 m in length with a row spacing of 1.42 m. The trial was surrounded by a four row buffer of Q110.

Fungicide application

The following fungicide was used in the trial.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Trade name &amp; supplier</th>
<th>Chemical name and active ingredient</th>
<th>Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxycarboxin</td>
<td>Plantvax</td>
<td>5,6-dihydro-2-methyl-1,4-</td>
<td>Wettable</td>
</tr>
<tr>
<td></td>
<td>ICI Aust. Pty Ltd</td>
<td>oxathiin-3-carboxanilide-3-dioxide;</td>
<td>powder</td>
</tr>
<tr>
<td></td>
<td></td>
<td>75% ai</td>
<td></td>
</tr>
</tbody>
</table>

Oxycarboxin was applied at nine day intervals. Fungicide application commenced on 12th May, 1982 at the shoot-rooting/tillering stage of growth and continued to the 8th June, 1983 (pre-maturity stage) when growth of the sugarcane prevented further application of the fungicide. Initially, fungicide was applied using a four row boom spray (Plate I). By November 1982, the sugarcane plants had become too tall for the four row boom spray to clear thus fungicide was applied from 22nd November 1982 to 8th June 1983 using a two row boom spray connected to an inter-row tractor (Plate II).
PLATE I - Application of oxycarboxin fungicide using a four-row boom spray - Isis trial.

PLATE II - Two row boom spray connected to an inter-row tractor used for the application of oxycarboxin fungicide - Isis trial.
Connected to the boom sprays were droppers which contained 80° flat fan nozzles directed towards the adaxial and abaxial sides of the leaves. These nozzles were changed from LF2 to LF5 as the growth of the sugarcane increased. The number and types of nozzles used on the booms, and rates of application of the fungicides are shown in Table I.

**TABLE I**

Application rate, date of application of oxycarboxin and number and type of nozzles used in the Isis rust yield loss assessment trial

<table>
<thead>
<tr>
<th>Date</th>
<th>Nozzle direction</th>
<th>Application rate (L/ha)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5.82</td>
<td>4,LF2</td>
<td>8,LF3</td>
</tr>
<tr>
<td>21.5.82</td>
<td>8,LF2</td>
<td>8,LF3</td>
</tr>
<tr>
<td>11.6.82</td>
<td>8,LF2</td>
<td>16,LF3</td>
</tr>
<tr>
<td>21.6.82</td>
<td>16,LF2</td>
<td>16,LF3</td>
</tr>
<tr>
<td>30.6.82</td>
<td>to</td>
<td></td>
</tr>
<tr>
<td>28.7.82</td>
<td>6,LF2</td>
<td>16,LF3</td>
</tr>
<tr>
<td>8.8.82</td>
<td>to</td>
<td>16,LF3</td>
</tr>
<tr>
<td>11.8.82</td>
<td>6,LF2</td>
<td>16,LF5</td>
</tr>
<tr>
<td>22.11.82</td>
<td>to</td>
<td>8,LF5</td>
</tr>
<tr>
<td>1.12.82</td>
<td>8,LF2</td>
<td>8,LF5</td>
</tr>
<tr>
<td>10.12.82</td>
<td>to</td>
<td>8,LF5</td>
</tr>
<tr>
<td>8.6.83</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Pump pressure 200 kPa; flow rates from nozzles were 0.65 (LF2), 1.0 (LF3) and 1.6 (LF5) L/min

** Fungicide applied from this date using a two row boom spray

† Application rate achieved by reducing tractor speed
The untreated section of the trial was sprayed with water at the same application rate as for the fungicide treatment.

Meteorological data

The mean daily maximum and minimum temperatures were recorded at the Elliott River Forestry Station which is 5.5 km from the trial site. The temperatures recorded were applicable to the Farnsfield area where the trial was located.

Rainfall was recorded at the trial site as well as the time of application of supplementary irrigation. Approximately 30 mm of irrigation was applied on 30th July, 10th November and 2nd December 1982 and on 30th January, 13th February and 10th March 1983.

Assessment

Level of rust infection

The influence of environmental conditions on the level of rust infection and the efficacy of the spray schedule to control the disease was monitored by measuring the level of rust infection immediately after each application of fungicide. Ten stalks of Q87 from each of the three untreated plots were randomly selected from the middle of two rows and the per cent infection of the basal, middle and distal sections of the abaxial side of the top five to seven fully expanded leaves was estimated by comparing the pustule densities on the leaves with a set of rust key diagrams (Peterson, Campbell and Hannah, 1948). Sections of leaves showing senescence due to rust infection were rated as 50 per cent infected. The mean per cent rust infection of the basal, middle and distal sections as well as for the first five fully expanded leaves was recorded.

