EFFECTS OF PACHYMETRA ROOT ROT AND NEMATODES ON SOME ELITE SUGARCANE CLONES IN AUSTRALIA

By

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Abstract

PACHYMETRA ROOT ROT and nematodes are the two most important soil-borne pathogens of sugarcane in Australia. An experiment was established in Yandaran, Queensland in grey forest soil with high *Pachymetra* spore counts (>100 000 spores/kg). Fifteen elite varieties and one advanced clone, from pachymetra root rot susceptible, intermediate and resistant categories, were planted in the experiment. The experiment was maintained until the second ratoon crop and *Pachymetra* and nematode populations were assessed in each crop. In addition, the incidence of smut was recorded before harvesting. Cane yield (TCH), commercial cane sugar (CCS) and sugar yield (TSH) were also measured in each crop. *Pachymetra* spore counts remained significantly lower in resistant varieties compared to susceptible and intermediate varieties until the second ratoon. In intermediate and susceptible varieties *Pachymetra* spore counts increased substantially, in particular, in second ratoon. In intermediate varieties such as Q232$^{\phi}$ and Q208$^{\phi}$ *Pachymetra* spore counts increased more than three times from plant crop to second ratoon. Numbers of nematodes, in particular root-lesion nematode, more than doubled in the second ratoon crop compared to the plant and first ratoon crops. Only Q248$^{\phi}$ had significant levels of smut, with 25% and 30% infected plants in the first and second ratoon crops, respectively. Yield reduction was substantial in the second ratoon compared to the plant and first-ratoon crop. Sugar yield decreased by 45% in the second ratoon compared to the first ratoon. Mostly, poor or negative correlations were observed between both *Pachymetra* spore counts and nematode numbers and yield.

Introduction

Pachymetra root rot, caused by *Pachymetra chaunorhiza*, is an important disease of sugarcane in Australia (Magarey and Bull, 2003). After infection through the primary roots, the pathogen produces a large number of oospores within the rotted roots, and these spores can survive in soil for at least 5 years (Magarey, 1986; Magarey and Mewing, 1994). After the incursion of sugarcane smut in Queensland in 2006, it was found that the most of the *Pachymetra*-resistant varieties were susceptible to smut. In some farms in the Southern cane-growing region, pachymetra root rot is becoming a major constraint on production. A survey conducted by Bundaberg Sugar Services (BSSL) in November 2010 found a high *Pachymetra* spore count (143 000 spores/kg of soil) at a farm at Yandaran near Bundaberg. Previously, the block was planted with Q155, a highly *Pachymetra*-susceptible variety.

Plant-parasitic nematodes are a significant contributing factor to yield decline in sugarcane, causing 5–20% yield loss/year in Australia (Stirling and Blair, 2000; Blair and Stirling, 2007). More than 20 species of plant parasitic nematodes can cause significant damage to sugarcane plants (Stirling and Blair, 2000), but the most important in Australia are root-lesion nematode (*Pratylenchus* spp.) and root-knot nematodes (*Meloidogyne* spp., but particularly *M. javanica*) (Blair and Stirling, 2007). These two nematodes are found in almost all sugarcane growing regions in Australia. There is limited information on the nematode resistance of varieties available to the Australian sugar industry.

The objectives of this study were to:

(i) determine the performance over 3 years of important commercial and advanced clones when planted in a poor sandy soil infested with *Pachymetra* and nematodes,

(ii) (ii) assess nematode numbers and determine whether there are varietal differences in supporting nematode populations.

This study also aimed to assess the incidence of smut infection in *Pachymetra*-resistant varieties that are moderately susceptible to smut under natural conditions during the trial period.

Materials and methods

The experiment was planted at South Littabella Road, Yandaran (24.38^{o} S and 152.07^{o} E) in August 2011, approximately 30 km north of Bundaberg, Queensland. The soil at the site was a sandy, grey forest soil. Fifteen commercial varieties and one advanced clone with varying resistance levels were included in the trial (Table 1). The fungicide Shirtan® (12% Hg as methoxy ethyl mercuric chloride, Crop Care Australasia) was applied (250 mL/200 L water) through a standard spray system attached to the planter during planting to control pineapple sett rot.

