A REVIEW OF RESEARCH INTO PACHYMETRA ROOT ROT, AN IMPORTANT NEW FUNGAL DISEASE OF SUGARCANE

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Key words: Root rot, Pachymetra, sugarcane

ABSTRACT

Pachymetra root rot is an important new disease and is a major component of the poor root syndrome of sugarcane in Queensland, Australia. The characteristic symptom of Pachymetra root rot is a flaccid rot of primary and secondary roots. The disease has been recorded in all regions of Queensland but has not been reported from any other cane-growing countries. Pachymetra chaunorhiza, the cause of Pachymetra root rot, has recently been described and has been placed in the Verrucalvaceae (Sclerosporales). P chaunorhiza has distinctive large verrucate oogonia. The disease is considered to cause significant yield losses in Queensland and is associated with poor anchorage of the stool of the sugarcane plant. A cultivar resistance screening technique has been developed and resistant cultivars with acceptable commercial characteristics have been identified. A range of other potential control measures, including fungicides, cultural treatments, solarisation, biological control agents and fumigation have either failed to control the disease effectively or are uneconomic.

INTRODUCTION

In the late 1970's and early 1980's, a complex problem called Poor Root Syndrome (PRS) seriously affected sugarcane crops in the high rainfall districts of northern Queensland (Egan et al13). Affected crops exhibited symptoms such as reduced vigour, water stress, leaf yellowing, poor stooling, uneven stalk height, and a loss of stool anchorage (Croft and Magarey8, Egan et al13, Lawrence15, Reghenzani21). Root symptoms were typically a flaccid rot of primary and secondary shoot roots, poor “fine” (tertiary) root growth and root lesions (Egan et al13, Lawrence15, Magarey17). Pachymetra chaunorhiza Croft and Dick was first isolated from diseased roots in 1981, and was found to be the cause of the root rot component of the syndrome (Croft and Magarey8). The root disease caused by this fungus has been termed Pachymetra root rot (Croft7).

DESCRIPTION

Pachymetra root rot is characterised by a flaccid rot of primary and larger secondary shoot roots (Croft and Magarey8, Magarey17). The rot principally occurs in the root tip region, and in susceptible cultivars may extend the length of the entire root. In fields infested at high levels with Pachymetra, root systems may be greatly restricted with many short flaccid roots extending from the stool. Lodged stools are often uprooted and many stools are pulled out of the ground during normal harvesting operations because of the loss of stool anchorage.

The initial root symptom of Pachymetra infection is a watersoaking of the affected section, and this symptom rapidly develops into a soft and flaccid rot. In advanced stages, affected roots are held intact only by the root epidermis, all other root structures having disintegrated (Magarey17). Root reddening in sections up to 2.0 mm long and usually...
encircling the root, almost always accompanies the flaccid rot, in many instances indi-
cating the limit of Pachymetra infection. Where high inoculum densities of P chaunorhi-
za prevail, 80 - 90% of primary shoot roots in susceptible cultivars may be completely
rotted (Lawrence15). Rotted roots contain large numbers of oospores of the pathogen.
The oogonial wall is verrucose (ie with rounded processes or warts) and very distinct-
ive; it provides a reliable diagnostic character for the identification of Pachymetra in-
fection (Magarey17).
Pachymetra root rot may be distinguished from Pythium root rot by the following charac-
teristics (Croft6, Magarey17):
(1) Rotted roots affected by Pachymetra contain large verrucose oogonia and no sporan-
gia while rotted roots affected by Pythium contain smaller, smooth-walled oogonia
and lobulate sporangia.
(2) Pachymetra has only a small effect on fine root growth. Pythium infection is accom-
panied by a flaccid rot of tertiary roots and a substantial reduction in fine root growth.
(3) Abundant red root lesions and discolorations usually accompany Pythium root rot but
not Pachymetra root rot.
(4) Optimum temperatures for Pachymetra root rot are 28-30°C (Table I) while for Py-
thium root rot, maximum yield loss and primary root rot occur at 18°C (Rands and
Table 1 - Percentage of primary shoot roots of cultivar Q90 affected by Pachymetra
root rot at temperatures of 22, 28 and 34°C. Isolates were from
northern (T86-1D) and Herbert River (T86-2H) canegrowing districts of
Queensland.