At the same time as the assessment of the per cent rust infection on Q87 untreated, all plots in the trial were visually rated for the level of rust infection on a 0 to 100 scale. Ratings were based on the plot of 70577 untreated, replicate 1, being rated as 50. The per cent level of rust infection for each cultivar in both treatments was then calculated by comparing the visual ratings to the Q87 unsprayed and then calculating the relative per cent infection. The major problem with this method is the assumption that the visual rating for a cultivar is an accurate assessment of the degree of infection. The greater the degree of infection within a plot, the less accurate is the visual assessment.
Shoot and stalk growth measurements

At the peak of rust infection in September 1982, the number of shoots in 10 m of the middle two rows in each plot was recorded and the number of shoots per hectare estimated.

At maturity (October 1983) the number of millable stalks, the diameter of 20 stalks at 90 cm above ground level and stalk heights to the top visible dewlap of 10 stalks were recorded in 10 m of the middle two rows in each plot. The number of stalks per hectare and stalk cross-sectional area were estimated.

Sugar quality assessment

In mid September 1983, samples from all plots were analysed for various parameters of sugar quality. A twelve stalk sample from the first and last 2.5 m of each plot was collected so as not to influence the final yield assessment of the plot. From each 12 stalk sample, three stalks were selected at random and analysed for fibre as per BSES Plant Breeding Manual; the remaining nine stalks were crushed and juice extracted using a two roller small mill. For each sample, spindle and refractometer brix; pol; c.c.s.; pol per cent juice; per cent sucrose, glucose and fructose; per cent dry substance and true purity; per cent ash as sulfated cations; reducing sugars to ash ratio and pH of juice were determined.

Yield assessment

Tonnes of cane per hectare, c.c.s., and tonnes of sugar per hectare were determined at maturity (19th October 1983). One hundred and twenty stalks were randomly selected from the middle 10 m of the middle two rows of each plot and weighed. The number of millable stalks in 10 m of the middle two rows in each plot was also recorded and tonnes of cane per hectare calculated. Fibre values for cultivars in each plot were those determined in the September 1983 fibre analysis. C.C.S. values were calculated, less 1.5 units to allow for small mill crushing. Brix was measured with a hydrometer and pol was measured with a polarimeter, Schmidt and Haensch, West Germany.

Analysis

Analysis of variance was performed on shoot and stalk growth measurements, sugar quality assessments and yield assessment.
2.2 Mourilyan trial

Trial design

The trial was planted at A. Campagnolo's, New Harbour Line Road, Mourilyan on 4th June, 1982 in Mourilyan Sands soil type. The trial design was similar to the Isis trial, however each replicate contained the cultivars 71A123, Q90, Q105, Q107 and Q113. Plots of each cultivar consisted of six rows, 15 m in length (Appendix I). The trial was surrounded by approximately 2.9 m (2 rows) buffer of Q107.

Fungicide application

Oxycarboxin was applied at approximately nine day intervals. Fungicide application commenced on 29th July 1982 and continued to 31st March 1983 when growth of the sugarcane prevented further application of the fungicide. Fungicide application rates at each spraying are shown in Table II. Fungicide was initially applied using a three row boom spray containing six, size LF3, 80° flat fan nozzles directed towards the adaxial side of the leaves, and twelve, size LF5, 80° flat fan nozzles directed towards the abaxial side of the leaves. From the 9th December 1982 fungicide was applied using a two row boom spray connected to an inter-row tractor, containing four, LF3, 80° flat fan nozzles and eight, LF5, 80° flat fan nozzles directed towards the adaxial and abaxial sides of the leaves respectively.

<table>
<thead>
<tr>
<th>Date</th>
<th>Application rate</th>
<th>Date</th>
<th>Application rate</th>
<th>Date</th>
<th>Application rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>29.7.82</td>
<td>400</td>
<td>20.10.82</td>
<td>920</td>
<td>23.12.82</td>
<td>798</td>
</tr>
<tr>
<td>23.8.82</td>
<td>310</td>
<td>28.10.82</td>
<td>736</td>
<td>5.1.83</td>
<td>181</td>
</tr>
<tr>
<td>9.9.82</td>
<td>270</td>
<td>18.11.82</td>
<td>798</td>
<td>19.1.83</td>
<td>161</td>
</tr>
<tr>
<td>16.9.82</td>
<td>2000</td>
<td>18.11.82</td>
<td>798</td>
<td>4.3.83</td>
<td>161</td>
</tr>
<tr>
<td>29.9.82</td>
<td>550</td>
<td>30.11.82</td>
<td>736</td>
<td>21.3.83</td>
<td>161</td>
</tr>
<tr>
<td>8.10.82</td>
<td>490</td>
<td>9.12.82</td>
<td>798</td>
<td>31.3.83</td>
<td>161</td>
</tr>
</tbody>
</table>