The experiment was planted using a whole-stalk planter in a randomised complete block design with five replications. Each plot comprised of four rows by 10 m with 1.5 m row spacing and a 2 m gap between adjacent plots.

Table 1—List of varieties/clones and their resistance categories for *Pachymetra* root rot and smut.

Clone	[1] Resistance category	
	Pachymetra root rot	Smut
KQ228$^{\Phi}$	I	R
Q138	R	S
Q151	IS	R
Q155	S	IR
Q171$^{\Phi}$	S	R
Q183$^{\Phi}$	R	I
Q188$^{\Phi}$	R	S
Q200$^{\Phi}$	I	R
Q208$^{\Phi}$	I	I
Q232$^{\Phi}$	I	R
Q238$^{\Phi}$	R	R
Q240$^{\Phi}$	I	R
Q242$^{\Phi}$	R	IR
Q245$^{\Phi}$	R	R
Q248$^{\Phi}$	IR	S
QS00-2319	IR	IR

[1] S= Susceptible, R resistant, I = Intermediate, IS = intermediate susceptible, IR= intermediate resistant

Harvesting and disease assessment

The plant crop was harvested in mid-September 2012, and the first- and second-ratoon crops were harvested in mid-August in 2013 and 2014, respectively. Smut incidence [(number of infection stool in plot/total number of stool in plot)*100] was determined prior to each harvest. *Pachymetra* and nematode numbers were assessed on soil samples collected from the plant and ratoon crops from individual plots after the harvest.

Two cores were taken in the centre two rows of each plot to a depth of 25 cm. Yield data were recorded as tonnes of sugarcane per hectare (TCH), commercial cane sugar (CCS) and tonnes of sugar per hectare (TSH).

Data analysis

SAS Mixed Model (SAS version 9.4, SAS Institute, Cary, NC) procedure was used to analyse the data. Nematode and *Pachymetra* numbers were log-transformed [log(nematode eggs or Pachymetra spore count+1)] prior to analyses.

Untransformed data were presented in the results to maintain uniformity. Pair-wise comparisons for the means were carried out using Fisher's protected least-significant-difference (*LSD*) test ($P<0.05$). *PROC CORR* of SAS was used to calculate correlations among *Pachymetra* spore counts, nematode counts and the yield components.

Results and discussion

Pachymetra

In the plant crop, the highest *Pachymetra* spore counts occurred in Q232$^{\Phi}$ followed by Q171$^{\Phi}$ and Q208$^{\Phi}$ (Table 2). The lowest spore counts were in two resistant varieties, Q245$^{\Phi}$ and Q242$^{\Phi}$. There was a general trend of lower spore counts in the resistant varieties compared to susceptible and intermediate varieties.

In the first-ratoon crop the average *Pachymetra* spore count for all varieties was 47 308 spores/kg of soil (Table 2). The overall spore counts decreased by 32% in first ratoon compared to those in the plant crop (70 000 spores/kg of soil).

The highest spore counts were in Q151 followed by Q155 and Q232$^{\Phi}$. The lowest spore counts were in the resistant variety Q242$^{\Phi}$, followed by Q245$^{\Phi}$ and Q188$^{\Phi}$. .

Pachymetra spore counts increased substantially in the second-ratoon crop, with mean spore counts over 100 000 spores/kg of soil (Table 2), an increase of 126% over the first ratoon.

Most of the susceptible and intermediate varieties had spore counts over 100 000 spores/kg. The highest spore counts were in Q232$^{\Phi}$, followed by Q208$^{\Phi}$ and Q151 (Table 2).

The lowest spore counts were in the resistant varieties Q242$^{\Phi}$, followed by Q245$^{\Phi}$, Q138, Q188$^{\Phi}$ and one intermediate resistant variety Q248$^{\Phi}$.

All resistant varieties reduced *Pachymetra* spore counts from the plant crop to the second ratoon. Very high spore counts were observed by the second ratoon in two intermediate varieties, Q232$^{\Phi}$ and Q208$^{\Phi}$.

These two varieties together cover approximately 46% of total sugarcane area cultivated in the Southern region. This result confirms the observations that intermediate varieties can build up high populations of *Pachymetra*, and that pachymetra root rot is an important industry issue because of the widespread planting of intermediate varieties.