<table>
<thead>
<tr>
<th>Temperature C°</th>
<th>Isolate</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T86-1D</td>
<td>T86-2H</td>
</tr>
<tr>
<td>22</td>
<td>23.6a</td>
<td>0</td>
</tr>
<tr>
<td>28</td>
<td>61.2a</td>
<td>23.2a</td>
</tr>
<tr>
<td>34</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

a. Pachymetra root rot infection was confirmed by microscopic examination
b. Rotted roots did not contain oospores of P chaunorhiza

DISTRIBUTION

P chaunorhiza is known only from Queensland canefields. Pachymetra root rot has never
been detected in sugarcane growing on land which has not previously grown sugarcane.
Surveys were undertaken in 1984-87 to determine the distribution of P chaunorhi-
za within Queensland. The results suggested that large areas of the northern, Herbert
River and central districts were infested (Magarey et al18), and the pathogen was later
identified in southern Queensland (Anon19). The highly productive Burdekin district is
largely unaffected; only one farm in the northern extremity of the district is known to
be infested (Magarey et al18).

CAUSAL ORGANISM AND HOST RANGE

In 1984, Croft and Magarey8 described an oomycete fungus which caused the flaccid
rot of primary sugarcane roots grown in PRS affected soils. This fungus was unknown
previously, and it was not until 1989 that the fungus was described as *Pachymetra chaunorhiza* Croft and Dick ([Dick et al](#)). The genus *Pachymetra* was created to contain this fungus, and has been placed in the Verrucalvaceae (Sclerosporales). Analysis of ribosomal DNA restriction sites has shown that *Pachymetra* is closely related to *Verrucalvus flavofaciens* Wong and Dick ([Belkhiri and Dick](#), [Klassen et al](#)), the causal agent of Kikuyu yellows in Australia ([Dick et al](#)).

A summary of the descriptions of *P chaunorhiza* as given by Croft and Magarey ([Croft et al](#)) and [Dick et al](#) is as follows:

Colonies on corn meal agar submerged with no distinct pattern. Vegetative hyphae slender, 0.9-6.3 (mean 2.5) μm in diameter. Sporangia not known. Sexual reproduction is homothallic with oogonia developing singly from vegetative hyphae or in clusters from small hyphal knots. Oogonia are large, 30-60 (mean 48.1) μm in diameter including verrucae, each containing a single plerotic oospore. Oogonial walls are verrucate, verrucae circular at first, increasing in thickness and length during swelling of the oogonial initial. Oospores plerotic, 22-51 (mean 34.1) μm in diameter, containing an ooplast (abnormally 2-3) and a nuclear spot. Antheridia mostly arise from the oogonia stalk, 1-3(6) per oogonium, inflated and making apical contact with the oogonium between verrucae.

Cardinal temperatures on corn meal agar are minimum 14°C, optimum 27-31°C (10-17 mm/24h) and maximum 36°C. The relationship between linear growth on corn meal agar and temperature is shown in Fig 1.

![Figure 1. Linear growth of *P chaunorhiza* on corn meal agar at temperatures from 7 to 40°C.](image)

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Extensive attempts to produce zoospores from pure cultures of the fungus and from infected roots have been unsuccessful (Croft and Magarey⁹, Dick et al¹⁰). *Pachymetra* can be isolated from roots at an early stage of soft rot by washing the infected root for 30-60 min in running tap water, cutting a 5 mm section of root from the reddened root tissue at the advancing margin of the infection and embedding the root section in potato dextrose agar plus 12.5 mg/l Pimaricin (Pimafucin, Gist-Brocades, Netherlands) and 25 mg/l Rifampicin (Sigma, USA). After 2-3 days incubation at 28°C, sparse hyphal growth of the fungus can be seen in the agar. Mycelium of *P chaunorhiza* loses viability on agar media once the mycelium has reached the edge of the dish in which it is grown. The fungus can be successfully sub-cultured from actively growing agar cultures or from broth cultures (Dick et al¹⁰). The fungus can be stored in sterile distilled water for 1-2 years, but cultures 10 months or older lose pathogenicity and produce fewer oospores (Anon¹). Cultures on potato dextrose agar fail to produce well developed oogonia (Croft²).

