THE INCIDENCE OF PLANT-PARASITIC NEMATODES ON SUGARCANE IN QUEENSLAND, AND STUDIES ON PATHOGENICITY AND ASSOCIATED CROP LOSSES, WITH PARTICULAR EMPHASIS ON LESION NEMATODE (*PRATYLENCHUS ZEAE*)

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ABSTRACT

In Queensland, sugarcane has been cropped as a monoculture for 80 years or more in most districts. In the last 30 years, plough-out and replant (no fallow) has increased, as has reliance upon inorganic fertilisers, and intensive tillage to remove soil compaction. An associated decline in the productive capacity of the soil to grow sugarcane has been identified, and has been termed ‘yield decline’ (YD). Root health and sugarcane yields are increased after fallowing, crop rotation, and soil fumigants (Magarey and Croft 1995; Garside *et al*. 2001; Meyer and Van Antwerpen 2001), implicating root pathogens in YD. However, in the past, nematode studies have been confined to testing the economics of using nematicides.

It was the objective of this work to explore the association between plant-parasitic nematodes and sugarcane in Queensland. Firstly, this thesis examines the incidence of nematodes on field crops. The regional distribution of nematodes is reported, together with nematode populations and dynamics relating to (a) root habit, (b) root distribution across the row to inter-row profile, and (c) temporal changes during the crop cycle.

Secondly, this thesis explores the parasitism of Queensland sugarcane by nematodes, and role in YD. The importance of sett roots, nematodes, and general YD biota on early plant establishment from 0-100 days after planting is examined in field miniplots. Crop losses due to nematodes are assessed at 16 field sites using non-volatile nematicides, and the pathogenicity of *Pratylenchus zeae* is examined in glasshouse pots and field miniplots.

The lesion nematode (*P. zeae*) was found to be ubiquitous in sugarcane fields, and usually at higher densities than other species. The density of root-knot nematode (*Meloidogyne* spp.) was also high in sandy soils (<20% clay), but a high proportion of other soils also contained this nematode, albeit at lower densities. The ectoparasites, spiral nematode (*Helicotylenchus dihystera*), stubby-root nematode (*Paratrichodorus minor*) and stunt nematode (*Tylenchorhynchus annulatus*) were also detected in a high number of fields (>66%). Historically, the sugar industry has perceived nematode problems to be confined to very sandy soils in south

Queensland. However, plant-parasitic nematodes occur in all soils, suggesting a more widespread role in YD.

Within sugarcane fields, nematodes were distributed in aggregated patterns. Thus, densities of lesion nematode varied up to five-fold across short distances (1.4 m) even at a constant distance (20 cm) from the sugarcane stool. Ring and spiral nematode were more aggregated than lesion nematode, perhaps due to more sedentary feeding habits and greater sensitivity to edaphic gradients (eg. soil texture and moisture) across the field at the macro-distributional level. The 'negative binomial model' was used to predict the sampling effort required to estimate mean nematode densities with degrees of precision.

Mean nematode densities across the row, near row (20-30 cm from the stool), and inter-row were very similar during the crop cycle. Because high densities of nematodes were regularly recovered from 'near the row' this zone was recommended for standard sampling. During the crop cycle, nematode densities were related to the volume of the root system and its growth rate, as influenced by season. Because sugarcane develops a new root system annually, nematode densities increased and then declined each year. At planting, up to 400 lesion nematodes and up to 100 spiral nematodes/200 mL of soil were present, which was usually more than other pest species (<50 nematodes/200 mL of soil). Lesion nematode generally persisted at higher densities than other pest species during the crop cycle.

Lesion nematode was pathogenic to sugarcane in 1.5 L pots, reducing root weight and sometimes reducing shoot biomass. In 50 L pots, this nematode caused a general blackening of roots and reduced fine root length by over 50%. Shoot biomass was generally not reduced, suggesting that YD is induced by a combination of root pathogens.