TABLE II

Application rate and dates of application of oxycarboxin in the Mourilyan rust yield loss assessment trial
Meteorological data

The mean daily maximum and minimum temperatures were recorded at Innisfail Post Office which is approximately 10 km from the trial site. Rainfall was recorded at Mourilyan Sugar Mill which is approximately 4.5 km from the trial site.

Assessment

Level of rust infection

The percentage rust infection for each cultivar was assessed in November 1982 when the level of rust visually appeared to be at its peak. Ten stalks of each cultivar in both treatments were randomly selected in the middle two rows of each of the three replicates and the per cent infection on the basal, middle and distal sections of the abaxial side of the top seven fully expanded leaves were estimated by comparing the pustule densities on the leaves with a set of rust key diagrams (Peterson et al, 1948). The mean per cent rust infection of the basal, middle and distal sections as well as for the first seven fully expanded leaves was recorded.

Shoot and stalk growth measurements

At the peak of rust infection (November 1982) the number of shoots in the middle 10 m of the middle four rows of each plot was counted and used to estimate the number of shoots per hectare.

The number of stalks, stalk cross-sectional area and stalk heights to the top visible dewlap were also recorded at pre-maturity (July 1983). All millable stalks, mean diameter of 20 stalks at 90 cm above ground level and height to the top visible dewlap of 10 stalks were recorded in the middle two rows of each plot. The number of stalks counted in each plot was used to estimate the number of stalks per hectare.

Yield assessment

Tonnes of cane per hectare, c.c.s. and tonnes of sugar per hectare were determined at maturity (30th September 1983). Sixty stalks were randomly selected from the middle 10 m of the middle four rows of each and weighed. The number of millable stalks in 10 m of the middle two rows in each plot was also recorded and tonnes of cane per hectare calculated. A fibre value of 12.6 for the cultivars was determined from data collected by the Mourilyan mill. C.C.S., brix and pol were determined as described for the Isis trial.
Analysis

Analysis of variance was performed on shoot and stalk growth measurements and yield assessments.

3. RESULTS

3.1 Isis trial

The mean monthly maximum and minimum temperatures, the weekly rainfall and date of application of irrigation for the Isis trial are shown in Figures 1 and 2. Very little rain was recorded during the tillering and stem elongation stages (August 1982 to February 1983) and irrigation was not adequate to maintain plant growth. Consequently, moisture stress symptoms were evident in all plots during late October, November, December 1982 and again in early February 1983. Plots in the elevated section of the trial were more severely affected by moisture stress than those in the lower part of the trial (Appendix I). Prolonged moisture stress resulted in severe necrosis of the mid to distal section of the leaves.

Light rust infection was noted in the susceptible cultivars less than four weeks after planting when plants were in the root and leaf formation stage, and a week prior to the first spray schedule (early May 1982) the level of rust on these cultivars was quite high (Figure 3).

During the trial period the level of rust infection fluctuated with peaks of infection occurring in July 1982, September 1982 and again in February 1983 (Figure 3). The highest level of rust infection occurred in 70S77 and the lowest in 0110. The level of rust infection was greater in the sixth and seventh leaves than in the first and second fully expanded leaves of the susceptible cultivars, especially at the peak of rust infection in September 1982 (Figure 4). Fungicide treatment reduced the level of rust infection on all leaves, including on the sixth and seventh leaves, in all cultivars, however, complete control was not attained especially after September 1982. The level of rust infection in the treated and untreated plots fluctuated similarly.

Counts made in September 1982 and July 1983 showed that there were significantly fewer young shoots or mature stalks in plots of the untreated, susceptible cultivar 70S77 than in the fungicide treated plots of 70S77. At harvest there was no significant reduction in stalk heights, stalk cross-sectional area, tonnes of cane per hectare, c.c.s. and tonnes of sugar per hectare. There also was no detectable effect by rust on sugar quality except in 087 where the treated plants had a significantly (p ≤ 0.05) greater reducing sugar to ash ratio than the untreated plants (Tables III and IV).
FIGURE 1 - Weekly rainfall and supplementary irrigation recorded at trial site from April 1982 to October 1983.