This trial clearly shows that planting resistant varieties could significantly reduce *Pachymetra* spore numbers within 2–3 years. *Pachymetra* spores can survive and remain viable in soil for years (Croft and Magarey, 2000).

More emphasis should be given to rotating *Pachymetra*-resistant varieties with intermediate varieties to reduce spore levels. This highlights the need to place more emphasis on breeding more high yielding *Pachymetra*-resistant varieties.

Table 2—Number of *Pachymetra* spores measured in soil from plots of 16 clones in plant, first ratoon and second ratoon crops (2012–2014) at Yandaran, Queensland.

Clone	Spores/ kg of soil			[2] Resistance category
	[1] P	1R	2R	
Q232$^{\phi}$	127 959 a	68 564 ab	421 195 a	I
Q208$^{\phi}$	102 557 abc	51 079 bc	309 149 ab	I
Q151	68 821 abcd	116 582 a	247 968 abc	IS
Q155	88 670 abcd	74 053 ab	226 376 abc	S
Q171$^{\phi}$	120 063 ab	54 029 abc	143 344 bc	S
Q200$^{\phi}$	82 143 abcd	55 566 abc	118 924 bc	I
Q240$^{\phi}$	54 231 cd	29 617 cde	115 038 c	I
QS00-2319	69 161 abcd	43 159 bc	113 775 c	IR
KQ228$^{\phi}$	83 838 abcd	66 605 bc	106 936 c	I
Q138	64 287 bcd	43 906 bcd	24 915 d	R
Q183$^{\phi}$	59 439 bcd	35 369 cde	21 446 d	R
Q248$^{\phi}$	37 593 d	30 485 cde	25 510 d	IR
Q238$^{\phi}$	39 692 d	27 097 def	30 039 d	R
Q188$^{\phi}$	66 884 abcd	25 364 ef	25 238 d	R
Q245$^{\phi}$	28 990 d	23 607 def	15 266 d	R
Q242$^{\phi}$	34 017 d	11 838 f	12 243 d	R
Mean	70 522	47 308	122 335	

[1] P= plant crop, 1R = first ratoon crop, 2R = second ratoon crop.
[2] S = susceptible, I = Intermediate, R = resistant, IS = intermediate susceptible, IR = intermediate resistant
Values are means of spore counts of five replicates; means in columns followed by the same letter(s) are not significantly different using *LSD* test (*P<0.05*)

Nematodes

Numbers of nematodes increased substantially in the second ratoon compared to the plant and first ratoon (Tables 3 and 4). Significant numbers of four species of nematodes were detected in the trial site: root-lesion (RLN, *Pratylenchus zeae*), root-knot (RKN, *Meloidogyne javanica*), spiral (*Helicotylenchus dihystera*), and stubby-root (*Paratrichodorus minor*) nematodes (Tables 3 and 4).

Lesion and spiral nematodes were the species with the highest populations in the second ratoon crop, with an average over all plots of 1018 and 575 nematodes per 200 g of soil, respectively, followed by root knot (117) and stubby root (96).

Other nematodes present at low numbers included stunt (*Tylenchorynchus annulatus*), dagger (*Xiphinema* sp), ring (*Criconemella* sp) and reniform (*Rotylenchulus* sp) nematodes. *P. zeae* and *M. javanica* are the nematode species considered to be the most important in Australia and worldwide and can cause major damage to sugarcane crops (Blair *et al.,* 1999; Blair, 2005). *Helicotylenchus dihystera*, *Paratrichodorus minor*, *Criconemella* sp. and *Tylenchorhynchus annulatus* are commonly detected in Queensland but their effects on crop yield are unclear (Blair *et al*., 1999).

In the second ratoon, the highest number of RLN was detected in Q138, followed by Q242$^{\phi}$, Q188$^{\phi}$, and Q245$^{\phi}$ (Table 3). The lowest number of RLNs was observed in KQ228$^{\phi}$, followed by Q155, and Q151. Nevertheless, the numbers of RLN in all varieties are above the economic threshold levels of 200 nematodes per 200 g of soil.