The effect of water potential on growth of *P chaunorhiza* on an artificial medium adjusted with KCl, using the techniques described by Lipps and Bruehl¹⁶, is shown in Fig.2. The effects of *Pythium graminicola* and *Pythium myriotylum* are shown for comparison. *P chaunorhiza* was more sensitive to low water potential than the two *Pythium* species and is more sensitive than other oomycete fungi (Duniway¹⁷). In a pot experiment with varying water potentials, *Pachymetra* root rot was reduced by low water potential, but this may have been due to the poor root growth of the plants at these soil moisture contents (Anon¹). Field observations suggest that *Pachymetra* root rot is worse in lower sections of fields which stay wetter for longer periods after rain.

**Figure 2.** Linear growth of *P chaunorhiza* on an artificial medium adjusted to water potentials from -2.5 to -39 bars with KCl. The linear growth of *Pythium graminicola* and *Pythium myriotylum* on the same medium are included for comparison.
Field solarisation and fumigation experiments have shown that re-infestation of small plots by *P chaunorhiza* is relatively slow. In small solarised plots within heavily infested fields, no *Pachymetra* root rot was detected in the treated soils for two years after treatment (Reghennan). Care was taken in these experiments to prevent re-infestation by machinery but there was no restriction on water movement between plots. *Pachymetra* root rot was transmitted to pasteurised soil by adding 10% unpasteurised, infested soil (Croft et al.) but no evidence of transmission by soil-water extracts has been obtained (Egan et al.). Since *P chaunorhiza* is not known to produce zoospores, transmission in water is probably of little importance in spread of the disease. The oospores of the fungus are large and relatively dense and would only be carried significant distances by rapidly flowing water. The most likely methods of spread of the fungus are by machinery contaminated with soil, and by soil or roots adhering to the butts of stalks used for planting material.

*P chaunorhiza* can infect sorghum (*Sorghum bicolor* (L.) Moench) but infection is generally restricted and oospore production is sparse (Croft, unpublished data). Dick et al. theorised that *Pachymetra* has colonised sugarcane from a native Australian grass. Inoculation of a range of grasses and weeds common in sugarcane fields failed to identify any alternative hosts (Perry). *P chaunorhiza* can infect clones of *Saccharum spontaneum* and the closely related *Erianthus* spp.

**ECONOMIC IMPORTANCE**

Comparisons of the levels of *P chaunorhiza* in sections of fields which have previously grown susceptible and resistant cultivars have shown much higher levels of *P chaunorhiza* under the susceptible cultivars. When a susceptible cultivar was grown in one field which had previously grown susceptible and resistant cultivars, the section of the field which had previously grown the resistant cultivar out-yielded the other section by 45% (Anon). This evidence suggests that *Pachymetra* root rot can cause large yield losses. Replicated experiments to duplicate these field observations are in progress.

It is difficult to measure the losses caused by *Pachymetra* root rot since it does not cause any specific above ground symptoms, and other soil-borne pathogens such as nematodes and Pythium spp are nearly always present in affected soils. However, the devastating effect which *Pachymetra* root rot has on root growth of highly susceptible cultivars suggests that yield losses are significant in these cultivars.

In areas badly affected by *Pachymetra* root rot, the loss of stool anchorage accentuates the importance of the disease. Mechanical harvesters pick up the stubble, root system and attached soil and this is carried to the mill in the cane supply. The soil causes increased wear and processing problems at the mills. The loss of the stubble causes gaps and consequent yield losses in ratoon crops.

**CONTROL**

Early investigations into cultivar reaction to PRS showed that some cultivars appeared to be less affected than others (Egan et al.). However, results of field screening trials were very variable. This would be expected since the range and density of root pathogens involved in PRS varies between and within sites. A glasshouse technique for screening cultivars for resistance to *Pachymetra* root rot has been developed (Croft). This involves growing young plants of the test cultivars in sand-peat potting mixture infested with oospores of *P chaunorhiza*. Levels of inoculum between $2 \times 10^4$ and $1 \times 10^5$ oospores/kg of potting mixture give consistent ratings between trials. The plants are grown for six to eight weeks and then the percentage of rotted primary shoot roots is deter-
mined. The ten standard cultivars included in each trial and their ratings are Q114 (rating 1), Q78 (2), S8N829 (3), Q117 and Q120 (4), Q113 (5), Q96 and Q132 (6), Q90 (8) and Q83 (9). Test cultivars are rated from a regression of the arcsin percent rotten roots in the standard cultivars versus the standard rating of these cultivars. The ratings for a number of commercial cultivars are shown in Table 2. Of the foreign cultivars tested, cultivars from Hawaii and Reunion have shown above average resistance to this fungus (Table 3).