FIGURE 2 - Mean daily maximum and minimum temperatures recorded at Elliott River Forestry Station from April 1982 to October 1983.
FIGURE 3 - Per cent rust infection of the first five fully expanded leaves for each cultivar in the trial from April 1982 to September 1983. Arrows indicate the commencement and finishing dates of spraying.
FIGURE 3 continued
FIGURE 4 - Mean percent rust infection for the first seven fully expanded leaves of 70S77 (——), Q108 (○—○), Q90 (x—x), Q87 (■—■) and Q110 (Δ—Δ) at the peak of rust infection (22 September 1982) in the Isis trial.
**TABLE III**

The effect of rust infection on growth and yield of 70S77, 090, 0108, 087 and 0110 in the Isis trial. Treated plots were sprayed with oxycarboxin.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Number of shoots/ha ((x10^5)) Sept 82</th>
<th>Number of stalks/ha ((x10^5)) Oct 83</th>
<th>Stalk cross sectional area ((cm^2))</th>
<th>Stalk height to T.V.D. ((cm))</th>
<th>Tonnes cane per hectare Oct 83</th>
<th>Tonnes sugar per hectare Oct 83</th>
</tr>
</thead>
<tbody>
<tr>
<td>70S77</td>
<td>Treated 1.945* 1.065* 2.68</td>
<td>177.2 46.15 13.75 6.37</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Untreated 1.449* 0.903* 2.43</td>
<td>160.3 34.00 13.86 4.73</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>090</td>
<td>Treated 1.279 0.832 4.28</td>
<td>184.7 66.00 15.06 9.95</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Untreated 1.221 0.799 4.21</td>
<td>184.5 65.38 14.96 9.76</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0108</td>
<td>Treated 1.635 0.966 3.21</td>
<td>228.4 74.77 13.21 9.89</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Untreated 1.394 0.900 3.15</td>
<td>233.0 72.66 13.52 9.82</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>087</td>
<td>Treated 1.556 0.926 4.26</td>
<td>182.8 72.65 15.26 11.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Untreated 1.279 0.832 4.62</td>
<td>189.0 74.40 15.30 11.39</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0110</td>
<td>Treated 1.612 1.231 3.12</td>
<td>183.8 71.63 15.13 10.89</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Untreated 1.527 1.250 3.36</td>
<td>188.3 76.61 15.38 11.77</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LSD (0.05)# 0.307 0.121 0.84 40.7 31.28 1.18 5.31

* 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.
TABLE IV

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

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Refrac. brix</th>
<th>Spindle brix</th>
<th>Pol Fibre</th>
<th>C.C.S. Sept 83</th>
<th>Pol % sucrose (HPLC) in juice</th>
<th>% glucose (HPLC) in juice</th>
<th>% fructose (HPLC) in juice</th>
<th>% dry sub in juice</th>
<th>% True purity in juice</th>
<th>% Ash in juice</th>
<th>Reducing sugar to ash ratio</th>
<th>pH of juice</th>
</tr>
</thead>
<tbody>
<tr>
<td>70S77</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated</td>
<td>20.23</td>
<td>20.31</td>
<td>77.63</td>
<td>11.62</td>
<td>13.19</td>
<td>18.66</td>
<td>18.70</td>
<td>0.06</td>
<td>0.09</td>
<td>20.01</td>
<td>93.48</td>
<td>0.31</td>
</tr>
<tr>
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* Means are significantly different (p ≤ 0.05); all values are the mean of three replicates.
# Least significant difference for comparing the two treatment means for each individual cultivar.
3.2 Mourilyan trial

The mean monthly maximum and minimum temperatures and the weekly rainfall for the Mourilyan trial are shown in figures 5 and 6. In August 1982 rainfall was the highest since 1881 and consequently fungicide was not applied from 30th July until 23rd August.

The level of rust infection at its peak in all treatments is shown in Figure 7. The resistant cultivar Q113 had no rust infection on the top seven leaves in both treated and untreated plots. The level of rust was reduced by fungicide in all other cultivars, however, complete control was not achieved in the lower leaves of the canopy.