The highest number of RKN was observed in Q242$^{\phi}$, followed by Q248$^{\phi}$ and Q200$^{\phi}$ (Table 3), at levels above the threshold level of 200 nematodes per 200 g of soil (Bull, 1979). Very low numbers of RKN were found under some varieties; the lowest count of RKN was observed in

Q238$^{\Phi}$ and Q245$^{\Phi}$), followed by Q183$^{\Phi}$ and Q232$^{\Phi}$. Previous research has found limited nematode resistance in varieties in Australia. A recent study found that Q245$^{\Phi}$ had some resistance to RKN (Croft *et al.,* 2015), which is supported by this field trial. Another field study in Bundaberg also confirmed this findings (Bruce Quinn, pers. comm.). Unfortunately Q245$^{\Phi}$ appears to be susceptible to RLN.

Blair and Stirling (2007) reported reduced nematode population in first ratoons compared to plant crops. In this experiment, we found lower populations of nematodes in the first ratoon compared to the plant crop, but the second ratoon had more than the plant and first ratoon. Cadet and Spaull (2005) also found ratoon crops as badly affected as plant crops in South Africa. The differences in nematode numbers may be related to seasonal effects and sampling time rather than crop age.

Table 3—Number of two major nematode species (per 200 g of soil) detected in soil from plots of 16 clones in plant, first ratoon and second ratoon crops (2012–2014) at Yandaran, Queensland.

Clone	*Pratylenchus zeae* (RLN)			*Meloidogyne javanica* (RKN)		
	[1] P	1R	2R	P	1R	2R
Q188$^{\Phi}$	697 a	513 a	1 553 a	91 ab	80 abc	22 cde
Q248$^{\Phi}$	308 cd	428 ab	1 396 a	142 ab	28 bcde	538 ab
Q238$^{\Phi}$	520 abc	366 ab	1 231 a	94 ab	11 de	3 e
Q242$^{\Phi}$	575 abc	351 ab	1 554 a	51 ab	26 bcde	654 a
Q138	415 abcd	332 ab	1 583 a	34 ab	19 bcde	6 de
Q200$^{\Phi}$	330 bcd	326 ab	688 bc	185 a	194 a	374 abc
Q240$^{\Phi}$	439 abcd	316 abc	1 211 a	72 ab	61 bcde	91 cde
Q183$^{\Phi}$	379 abcd	292 ab	1 041 ab	67 ab	9 cde	5 de
Q155	364 bcd	257 bcd	453 c	16 b	62 abcd	10 cde
Q208$^{\Phi}$	580 abc	247 abcd	973 ab	59 ab	33 bcde	14 cde
Q151	474 abc	229 bcd	559 c	16 b	25 bcde	82 cde
Q232$^{\Phi}$	176 d	224 bcde	651 bc	25 ab	27 cde	6 de
Q171$^{\Phi}$	594 ab	201 bcde	562 c	49 ab	6 e	17 de
QS00-2319	364 bcd	151 cde	1 030 ab	20 b	30 bcde	10 cde
Q245$^{\Phi}$	435 abcd	122 de	1 417 a	71 ab	4 e	5 de
KQ228$^{\Phi}$	394 abcd	119 e	393 c	168 a	54 ab	31 bcd
Mean	440	254	1 018	73	42	117

[1] P= plant crop, 1R = first ratoon crop, 2R = second ratoon crop.
Values are means of five replications; means in columns followed by the same letter(s) are not significantly different using LSD test (P<0.05)

There were high numbers of spiral nematodes (*H. dihystera*) (>300 to 1000 nematodes per 200 g of soil) in plant, first and second ratoons. The significance of this ectoparasitic nematode in sugarcane is poorly understood. Blair (2005) reported >6000 spiral nematodes are required to reduce sugarcane yield significantly.

There were significant negative correlations between spiral and RKN, and positive correlations between RKN and stubby nematodes (Table 5). Cadet and Spaull (2005) observed reduced numbers of other parasitic nematodes in the field when large of numbers of spiral nematodes were present.

Table 4—Numbers of spiral, stubby root and other nematode species (per 200 g of soil) detected in soil from plots of 16 clones in plant, first ratoon and second ratoon crops (2012–2014) at Yandaran, Queensland.

