Effect of Sugarcane Cultivars and Location on Inoculum Density of *Pachymetra chaunorhiza* in Queensland

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ABSTRACT

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The influence of sugarcane cultivars on the inoculum density of *Pachymetra chaunorhiza* was assessed by monitoring the changes in numbers of oospores of *P. chaunorhiza* in the soil of field plots by a direct count assay. Cultivars with different levels of disease resistance were planted at each of six sites in a district where Pachymetra root rot was known to occur. Inoculum densities were quantified before planting and after either 2 or 3 yr of cropping. The effects of cultivar, site, and the interaction between site and cultivar were examined by analysis of variance. All three parameters were significant, suggesting that cultivars have a measurable effect on inoculum density and that this effect varies with location. Field ratings were assigned on the basis of changes in soil inoculum density and were compared with glasshouse ratings for each cultivar. The correlation between glasshouse and field ratings was high ($r^2 = 0.59$, and $P < 0.001$). Monitoring changes in soil inoculum density in fallow plots enabled the natural rate of attrition of oospores in the absence of the host to be assessed. Oospores survived in fallow plots for at least 5 yr.

In the late 1970s to early 1980s, a root condition of sugarcane (interspecific hybrids of *Saccharum* L.) termed northern poor root syndrome resulted in low-yielding crops in northern Queensland (6). The widely grown cultivar Q90 exhibited a poorly developed root system characterized by rotted primary shoot roots (3,7,8). From these rotted roots, Croft (3) isolated a previously unknown oomycete, now described as *Pachymetra chaunorhiza* Croft & Dick (5), and showed through pathogenicity tests that this fungus causes the primary root rot symptom.

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Croft (1) developed a glasshouse technique to assess the resistance of commercial and near-commercial cultivars in the plant-breeding program. The resistance screening technique compares the growth of test cultivars in infested potting mix under standard conditions. After 6 wk, an assessment of the number of rotted primary shoot roots as a proportion of the total number of roots is made for each cultivar (1). With regression techniques and a set of standard cultivars of known reaction, ratings can be assigned to test cultivars. With this technique, it has been shown that Australian commercial cultivars are widely divergent in resistance to *P. chaunorhiza* (1).

A soil assay for quantifying *P. chaunorhiza* based on direct counts of soil-borne oospores has been developed (9). Oospores are the only known propagule of the pathogen and are produced in abundance in rotted primary roots (8). Field plot sampling strategies for use with the assay have been described (10), together with the number of soil cores required per unit area to minimize sam-

Table 1. Details of field plots at locations 1–6 planted to assess the effect of sugarcane cultivars on *Pachymetra chaunorhiza* inoculum density after 2 or 3 yr of cropping

Location[a]	Date planted	Soil series	District	Preplant inoculum density (oospores/g of soil)	Years before sampling (postplant)	Cultivation
1	30 May 1988	Tully	Babinda	Undetectable	3	Minimum tillage, trash retention
2	20 September 1988	Pin Gin	Bellenden Ker	29.3	2	Minimum tillage, trash retention
3	3 August 1989	Coom	Bellenden Ker	125.8	2	Minimum tillage, no trash
4	11 August 1989	Thorpe	Cucania	105.3	2	Full cultivation
5	11 August 1989	Thorpe	Cod Fish Creek	59.8	2	Minimum tillage, trash retention
6	18 August 1989	Virgil	Highleigh	55.7	2	Full cultivation

[a]Least significant difference for comparison of data from locations 2–6 = 14.52 ($P = 0.05$).

Table 2. Comparison of the effects of sugarcane cultivars on *Pachymetra chaunorhiza* inoculum densities at locations 1–6 after the growth of plant and one or two ratoon crops

	Mean inoculum density postplant (oospores/g of soil)	
Cultivar	Location 1	Locations 2–6[a]
Q138	0	89.5
Q78	0	94.8
58N829	1	99.8
Q117	0	104.0
Q114	0	115.6
Q130	0	143.3
Cassius	1	144.9
Q57	0	156.6
Q132	5	193.8
Q122	4	215.9
Badila	1	225.9
Q113	4	227.4
Q124	12	243.2
Q120	0	249.2
H56-752	16	268.4
79N1348	2	280.5
Triton	0	284.4
Q107	1	305.8
Pindar	2	326.2
Q128	1	359.0
Q121	72	370.4
Q90	23	385.0
79N1284	1	386.2
Q99	48	408.5
Q83	83	514.9

[a]Least significant difference for comparison of data from locations 2–6 = 106.8 ($P = 0.01$).

pling error. In preliminary field experiments, it has been shown that cultivar resistance can greatly influence *P. chaunorhiza* soil inoculum levels (11) and that the pathogen may reduce the yield of a susceptible cultivar (13). However, little information is available on the influence of cultivar resistance on *P. chaunorhiza* inoculum density.