Shoot counts made at the peak of rust infection in November 1982 showed that there were significantly fewer shoots in the untreated plots of 71A123 and Q105 (Table V) (p ≤ 0.05). At maturity, only in Q105 were there significantly fewer stalks although there was a slight (seven per cent) reduction in number in the untreated 71A123. There was also a significant reduction in stalk cross-sectional area, and stalk heights. There was a significant reduction in tonnes of sugar per hectare (p ≤ 0.10), but no significant difference in tonnes of cane per hectare and c.c.s. in untreated plots of Q105. All other untreated cultivars had no significant reduction in growth and yield.
FIGURE 5 - Weekly rainfall recorded at Mourilyan Sugar Mill from June 1982 to September 1983

FIGURE 6 - Mean daily maximum and minimum temperatures recorded at Innisfail Post Office from June 1982 to September 1983
FIGURE 7 - Mean percent rust infection for the first seven fully expanded leaves of 71A123 (——), Q105 (o—o), Q90 (x—x), and Q107 (o—o) at the peak of rust infection (9th November 1982) in the Mourilyan trial. Q113 had no rust infection on the top seven leaves for both treated and untreated plots.
TABLE V

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.

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<tr>
<th>Cultivar</th>
<th>Number of shoots/ha (x10^5) Nov 82</th>
<th>Number of stalks/ha (x10^5) Sept 85</th>
<th>Stalk cross sectional area (cm²)</th>
<th>Stalk height to T.V.D. (cm)</th>
<th>Tonnes cane per hectare</th>
<th>C.C.S.</th>
<th>Tonnes sugar per hectare</th>
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<td>0.765*</td>
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* Means are significantly different (p ≤ 0.05); ** Means are significantly different (p ≤ 0.10); all values are the mean of three replicates.
# Least significant difference for comparing the two treatment means for each individual cultivar.
**4. DISCUSSION**

The level of rust infection fluctuated during the trials at Isis and Mourilyan, with peaks of infection following conditions favourable for disease development. At Isis, where most data were collected, the peaks of infection appeared to be associated with rainfall and in the susceptible cultivar 70S77 there were numerous peaks throughout the duration of the trial. Purdy et al. (1983) reported that leaf wetness and air temperatures in the range 15 to 30°C were optimum for appressorial formation of the pathogen. At Isis these conditions would have occurred following rainfall. At Mourilyan a major peak of infection occurred in the trial during November 1982 and observations indicate that the environmental conditions at that time were similar to those described by Purdy et al. (1983) to be optimum for infection.

In both trials, oxycarboxin did not give complete control of rust but this was not unexpected as similar results were obtained in other experiments (Taylor, Croft and Ryan, 1983). At Isis, infection occurred in young plants and the epiphytotic was well developed before the first application of fungicide on 12th May 1982. This accounts for the large peak of infection in July 1982 in sprayed plots. The inability of oxycarboxin to completely control rust could have been due to several factors including reduced translocative properties due to severe moisture stress; the inability of the fungicide to control rust under high levels of infection during the stem elongation, prematurity and maturity stages; or some degree of resistance by *P. melanocephala* towards the fungicide. Scarlett (1979) found that the protectant fungicide mancozeb, initially applied to a four week old ratoon crop of B4362 and then continued at eight day intervals, significantly reduced the level of rust infection after four applications. However, after ten applications the level of rust infection on the treated and untreated leaves was not significantly different. Oxycarboxin is a systemic fungicide and it is expected that greater trans-laminar dispersion throughout the canopy should have been attained compared to the dispersion of protectant fungicides (Ricaud, Sullivan, Soopramanien and Julien, 1979).

Rust caused a significant reduction in the number of shoots in susceptible cultivars 70S77 - Isis trial and 71A123, Q105 - Mourilyan trial which was evident when counts were taken at the peak of infection in September 1982 and November 1982 respectively. A reduction in stalks was also noted in these cultivars at harvest.

Yield in the Isis trial was influenced by lack of soil moisture midway through the trial; some plots suffered more than others and thus caused large variations in yields between replicates. Analysis of the harvest data revealed a 26 per cent reduction in tonnes of cane and tonnes of sugar per hectare, and a ten per cent decrease in stalk heights in the most susceptible cultivar 70S77 but this was not statistically significant ($p < 0.05$). C.C.S. in most of the untreated plots was slightly higher but not statistically significantly different to the treated plots.
In the Mourilyan trial rust caused a statistically significant (p ≤ 0.05) reduction in stalk numbers, stalk cross-sectional area and stalk heights, and a significant (p ≤ 0.10) reduction of 31 per cent in tonnes of sugar per hectare in the susceptible cultivar Q105. However, a 33 per cent reduction in tonnes cane per hectare in Q105 untreated plots was not significantly different from the fungicide treated plots. In Q90 there was 16 and 18 per cent reduction in tonnes of cane and tonnes of sugar per hectare respectively in the untreated plots but these parameters were not significantly different from the fungicide treated plots. The cultivar 71A123 was the most susceptible to rust infection as indicated by leaf per cent rust infection, but a 16 per cent reduction in tonnes cane per hectare and a six per cent reduction in tonnes sugar per hectare were not significantly different from the control treatment.