Clone	*Helicotylenchus dihystera* (Spiral)			*Paratrichodorus minor* (Stubby)			Others		
	P	1R	2R	P	1R	2R	P	1R	2R
Q188$^{\Phi}$	433	135 bcd	588 bcd	57 bc	9 abc	105 abc	0 b	3 abc	1 c
Q248$^{\Phi}$	395	74 de	335 def	89 bc	5 c	148 a	30 ab	2 bc	3 bc
Q238$^{\Phi}$	555	104 cde	408 cdef	66 bc	11 abc	67 bcd	13 b	3 abc	2 bc
Q242$^{\Phi}$	242	75 e	310 ef	154 ab	11 abc	114 abc	41 ab	4 abc	10 bc
Q138	360	131 bcd	310 f	76 bc	10 abc	61 bcd	50 ab	7 abc	14 bc
Q200$^{\Phi}$	391	167 abc	310 ef	67 bc	32 ab	103 abc	79 a	6 abc	19 ab
Q240$^{\Phi}$	433	139 bc	493 cde	50 c	11 abc	45 d	42 ab	3 abc	3 bc
Q183$^{\Phi}$	481	226 ab	994 a	92 bc	9 abc	67 cd	30 ab	8 ab	6 bc
Q155	543	238 ab	667 abc	65 bc	10 bc	42 d	16 b	8 ab	10 bc
Q208$^{\Phi}$	576	215 ab	857 abc	70 bc	6 abc	74 bcd	4 b	7 abc	10 bc
Q151	536	301 a	1013 a	180 a	15 abc	169 ab	0 b	3 abc	7 bc
Q232$^{\Phi}$	317	162 abc	642 abc	72 bc	14 abc	98 abcd	19 b	8 ab	20 ab
Q171$^{\Phi}$	580	222 abc	708 abc	50 c	15 abc	82 abcd	6 b	2 abc	10 bc
QS00-2319	346	143 bc	386 edef	80 bc	15 abc	174 a	1 b	7 abc	22 ab
Q245$^{\Phi}$	525	155 bcd	678 abc	94 bc	9 abc	67 cd	31 ab	2 abc	5 bc
KQ228$^{\Phi}$	321	156 bc	504 cde	41 c	25 a	120 abc	12 b	5 abc	27 a
Mean	440	165	504	81	13	96	23	5	11

[1] P= plant crop, 1R = first ratoon crop, 2R = second ratoon crop.
Values are means of five replication; means in columns followed by the same letter(s) are not significantly different using LSD test (P<0.05)

Table 5—Pearson correlation coefficients to compare numbers of major species of nematodes (per 200 g of soil).

	RKN	Spiral	Stubby
RLN	0.016	–0.16	0.06
P value	*0.8902*	*0.1648*	*0.5876*
RKN		–0.3	0.24
P value		*0.0071*	*0.0316*
Spiral			–0.21
P value			*0.056*

There was a highly significant negative correlation (*P<0.0001*) between Pachymetra spore counts and both RLN and total nematode numbers (Table 6). There was a highly significant (*P=0.003*) positive correlation between spiral nematode numbers and *Pachymetra* spore counts. The interaction of spiral nematode and *Pachymetra* is unknown. Spiral nematodes are considered to be minor ectoparasites that live outside of sugarcane roots, feed on the outer epidermis of the roots and are usually present in almost all sugarcane fields.

These parasites do not inflict yield loss unless present in very high numbers. It is possible that the wound created by the spiral nematodes on the root surface may act as an avenue for *Pachymetra* infection. The creation of entry points by nematodes for fungal root diseases is manifested in other crops. For example, *Fusarium acuminatum* enters into roots of wheat through the wound caused by lesion nematode, *Pratylenchus neglectus* (Taheri, 1996).

There was no significant correlation between *Pachymetra* spore counts and root knot and stubby root nematode numbers.

RLN is an endoparasite, lives within the root tissue and is the most abundant nematode in sugarcane soils. *Pachymetra* and RLN would compete for space and food source within root tissue. The competition between them may also be influenced by the root mass of the cane.