MATERIALS AND METHODS

Six field plots, each containing 25 sugarcane cultivars representing a range of resistance to *P. chaunorhiza,* were planted during 1988 and 1989 in northern Queensland. The individual glasshouse ratings for these cultivars have been published (1,2,4,11). Fallow plots were included at most sites to investigate the natural rate of attrition of the oospores in the absence of the host.

Table 3. Mean inoculum densities of *Pachymetra chaunorhiza* at locations 2–6 after the growth of plant and first ratoon crops

Location	Mean inoculum density (oospores/g of soil)[a]
2	246.06 bc
3	361.82 d
4	255.24 c
5	168.50 a
6	207.02 ab

[a]Values followed by the same letter do not differ significantly ($P = 0.01$ with square root-transformed data).

Inoculum density of *P. chaunorhiza* was measured prior to planting by collecting three soil cores per plot along the planting line to a depth of 45 cm with an Edelman auger (4-cm diameter). Statistical analyses of sampling errors associated with the assay (10) showed that this intensity of sampling would be sufficient to minimize variation. Soil samples were bulked, sieved, mixed thoroughly by hand, and then assayed for oospores (9).

Planting material free of ratoon stunting disease, caused by *Clavibacter xyli* subsp. *xyli,* was planted with a whole-stick trash planter. Crops were fertilized with N, P, and K according to district recommendations. A randomized complete block design was employed with two replicates. Plot size was one row by 7.5 m, except at location 5 where it was 6.5 m. Row spacing was 1.5 m. Cultivars included at each location were Badila, Cassius, H56-752, 58N829, 79N1284, 79N1348, Pindar, Q57, Q78, Q83, Q90, Q99, Q107, Q113, Q114, Q117, Q120, Q121, Q122, Q124, Q128, Q130, Q132, Q138, and Triton. Details of the six locations are presented in Table 1. Plant and first ratoon crops were grown, i.e., two 12-mo sugarcane crops from the same planting, before postplant *P. chaunorhiza* inoculum density was assessed, except in experiment 1, where sampling occurred after the second ratoon crop. Four soil cores per plot were taken at random directly through the stools of the previously harvested plants, since earlier research had shown that maximum build-up in inoculum density occurs immediately beneath the sugarcane stool (12). The four cores were bulked, and the soil was sieved (0.5-cm aperture), mixed thoroughly by hand, and assayed for oospores of *P. chaunorhiza* (9).

Analysis of variance was conducted on the combined results from locations 2–6 after a square root transformation of the data to ensure homogeneity of variances. The effect of cultivars on *P. chaunorhiza* inoculum density was compared between locations and also with glasshouse resistance ratings by simple correlation with the STATISTIX program, version 4 (Analytical Software, Roseville, MN). This analysis was undertaken to identify sites where there were inconsistent changes in inoculum density. To identify cultivars leading to changes in soil inoculum density inconsistent with glasshouse ratings, field ratings, based on mean soil inoculum densities at locations 2–6, were assigned and compared with glasshouse ratings. To calculate field ratings, the cultivars leading to the least and greatest increase in inoculum density over the trial period were given a rating of 1 and 9, respectively. The mathematical equation relating mean inoculum density and field rating for these two cultivars was calculated. To provide a field rating for all other cultivars, mean spore counts (locations 2–6) were fitted to the equation. In this way, all cultivars received a rating between 1 and 9.

RESULTS

Preplant inoculum densities averaged over all plots for each location are detailed in Table 1. Plots at locations 3 and 4 had the highest number of oospores per gram of soil.

At location 1, inoculum density was at an undetectable level in preplant soil samples. After a plant and two ratoon crops, the more susceptible cultivars had increased the inoculum densities to detectable levels (Table 2). Data from this experiment were not included in the analysis of variance or calculation of field ratings because of the generally low and variable inoculum densities.

Mean inoculum densities (locations 2–6) for cultivars are detailed in Table 2. The highest inoculum density was recorded at location 3 and the lowest at location 5 (Table 3). Analysis of variance

showed highly significant effects of location ($P<0.001$), cultivar ($P<0.001$), and the interaction of cultivar with location ($P < 0.05$) (Table 4). An analysis of covariance, with preplant inoculum density as the covariant, was not significant, suggesting that preplant inoculum density did not influence the analysis of variance.