The results obtained in these trials agree to some extent with the findings of Purdy et al (1983) who reported that the number of canes per stool was reduced due to infection by \textit{P. melanocephala}. Purdy et al. also reported that cane diameter and cane length were reduced due to infection by rust. However, these findings were not based on replicated trials but on field observations. Scarlett (1978) reported that there was a trend towards greater stalk heights in treated plots in yield loss assessment trials. He also failed to demonstrate a significant yield loss due to rust infection.

In the Isis trial, rust infection had no measurable effect on physiology of sugar production or quality of extracted cane juice. There was no significant difference between treatments for c.c.s., per cent sucrose, glucose and fructose in juice, true purity and pH of the juice. There also was no significant difference in the reducing sugars to ash ratio except in the cultivar Q87. The treated Q87 plants had a significantly greater reducing sugar to ash ratio than the untreated plants. Scarlett (1980) also found that there was no significant difference in brix, pol and per cent fibre between fungicide treated and untreated plants of B4362. A high reducing sugar to ash ratio implies that more sucrose can be recovered in the milling process. Ash tends to bind sucrose in the juice. From Table IV, the levels of ash in the treated and untreated Q87 plants appeared similar, however, the combined glucose and fructose levels in the Q87 treated plants appeared higher than in the untreated plants. Therefore, it can be deduced that either the fungicide was increasing the reducing sugar levels or rust infection was lowering the reducing sugar levels. The error in HPLC determination of reducing sugars is very high where small levels of reducing sugars occur in juice. This error, combined with the large variability between replicates (Appendix II) would suggest that the significant difference in reducing sugars to ash ratio in Q87 was an experimental error.
5. **CONCLUSION**

In yield loss assessment trials using fungicides to control rust, it was found that there were fewer shoots at the tillering stage and fewer stalks at harvest in the untreated plots of the susceptible cultivars 71A123, Q105 and 70S77. In the trial at Mourilyan the fungicide treatment increased the stalk-cross sectional area and stalk height of Q105 and consequently improved the tonnes of sugar per hectare of Q105 by 31 per cent and increased tonnes of cane per hectare by 33 per cent.

Three major factors prevented a more definitive outcome to these trials, and need to be considered in any future studies. The fungicide regime, although the best available at the time, was unable to give complete control of rust throughout the entire crop - this is essential. Consequently, differences in yield between some treated and untreated plots may have been reduced. Trial sites should have facilities for supplementary irrigation, to avoid prolonged periods of moisture stress which unduly affected the better grown plots. The trial design was partly chosen to reduce the large amount of time required for spraying; a split plot design with sprayed and unsprayed treatments in each split plot of the same cultivar would greatly reduce variability, although work time would be increased considerably.

Further studies could be undertaken to determine the effect of rust infection at different stages of crop development on the final yield. This may have important implications in the development of a fungicide control program to ascertain the effect of rust on yield.

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fungicides for controlling sugarcane rust (Puccinia melanocephala)

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7. ACKNOWLEDGEMENTS

We wish to thank Norm McGill of Bundaberg Sugar Experiment Station, and
John Witherspoon of Tully Sugar Experiment Station for their assistance
during the trials; and ICI Australia Pty Ltd for the supply of oxycarboxin
fungicide.
APPENDIX I

Trial design at J. Cardillo's, Farnsfield Headland

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APPENDIX I

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† Plots treated with fungicide

Elevated section of trial where plants showed severe moisture stress symptoms in late October, November, December 1982 and early February 1983.
Trial design at A. Campagnelo's, Mourilyan

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Headland

† Plots treated with fungicide
### APPENDIX II

#### I ISIS TRIAL

Data for the effect of rust infection on growth and yield of 70577, Q90, Q108, Q87 and Q110 in the Isis trial; and analysis of variance tables

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<th>Number of stalks/ha (x 10^5) October 83</th>
<th>Stalk cross-sectional area (cm^2)</th>
<th>Stalk height to T.V.D. (cm)</th>
<th>Tonnes cane per hectare</th>
<th>C.C.S. October 83</th>
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### Analysis of variance table for tonnes sugar per hectare

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**Data for the effect of rust infection on sugar quality of 70577, Q90, Q108, Q87 and Q110 in the Isis trial; and analysis of variance tables**

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### Analysis of variance table for pol

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### Analysis of variance table for fibre

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Analysis of variance table for c.c.s. (September 1983)

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Analysis of variance table for pol % juice

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Analysis of variance table for % sucrose in juice

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Analysis of variance table for % glucose in juice