**Table 2 - Pachymetra root rot resistance ratings of a range of commercial cultivars.**

<table>
<thead>
<tr>
<th>Resistance 1-3</th>
<th>Q57, Q70, Q77, Q78, Q114, Q125, Q127, Q138, Cassius, Eros, Sidon, Triton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermediate 4-6</td>
<td>Q63, Q96, Q100, Q113, Q115, Q117, Q124, Q130, Q132, Q135, Q136, CP29-116, CP44-101, H56-732, NCo310, Pelorus</td>
</tr>
<tr>
<td>Susceptible 7-9</td>
<td>Q50, Q68, Q90, Q94, Q121, Q123, Q126, Q142, Q143, Q144, Q146, Pindar, Titan, Trojan, B42231, Co290, CP51-21, Fl68, FOJ2578</td>
</tr>
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**Table 3 - The mean Pachymetra root rot resistance rating from glasshouse screening trials of cultivars from different plant breeding programmes**

<table>
<thead>
<tr>
<th>Cultivar source</th>
<th>Mean rating</th>
<th>Number of cultivars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiji</td>
<td>6.0</td>
<td>10</td>
</tr>
<tr>
<td>Hawaii</td>
<td>4.0</td>
<td>23</td>
</tr>
<tr>
<td>India (Coimbatore)</td>
<td>4.9</td>
<td>9</td>
</tr>
<tr>
<td>Queensland (BSES)</td>
<td>5.9</td>
<td>60</td>
</tr>
<tr>
<td>Queensland (CSR)</td>
<td>5.0</td>
<td>17</td>
</tr>
<tr>
<td>Reunion</td>
<td>4.0</td>
<td>6</td>
</tr>
<tr>
<td>South Africa</td>
<td>6.2</td>
<td>5</td>
</tr>
<tr>
<td>USA (Canal Point)</td>
<td>5.6</td>
<td>15</td>
</tr>
</tbody>
</table>

Ratings obtained from glasshouse screening trials for a range of cultivars were significantly related to the percentage of rotten roots on the same cultivars grown in an infested field (Craft7), and to the build-up of oospores in the soil beneath the cultivars (Anon3). Cultivar resistance is the basis of the BSES control strategy for Pachymetra root rot. Parent cultivars are screened for resistance and crosses between susceptible parents are not made. Cultivars in the latter stages of the plant breeding programme are tested for resistance and farmers are advised of the ratings of cultivars released for commercial production. The percentage of resistant-intermediate cultivars in the northern region of Queensland has increased from 21% in 1979 to 58% in 1987.

A range of fungicides active against oomycete fungi has been tested for control of Pachymetra root rot. Metalaxyl and fosetyl-Al, which are very active against many oomycetes, had no activity against P. chaunorhiza in pot and field experiments (Craft et al6). In artificially infested soil, fenamidone, etridiazole, propamocarb and pyroxyfen significantly reduced the level of Pachymetra root rot. However, all of these chemicals were phytotoxic at effective rates. Quintozene (PCNB) has recently been shown to be effective in controlling Pachymetra root rot but it is also slightly phytotoxic (Anon3). Unless
an inexpensive fungicide with extremely high activity and relatively high persistence can be found it is unlikely that fungicides can be used for commercial control of this disease.

Soil solarisation (Reghenzani\textsuperscript{22}) and broad spectrum soil fumigants (Croft et al\textsuperscript{8}) can eliminate Pachymetra from treated soils but are uneconomic for broadacre application.

No cultural treatments or nutritional amendments have been found that significantly reduce the level of Pachymetra root rot of plants grown in affected soils (Egan et al\textsuperscript{83}, Croft et al\textsuperscript{8}). Following for three years has been found to reduce the oospore population in soil by about 60% (Magarey, unpublished data).