Correlation coefficients (r), when inoculum densities by cultivar, site, and glasshouse resistance ratings were compared, were all significant, with coefficients above 0.56 (Table 5). The correlation of individual site inoculum density data with glasshouse ratings was comparable to the correlation of inoculum density data between sites.

Field ratings, calculated for each cultivar from combined data from locations 2–6, were correlated with glasshouse resistance ratings (Fig. 1). The coefficient of determination was 0.59 ($P < 0.001$). In general, the field ratings of cultivars were lower than would be expected from glasshouse-assigned resistance ratings. This was pronounced in the cultivars Q117, Q130, Q138, and 58N829. A few cultivars, including Q57, Q99, Q120, and Q128, increased inoculum density more than expected. The change in inoculum density (Y), averaged over all sites for each cultivar, was regressed with the cultivar glasshouse resistance rating (X) (Fig. 2; $Y = 41.75X - 39.98$, $r^2 = 0.74$). This suggests that the most resistant cultivars, with a rating of 1, would still slightly increase inoculum density, whereas a nonhost fallow would decrease preplant inoculum densities.

In assessing the natural rate of attrition of oospores with time, fallow plots were sampled up to 57 mo after trial establishment. Oospore counts were transformed to a percentage of the oospore population present in fallow plots at the beginning of the trial period. In this way, data from all trials were combined, and the relationship between oospore count and fallow period was determined (Fig. 3; $Y = 100.18 + 0.355X - 0.026X^2$, where Y = percentage of original inoculum and X = fallow period; $r^2 = 0.96$). The data suggest that oospore populations decline slightly with a 2-yr fallow period but more rapidly after that. Oospores were still present after a 5-yr fallow period. It should be noted that oospore viability was not assessed.

DISCUSSION

The results reported in this paper show that cultivar resistance has a major influence on *P. chaunorhiza* soil inoculum density. Resistant cultivars maintained densities close to those prevailing preplant, while some susceptible cultivars, particularly Q83, Q90, Q99, Q121, and 79N1284, allowed rapid increase of inoculum density. The results from location 1 illustrate both these points. After 20 yr under cultivation with a resis-

Table 4. Analysis of variance of data on the effect of cultivar and site on *Pachymetra chaunorhiza* inoculum densities at five locations in northern Queensland between 1988 and 1991

Source of variance	df	Mean squares	F value	$P > F$
Location	4	259.36	37.58	0.000
Location × replicate	5	18.13	2.63	0.027
Cultivar	24	139.50	20.21	0.000
Location × cultivar	96	11.22	1.63	0.006
Error	120	6.90	1.00	0.500

Table 5. Correlations of *Pachymetra chaunorhiza* inoculum density data for locations 2–6 with glasshouse resistance ratings of cultivars

Location	Glasshouse rating	Location 2	3	4	5
2	0.82				
3	0.75	0.84			
4	0.58	0.67	0.67		
5	0.66	0.69	0.74	0.57	
6	0.81	0.75	0.74	0.67	0.78

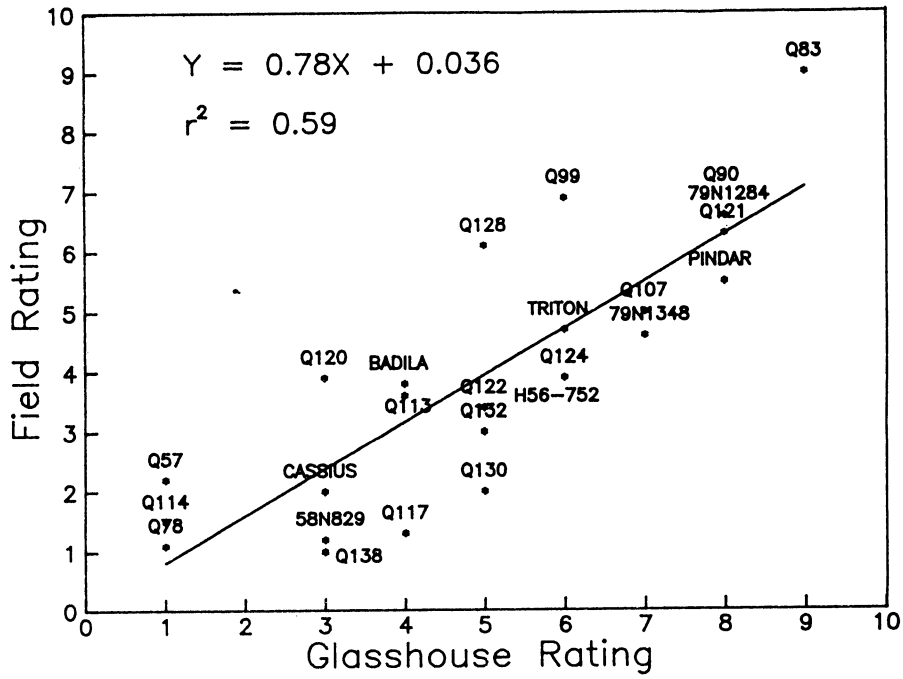

Fig. 1. A correlation of *Pachymetra chaunorhiza* glasshouse resistance ratings and field ratings for all cultivars.