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<td>0.0032</td>
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### Analysis of variance table for % fructose in juice

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<tr>
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<tr>
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<td>0.0032</td>
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### Analysis of variance table for % dry substance in juice

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<td>0.099</td>
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### Analysis of variance table for % true purity

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### Analysis of variance table for % ash in juice

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<td>0.004</td>
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<tr>
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<td>0.039</td>
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### Analysis of variance table for reducing sugars to ash ratio

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<td>Replicates</td>
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<td>0.033</td>
<td>9.89</td>
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<td>0.061</td>
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<td>0.003</td>
<td>1.00</td>
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### Analysis of variance table for pH of juice

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<tr>
<td>Replicates</td>
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<td>0.0037</td>
<td>0.83</td>
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</table>
### II MOURILYAN TRIAL

Data for the effect of rust infection on growth and yield of 71A123, Q90, Q105, Q107 and Q113 in the Mourilyan trial; and analysis of variance tables.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Number of shoots/ha (x 10^5) November 82</th>
<th>Number of stalks/ha (x 10^5) September 83</th>
<th>Stalk cross-sectional area (cm²)</th>
<th>Stalk height to T.V.D. (cm)</th>
<th>Tonnes cane per hectare</th>
<th>Tonnes sugar per hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>71A123</td>
<td>0.921 0.801 0.955 0.747 0.656 0.801 4.13 4.17 4.23 302.7 279.3 334.2</td>
<td>82.58 113.87 108.80 14.38 13.47 11.54</td>
<td>11.87 16.34 12.56</td>
<td>4.13 4.17 4.23</td>
<td>302.7 279.3 334.2</td>
<td>82.58 113.87 108.80 14.38 13.47 11.54</td>
</tr>
<tr>
<td></td>
<td>0.673 0.678 0.794 0.661 0.638 0.753 3.53 4.03 3.80 265.1 263.4 303.2</td>
<td>79.89 104.83 72.86 14.95 14.12 14.62</td>
<td>11.94 14.80 10.65</td>
<td>3.53 4.03 3.80</td>
<td>265.1 263.4 303.2</td>
<td>79.89 104.83 72.86 14.95 14.12 14.62</td>
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<tr>
<td>Q90</td>
<td>1.207 1.281 1.054 0.868 0.816 0.806 4.63 4.75 4.15 364.7 338.3 347.1</td>
<td>139.26 172.96 156.48 15.95 15.53 15.41</td>
<td>22.23 26.86 24.11</td>
<td>4.63 4.75 4.15</td>
<td>364.7 338.3 347.1</td>
<td>139.26 172.96 156.48 15.95 15.53 15.41</td>
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<tr>
<td></td>
<td>1.208 1.110 1.041 0.801 0.819 0.773 4.33 4.40 4.10 345.2 351.3 368.2</td>
<td>135.50 112.73 144.02 15.37 15.13 15.24</td>
<td>20.83 17.06 21.45</td>
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<td>345.2 351.3 368.2</td>
<td>135.50 112.73 144.02 15.37 15.13 15.24</td>
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<tr>
<td>Q105</td>
<td>1.176 1.100 1.184 0.896 0.873 0.845 4.05 3.98 4.23 244.5 260.3 291.1</td>
<td>112.81 105.32 110.61 16.61 17.02 15.33</td>
<td>18.74 17.93 16.96</td>
<td>4.05 3.98 4.23</td>
<td>244.5 260.3 291.1</td>
<td>112.81 105.32 110.61 16.61 17.02 15.33</td>
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<tr>
<td></td>
<td>1.031 0.890 0.956 0.742 0.789 0.765 3.35 3.53 3.55 226.3 231.9 232.6</td>
<td>69.85 73.29 78.29 16.47 16.73 16.75</td>
<td>11.50 12.26 13.11</td>
<td>3.35 3.53 3.55</td>
<td>226.3 231.9 232.6</td>
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<tr>
<td>Q107</td>
<td>1.164 1.117 1.118 0.643 0.609 0.592 6.70 6.83 7.13 368.5 366.1 361.2</td>
<td>156.70 165.60 151.48 14.86 15.13 14.52</td>
<td>23.29 26.05 21.99</td>
<td>6.70 6.83 7.13</td>
<td>368.5 366.1 361.2</td>
<td>156.70 165.60 151.48 14.86 15.13 14.52</td>
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<tr>
<td></td>
<td>1.204 1.010 0.998 0.617 0.571 0.579 6.15 7.00 6.78 345.9 362.4 381.8</td>
<td>140.32 150.04 147.91 15.27 15.08 15.20</td>
<td>21.43 22.63 22.48</td>
<td>6.15 7.00 6.78</td>
<td>345.9 362.4 381.8</td>
<td>140.32 150.04 147.91 15.27 15.08 15.20</td>
</tr>
<tr>
<td>Q113</td>
<td>1.137 1.209 1.166 0.910 0.949 0.949 3.68 3.85 3.55 336.5 337.7 337.7</td>
<td>121.00 156.90 151.05 15.19 15.55 15.55</td>
<td>18.38 24.40 20.50</td>
<td>3.68 3.85 3.55</td>
<td>336.5 337.7 337.7</td>
<td>121.00 156.90 151.05 15.19 15.55 15.55</td>
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<tr>
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<td>1.127 1.240 1.035 1.026 0.949 0.910 4.00 4.23 4.05 316.0 353.5 324.0</td>
<td>144.54 112.93 151.05 15.49 15.23 13.57</td>
<td>22.39 17.20 20.50</td>
<td>4.00 4.23 4.05</td>
<td>316.0 353.5 324.0</td>
<td>144.54 112.93 151.05 15.49 15.23 13.57</td>
</tr>
</tbody>
</table>