Cane severely affected by *Pachymetra* may provide less root mass for breeding of most of the nematodes. There has been significant research conducted to understand the interaction of nematodes and fungal pathogens in other crops.

Back *et al.* (2002) documented four mechanisms of synergistic interactions between pathogenic fungi and nematodes:

(i) utilisation of nematode-induced wound for fungal infection,

(ii) nematode induced physiological change that makes plants vulnerable to fungal pathogens or vice versa,

(iii) modification in rhizosphere environments due to nematode infection in roots attracts fungal pathogens,

(iv) reduction of host resistance due to nematode or fungal infection. No information is available on the mechanisms of interactions between the different nematode species and *Pachymetra* in sugarcane.

Previous research has shown that *Pythium* species can reduce infection from *Pachymetra* (Croft and Magarey, 1984).

Further research is required to understand the interaction of sugarcane root pathogens.

Table 6—Pearson correlation coefficients to compare *Pachymetra* spores counts (per kg), and nematode counts (per 200 g of soil).

Pachymetra spores	RLN	RKN	Spiral	Stubby	Total nematode
Correlation co-efficient (r)	–0.53	–0.09	0.32	–0.12	–0.36
P value	*<0.0001*	*0.4283*	*0.0034*	*0.2891*	*0.001*

Smut

No smut was found in any clone in the plant crop. Very low or no smut occurred in resistant varieties in the first and second ratoons. Very low incidence (<5%) of smut was found in most of the intermediate and susceptible varieties, except for Q248$^{\phi}$, which had 25% and 30% smut incidence in first and second ratoon crop, respectively (Table 7).

Smut levels did not increase significantly after the first ratoon in other clones. Infection of smut depends on environmental conditions, susceptibility of varieties and amount of inoculum present.

Previous research suggested that it can take one to two years for moderately susceptible and intermediate varieties to show smut disease symptoms if the planting material is disease-free (Bhuiyan *et al.,* 2010).

Since most growers now plant resistant or intermediate varieties, the amount of smut inoculum would be low compared to a few years back when susceptible varieties were prevalent. This may explain the slow development of smut in the susceptible and intermediate varieties. Q248$^{\phi}$ showed higher levels of smut in this trial which supports the decision not to release this variety in the Bundaberg/Isis region.

Q138 which is rated moderately susceptible only showed 4% smut incidence in second ratoon which suggests that smut should not be a significant issue in this variety under these conditions.

Table 7—Incidence of smut (%) in 16 clones from first ratoon and second ratoon crops (2012–2014) at Yandaran, Queensland.

Clone	1R	2R	Resistant category
Q248$^{\phi}$	24.6 a	30.1 a	S
QS00-2319	1.7 b	1.7 b	IR
Q138	1.7 b	4.1 b	S
Q188$^{\phi}$	0.7 b	1.3 b	S
Q155	0.7 b	0.7 b	IR
Q151	0 b	0.6 b	R
Q242$^{\phi}$	0 b	0 b	IR
Q245$^{\phi}$	0 b	3.3 b	R
Q238$^{\phi}$	0 b	0 b	R
Q240$^{\phi}$	0 b	0 b	R
Q183$^{\phi}$	0 b	0.7 b	IR
Q208$^{\phi}$	0 b	0 b	IR
Q171$^{\phi}$	0 b	0 b	R
Q200$^{\phi}$	0 b	0 b	R
KQ228$^{\phi}$	0 b	0 b	R
Q232$^{\phi}$	0 b	0.6 b	R

[1] 1R = first ratoon crop, 2R = second ratoon crop.
Values are means of five replications; means in columns followed by the same letter(s) are not significantly different using LSD test (P<0.05)

Yield

Substantial yield reductions were observed in all varieties in the second ratoon compared to plant and first ratoon crop (Table 8), with second-ratoon sugar yield approximately 45% lower than the first ratoon. Rainfall was significantly lower during the growth of the second ratoon crop, which severely affected yields on this sandy soil.

Table 8—Yield performance of 16 clones in plant, first ratoon and second ratoon crops (2012–2014) at Yandaran, Queensland.