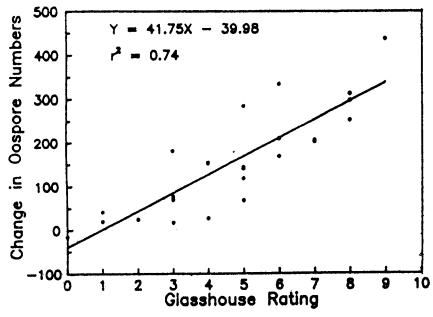

Fig. 2. Change in *Pachymetra chaunorhiza* inoculum density regressed with cultivar glasshouse resistance rating. Data presented are composites of results from locations 2–6.

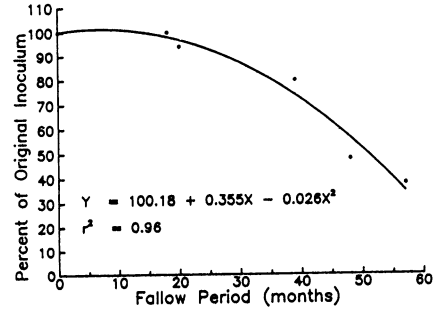

Fig. 3. Reduction in *Pachymetra chaunorhiza* inoculum density associated with fallow periods of up to 57 mo. Data presented are composites of results from three field experiments.

tant cultivar (Q78), inoculum densities at this site were below detectable levels. (This suggests stable resistance.) After 3 yr of growth, the susceptible cultivars Q83, Q99, and Q121 increased inoculum to levels associated with significant yield loss in a susceptible cultivar (50 oospores per gram of soil) (12). The growth of some cultivars with a glasshouse rating of 8 or 9 would appear unsustainable in these circumstances and indeed in many areas of northern Queensland.

Analysis of variance indicated that there were significant effects of location and cultivar on *P. chaunorhiza* inoculum density and that the effect of cultivar on inoculum density was site dependent.

When glasshouse resistance ratings where correlated with individual location and combined field inoculum densities, it was found that the resistance ratings were generally effective in predicting changes in inoculation density in the field. Correlation coefficients tended to be lower for location 4, but it was not possible to establish what factors could be responsible. Factors that might have contributed include the interaction of *P. chaunorhiza* with other root pathogens. Previous research has shown that *Pythium arrhenomanes* Drechs. can reduce the level of Pachymetra root rot in a susceptible cultivar when coinoculated (4). Soil nutritional status has also been implicated as an interacting variable with Pachymetra root rot (14).

Some cultivars showed differences between glasshouse and field ratings. For example, Q117 had a rating of 4 in the glasshouse and 1 in the field, and Q130 rated 5 in the glasshouse and 2 in the field. The reason(s) for these differences remain unclear. It is possible that oospore production in rotted roots of these cultivars is lower than that in similar cultivars of the same resistance rating.

The oospore of *P. chaunorhiza* is very resistant to degradation, and populations remained largely unaltered for up to 2 yr in fallow plots. Because there are very few other known hosts to *P. chaunorhiza* (15), the results reflect the survival of inoculum present at the beginning of the trial period. Schuh et al (16) found that oospores of *Peronosclerospora sorghi* (W. Weston & Uppal) C.G. Shaw also remain intact in the soil for many years. No attempt was made in this study to assess oospore viability. Recent results (R. C. Magarey, *unpublished data*) have suggested that some of these oospores were still viable. In Queensland, sugarcane is grown as a monoculture, and the normal length of fallow between crop cycles is usually 5–6 mo but may be as short as 2 wk. Little benefit in disease control would be achieved through short fallowing treatments.

In conclusion, research reported in this paper clearly shows the differential effect of cultivars on changes in *P. chaunorhiza* inoculum density in the field. The disease could be controlled through the cropping of resistant cultivars. The glasshouse resistance screening technique has value for predicting the effect of cultivars on the epidemiology of the disease.

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