* These values were determined by the missing plot technique (see page...*)
Missing plot determination

The third replicate of Q113 fungicide treated was not assessed at maturity because of severe lodging of the cane. The values for number stalks per hectare, stalk cross-sectional area, stalk heights to T.V.D., tonnes cane per hectare and tonnes sugar per hectare were determined by the missing plot technique (Steel and Torrie, 1980)*1

<table>
<thead>
<tr>
<th>Q113 treated</th>
<th>Number stalks per hectare ($x 10^5)$</th>
<th>Stalk cross-sectional area ($cm^2$)</th>
<th>Stalk height to T.V.D. (cm)</th>
<th>Tonnes cane per hectare</th>
<th>C.C.S.</th>
<th>Tonnes sugar per hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
<td>0.925</td>
<td>3.76</td>
<td>337.1</td>
<td>141.70</td>
<td>14.20</td>
<td>20.12</td>
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</tbody>
</table>

### Analysis of variance table for the number of shoots per hectare $\times 10^5$

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
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<th>MS</th>
<th>F</th>
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</thead>
<tbody>
<tr>
<td>Replicates</td>
<td>2</td>
<td>0.0057</td>
<td>0.0028</td>
<td>4.59</td>
</tr>
<tr>
<td>Treatments</td>
<td>1</td>
<td>0.1098</td>
<td>0.1098</td>
<td>178.00**</td>
</tr>
<tr>
<td>Error 1</td>
<td>2</td>
<td>0.0012</td>
<td>0.0006</td>
<td>1.00</td>
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<tr>
<td>Cultivars</td>
<td>4</td>
<td>0.4533</td>
<td>0.1133</td>
<td>15.30**</td>
</tr>
<tr>
<td>Treatments x Cultivars</td>
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<td>0.0312</td>
<td>0.0078</td>
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<tr>
<td>Error 2</td>
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<td>0.0074</td>
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</tbody>
</table>

### Analysis of variance table for the number of stalks per hectare $\times 10^5$

<table>
<thead>
<tr>
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<tr>
<td>Replicates</td>
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<tr>
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<td>0.0997</td>
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</tr>
<tr>
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### Analysis of variance table for stalk cross-sectional area

<table>
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<tbody>
<tr>
<td>Replicates</td>
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<td>0.249</td>
<td>0.124</td>
<td>2.43</td>
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<tr>
<td>Treatments</td>
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<td>0.394</td>
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</tr>
<tr>
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<td>0.102</td>
<td>0.051</td>
<td>1.00</td>
</tr>
<tr>
<td>Cultivars</td>
<td>4</td>
<td>37.359</td>
<td>9.340</td>
<td>244.17**</td>
</tr>
<tr>
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<tr>
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<td>16</td>
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### Analysis of variance table for stalk height to T.V.D.

<table>
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<tr>
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<tr>
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<td>695.010</td>
<td>6.57</td>
</tr>
<tr>
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<tr>
<td>Cultivars</td>
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<td>373.359</td>
<td>343.340</td>
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<tr>
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<tr>
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### Analysis of variance table for tonnes cane per hectare

<table>
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<tbody>
<tr>
<td>Replicates</td>
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<td>170.056</td>
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<td>2 577.609</td>
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<tr>
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<tr>
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### Analysis of variance table for c.c.s.

<table>
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<tbody>
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### Analysis of variance table for tonnes sugar per hectare

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Replicates</td>
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