Clone	TCH 1			CCS			TSH			Mean TSH (P+1R+2R)
	P	1R	2R	P	1R	2R	P	1R	2R	
Q248$^{\phi}$	99.5 ab	112.3 a	59.5 ab	15.9 bcde	16.9 ab	16.4b	15.8 ab	19.0 a	9.9 ab	14.9
Q238$^{\phi}$	103.9 a	111.2 ab	59.6 ab	15.5 efgh	16.0 d	15.3 ab	16.1 ab	17.7 ab	9.3 ab	14.4
Q242$^{\phi}$	97.7 ab	106.3 abc	54 ab	16.4 ab	16.5 abcd	15.8 ab	16.0 ab	17.6 ab	8.7 ab	14.1
Q183$^{\phi}$	96.8 ab	104.5 abcd	46 b	15.6 defg	16.1 cd	15.5 ab	15.1 ab	16.8 abc	7.2 ab	13.0
Q151	101.5 ab	101.6 abcd	54.5 ab	15.6 defg	16.0 d	15.9 ab	15.8 ab	16.2 bcd	8.8 ab	13.6
Q232$^{\phi}$	98.3 ab	101.5abcde	58.1 ab	15.3 fgh	16.6 abc	15.9 ab	15.1 ab	16.9 abc	9.4 ab	13.8
KQ228$^{\phi}$	94.1 ab	98.5 bcde	58.1 ab	16.2 bc	16.5 bcd	15.5 a	15.2 ab	16.2 bcd	9.1 ab	13.5
QS00-2319	99.1 ab	97.9 bcde	45.1 b	16.9 a	16.0 d	15.0 b	16.7 a	15.6 bcde	6.8 b	13.0
Q138	94.8 ab	96.5 cdef	67.2 a	15.3 fgh	17.1 a	15.8 ab	14.5 ab	16.6 bc	10.6 a	13.9
Q240$^{\phi}$	93.7 ab	94.8 cdefg	53.6 ab	15.7 cdef	16.8 ab	15.0 ab	14.7 ab	16.0 bcde	8.1 ab	12.9
Q200$^{\phi}$	92.4 ab	92.4 cdefg	62 ab	15.3 fgh	16.5 abcd	16.2 ab	14.1 bc	15.4 bcde	10.1 ab	13.2
Q208$^{\phi}$	87.1 bc	92.1defg	53.2 ab	16.1 bcd	16.9 ab	15.2 ab	14.1 bc	14.9 cde	8.0 ab	12.3
Q245$^{\phi}$	75.5 cd	91.1 defg	53.9 ab	14.9 h	16.9 ab	15.1 ab	11.2 d	15.3 bcde	8.3 ab	11.6
Q188$^{\phi}$	76.3 cd	88.1 efg	52.7 ab	15.0 gh	16.5 abcd	15.6 ab	11.5 d	14.6 cde	8.3 ab	11.5
Q171$^{\phi}$	76.3 cd	83.6 fg	57.5 ab	15.4 efgh	16.5 abcd	15.2 ab	11.7 cd	13.8 e	8.8 ab	11.4
Q155	62.0 d	82.8 g	61.1 ab	15.6 def	17.0 ab	16.6 ab	9.7 d	14.1 de	10.2ab	11.3
Mean	90.6	97.2	56.0	15.7	16.6	15.6	14.2	16.0	8.9	13.0

[1] P= plant crop, 1R = first ratoon crop, 2R = second ratoon crop. TCH = tonnes of cane per hectare, CCS = per cent of commercial cane sugar, TSH = tonnes of sugar per hectare.
Values are means of five replications; means followed by the same letter(s) are not significantly different using LSD test (P<0.05)

There were virtually no significant differences in cane yield (TCH), percent of commercial cane sugar (CCS) or sugar yield (TSH) among any of the varieties in the second ratoon. The average TSH for plant, first ratoon and second ratoon was the highest in Q248$^{\Phi}$ followed by Q238$^{\Phi}$, Q242$^{\Phi}$, and Q183$^{\Phi}$. The *Pachymetra*-susceptible varieties Q155 and Q171$^{\Phi}$ had the lowest average yields across the three crops.

In the second ratoon crop there were no significant correlations between yield components and *Pachymetra* and nematode counts except for a weak but significant positive correlation between *Pachymetra* spore count and CCS (Table 9).