At planting, prior studies have related poor primary tiller emergence to poor sett root growth in field soil (Cadet and Spaull 1985; Garside *et al.* 2002 a; Pankhurst *et al.* 2002). However, this study showed that buds can rely entirely upon the stem cutting to shoot and become established primary tillers. It was concluded that damaged buds, dormant buds, a poorly nurtured seed source, and poor sett root growth, all contribute to poor primary tiller establishment. Deleterious soil biota and nematodes also reduced the health and volume of shoot roots, which reduced the number of secondary tillers emerging at early establishment. While the experimental sites had a history of consistent fumigation responses (>80%), nematicide responses were quite variable (0-50%). Experiments in glasshouse pots confirmed that nematodes contribute in part to fumigation responses in YD soils.

To assess crop losses, nematodes were controlled for the entire crop cycle using non-volatile nematicides at 16 field sites. Fertile sandy loam to clay soils were chosen where losses from nematodes have only been speculated on previously. While poor tillering due to serious nematodes problems is well documented in sandy soils (<10% clay) in Queensland and around the world (Bull 1981; Spaull and Cadet 1990), stalk numbers were increased with nematicides only at some of the sites reported in this thesis. This contrast was attributed to the relatively low populations of root-knot nematodes (*Meloidogyne* spp.) at planting, and higher soil fertility. However, stalk length was significantly increased in nematicide-treated plots at most sites. Thus, responses in harvest yield of 0-20 T/ha were usually observed in both plant and ratoon crops. Untreated crop yields were average for the surrounding districts, as were nematode densities, suggesting the responses were robust across regions. Upon extrapolation, lost productivity from nematodes is estimated at over A$ 100 million annually. These results indicate that nematodes are a subtle but important pest, and contribute to YD on the sandy loam to clay soils on which 95% of Australia’s sugarcane is grown.

The environment and/or level of crop management influenced yield losses from nematodes, and nematicides responses were related to the control of a number of species, especially in ratoons. However, lesion nematode was correlated most consistently with reduced sugarcane yield. It was concluded that lesion nematode is the most important nematode pest of sugarcane in Queensland, and contributes to YD by reducing the health of primary and secondary roots, and by decreasing the length and number of fine roots.

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LIST OF ABBREVIATIONS

A	Australian
BSES	Bureau of Sugar Experiment Stations
CCS	commercial cane sucrose
DAP	days after planting
DAR	days of ratoon
DOF	days of fallow
EM	environmental factors and/or level of management
P_i	nematode density in the soil at planting
PVC	poly vinyl chloride
QDPI	Queensland Department of Primary Industries
®	registered trading name
SL	stalk length
SN	shoot or stalk numbers
YD	yield decline
UC	University of California
CEC	cation exchange capacity
EDB	ethylene dibromide
Ca	calcium
K	potassium
Mg	magnesium
P	phosphorus
a.i.	active ingredient
cv.	cultivar
dry wt.	oven dry weight
wt.	weight
eg.	for example
i.e.	specifically
n	number of sub-samples
no.	number of
pers comm.	unpublished personal communication
unpub.	unpublished observation by Blair

spp.	species
°C	degrees celcius
ha	hectares
T/ha	tonnes per hectare
ML	megalitres
mL	millilitres
m	metres
cm	centimetres
mm	millimetres
µm	micrometres
kg	kilograms
g	grams

ANOVA	analysis of variance
CV	coefficient of variation
E	standard error/mean ratio
F test	A test of data variance, estimating the probability that observations are random events (eg. $P<0.05$ = the probability that data sets are random is less than 5%).
LSD	least significant difference
ns	not significant at $P=0.05$
P	probability
R^2	coefficient of determination
s^2	sample variance
0	sample mean
x	sample mean in an equation
%	percent of
$<$	is less than
≤	equal to or lower than
$>$	is greater than
≅	is approximately equal to
≈	approximately
×	multiplied by