A large number of potential biocontrol organisms have been screened for control of Pachymetra root rot (Birch\textsuperscript{3}). Eight organisms including species of Pseudomonas, Trichoderma, Baccillus, Enterobacter, Bipolaris and Penicillium gave significant control in initial pot experiments but did not significantly control the disease in the field (Anon\textsuperscript{5}). P graminicola has consistently reduced the level of Pachymetra root rot when both pathogens occur in the same soil (Croft and Magarey\textsuperscript{9}, Croft et al\textsuperscript{8}). This may be due to competition for infection sites.

**CONCLUSION**

Research during the past ten years has identified P chaunorhiza as an important new fungal pathogen of sugarcane. The Pachymetra root rot epidemic in the northern region of Queensland during the 1970’s was probably caused by widespread cultivation of the susceptible cultivar Q90. Pachymetra root rot was most likely responsible for the failure of other susceptible cultivars which were highly promising in plant breeding trials, eg Q83. Resistant cultivars appear to be the only economic method of reducing the levels of P chaunorhiza in sugarcane fields; the inheritance of resistance is currently being investigated. A system of rotating resistant with intermediate-susceptible cultivars may allow a wider range of cultivars to be grown while still keeping inoculum levels below the threshold at which economic losses occur. Further research into the thresholds for economic losses for cultivars with differing levels of resistance is required.

**REFERENCES**


UNE REVUE DES RECHERCHES EFFECTUEES SUR LA POURRITURE DES RACINES, LE PACHYMETRA, UNE IMPORTANT NOUVELLE MALADIE DE LA CANNE A SUCRE

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EXTRAIT

La pourriture des racines, le Pachymetra est une importante nouvelle maladie et est une des causes majeures du faible développement des racines de la canne à sucre au Queensland en Australie. Le symptôme qui caractérise cette maladie est une pourriture gluante des racines primaires et secondaires. Cette maladie a été observée dans toutes les régions du Queensland mais ne l'a jamais été dans aucun autre pays où la canne est cultivée. Pachymetra chaunorhiza, l'agent causal de la maladie, a récemment été décrit et été classifié chez les Verrucalceae (Scleroporales). Pachymetra chaunorhiza a de larges oogones verruqueuses qui lui sont distinctives.
PATHOLOGY

Cette maladie cause des chutes de rendements significatives associées à un faible enracinement de la souche dans le sol. Une technique visant à la sélection de variétés résistantes a été établie et de telles variétés ayant des caractères commerciaux acceptables ont été identifiées. Quant aux mesures potentielles de contrôle, tels l'usage de fongicides, de pratiques culturales, la solarisation, le contrôle biologique et la fumigation, certaines n'ont pas réussi à effectuer un contrôle efficace de la maladie et d'autres ne sont tout simplement pas économiques.

REVISION DE LAS INVESTIGACIONES EN PODREDUMBRE RADICULAR POR PACHYMETRA, UNA IMPORTANTE NUEVA ENFERMEDAD FUNGICA DE LA CANA DE AZUCAR

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Palabras claves: podredumbre radicular, Pachymetra, caña de azúcar.

RESUMEN

La podredumbre radicular por Pachymetra, es una enfermedad nueva e importante y es el principal componente del síndrome del empobrecimiento radicular de la caña de azúcar en Queensland, Australia. El síntoma característico de la podredumbre radicular por Pachymetra, es una podredumbre flácida de las raíces primarias y secundarias. La enfermedad fue registrada en todas las regiones de Queensland pero no en los otros países donde se cultiva caña de azúcar. El agente causal de la podredumbre radicular por Pachymetra (Pachymetra chaunorhiza) ha sido recientemente descripto y ubicado dentro de las Verruculaceae (Sclerosporales). P. chaunorhiza posee un oogonio grande y verrugoso que lo caracteriza. Se considera a la enfermedad como causante de significativas pérdidas del rendimiento en Queensland y esta asociada con un anclaje pobre de las cepas de la planta de caña de azúcar. Se ha desarrollado una técnica de detección de cultivares resistentes y se han identificado algunos con características comerciales aceptables. Otras medidas potenciales de control tales como fongicidas, tratamientos culturales, solarización, agentes de control biológico y fumigaciones han fracasado como medidas eficaces de control o bien resultaron antiéconomicas.