Table 9—Pearson correlation coefficients to compare yield and *Pachymetra* spores counts (per kg) and total nematode counts (per 200 g of soil).

Yield	Pachymetra	[1] RLN	[2] RKN	Spiral	Stubby	other	Total nematode
TCH	0.14	–0.09	0.1	0.01	–0.07	–0.14	–0.13
P value	*0.2211*	*0.4059*	*0.3885*	*0.9467*	*0.518*	*0.2054*	*0.2548*
CCS	0.24	–0.12	0.21	0.04	0.02	–0.07	–0.05
P value	*0.0357*	*0.2956*	*0.0681*	*0.7056*	*0.8413*	*0.5267*	*0.6343*
TSH	0.17	–0.11	0.13	0.01	–0.05	–0.14	–0.12
P value	0.1349	0.3475	0.2229	0.9097	0.6421	0.2078	0.2857
[3] N	80	80	80	80	80	80	80

[1] RLN = Root lesion nematode, [2] RKN = root knot nematode, [3] N= number of observations.

Conclusions

Our work shows

(i) substantial increase of Pachymetra spore counts in most of the intermediate and the susceptible varieties, but relatively low *Pachymetra* spore counts in the resistant varieties,

(ii) very high nematodes numbers, in particular RLN, in all varieties, although there were some differences among varieties,

(iii) significant yield reduction in all varieties between the plant and the first ratoon compared to the second ratoon,

(iv) no significant differences in yield in the second ratoon crop – all yields were poor,

(v) no significant correlations among yield components and *Pachymetra* spores or nematodes numbers, and

(vi) only Q248$^{\Phi}$ had significant levels of smut with 30% of plants infected in second ratoon.

This trial has provided valuable information on the performance of varieties on the poorer sandy soils. Overall, the variety Q248$^{\Phi}$ was the best performer producing the highest TSH, although it had highest smut incidence.

This variety is intermediate to resistant for *Pachymetra*. Two *Pachymetra*-resistant varieties, Q238$^{\Phi}$ and Q242$^{\Phi}$ were ranked second and third in terms of overall TSH and Q138, another *Pachymetra*-resistant variety, was fourth.

These four varieties maintained relatively low *Pachymetra* spore counts. Q238$^{\Phi}$ and Q242$^{\Phi}$ would appear to be good smut intermediate to resistant varieties that are resistant to *Pachymetra* for planting in poor soils in the Bundaberg/Isis district.

There was no clear relationship between *Pachymetra* resistance and yield, although the two Pachymetra susceptible varieties had the lowest overall yield across the three crops. These are interesting results considering the large number spore counts under varieties such as Q232$^{\phi}$ and Q208$^{\phi}$. Magarey (1994) found a clear relationship between *Pachymetra* spore counts and yield in susceptible varieties such as Q90. These intermediate varieties may have some degree of tolerance to this pathogen. The *Pachymetra* susceptible and intermediate varieties had the highest *Pachymetra* spore counts. Although, there were significant differences in nematode counts for different varieties, all varieties had nematode counts higher than the economic threshold level (Bull, 1979; Blair, 2005).

The low incidence of smut in two of the moderately susceptible varieties, Q138 and Q188$^{\phi}$, in this experiment suggests that in this environment these moderately smut susceptible varieties could be grown with minimal yield losses.

One moderately smut susceptible variety, Q248$^{\phi}$, had higher incidence of smut. Any decision to grow moderately smut susceptible varieties would need to be managed and monitored to ensure smut does not increase and cause yield losses.

Soil is a very complex environment with many interactions between sugarcane plants and the many organisms in the soil. High *Pachymetra* and nematode counts would adversely affect the yield and ratoonability of any variety.

Interactions of nematodes and *Pachymetra* are poorly understood. More work needs to be done to understand this complex phenomenon. In future, more sugarcane will be grown in poor/marginal soils that are conducive to nematodes and *Pachymetra*.

More research needs to be done with more advanced clones and new varieties in marginal soils in different geographical locations to understand their performance. We believe this trial provided valuable information on the performance of a selection of the most important commercial varieties and some newer varieties on this soil type and the field reaction to *Pachymetra* and nematodes.

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