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Plant parasitic nematodes associated with six subtropical crops in New Zealand

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Abstract The plant parasitic nematode fauna was examined from the soil and roots of six subtropical crops. Six nematode species not previously reported in New Zealand were discovered: *Criconema annuliferum* (de Man, 1921) Micoletzky, 1925; *Crossonema civellae* (Steiner, 1949) Mehta & Raski, 1971; *Helicotylenchus paraplatyurus* Siddiqi, 1972; *Paratylenchus elachistus* Steiner, 1949; *Scutellonema brachyurus* (Steiner, 1949) Andrassy, 1958; and *Zygotylenchus guevarai* (Tobar Jimenez, 1963) Braun & Loof, 1966. Six pest:host relationships, not previously recorded in New Zealand, are proposed: *Pratylenchus crenatus* on the hosts *Passiflora edulis* and *Cyphomandra betaceae*, *Pratylenchus penetrans* and *Zygotylenchus guevarai* on *P. edulis*, *Tylenchulus semipenetrans* on *Diospyros kaki*, and *Meloidogyne hapla* on *Persea americana*.

Keywords nematode; avocado; kiwifruit; persimmon; feijoa; passionfruit; tamarillo

INTRODUCTION

Between September 1998 and June 1999 a national survey of plant pests and diseases was conducted on six subtropical fruit crops in New Zealand: avocado (*Persea americana* Mill.), feijoa (*Feijoa sellowiana* O. Berg.), kiwifruit (*Actinidia deliciosa* (A. Chev.) C.F. Liang et A.R. Fergusson), passionfruit (*Passiflora edulis* Sims.), persimmon (*Diospyros kaki* L.f.), and tamarillo (*Cyphomandra betacea* (Cav.) Sendtner). The objective of this survey was to provide an accurate record of the occurrence and distribution of plant pests and diseases associated with these crops including: those pests and diseases already known to occur in New Zealand in association with these hosts; new associations (pests and diseases known to occur in the country but not known in association with these hosts including new pest:host relationships); and plant pests and diseases not previously recorded in New Zealand. This paper reports the plant parasitic nematode component of that survey.

Before this survey, little work had been done on plant parasitic nematodes in subtropical crops in New Zealand. The root knot nematode, *Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949, had been implicated in reducing the productivity of tamarillo (Cooper & Grandison 1987) and *Meloidogyne hapla* Chitwood, 1949 had been acknowledged as a common parasite of kiwifruit (Sale 1985). Sale, however, reported little restriction of vigour or loss of crop production as a result of *M. hapla* parasitism on established kiwifruit vines unless they are suffering other stresses. During a 1 year study of kiwifruit, Watson et al. (1992) found *M. hapla* to be the only plant parasitic nematode consistently associated with kiwifruit roots.

MATERIALS AND METHODS

Sites

The survey covered the geographical range of the crops within the country, including domestic sites and all commercial production areas, in approximately the ratio of occurrence of these crops in these areas. For the purposes of both selecting the sites and tracking known and new distributions the system of Crosby et al. (1976) districts was used. In this system New Zealand is divided into 29

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approximately equally sized areas designated by two-letter codes. The districts where subtropical crops were sufficiently represented for survey were: AK (Auckland), BP (Bay of Plenty), CL (Coromandel), GB (Gisborne), HB (Hawke's Bay), MB (Marlborough), ND (Northland), NN (Nelson), TK (Taranaki), WI (Wanganui), WN (Wellington), and WO (Waikato).

Sampling

Samples consisted of a total of 2 litres of soil taken from at least 10 locations within a commercial crop, with a bias to areas in the crop showing reduced vigour, nutrient deficiency, or poor growth. In domestic sites, with fewer host plants, 0.5 litre of soil was collected. Samples were taken to a depth of 20 cm in the drip zone of the host. Roots were collected at all sites where they could be differentiated from the roots of neighbouring species. Areas, where the roots of weeds or other species may have been present, were avoided wherever possible. Where this was not possible the laboratory was alerted to the possibility that any nematodes present might be associated with nontarget hosts.

Extraction

The soil was thoroughly mixed. Nematodes were extracted from a 250–300 ml subsample using a modified Whitehead tray (Whitehead & Hemming 1965) for 48–72 h. The extract was then condensed

Table 1 Plant parasitic nematodes associated with avocado (*Persea americana*) in New Zealand, 1998–99.

	Number of sites surveyed (total = 95)							
	75	3	2	1	10	1	2	1
	Crosby et al. (1976) district							
Nematode	ND	AK	WO	CL	BP	GB	TK	NN
Triplonchida								
Paratrichodorus minor	13						2	
P. porosus	8				3			
Paratrichodorus sp.	1							
Dorylaimida								
Xiphinema diversicaudatum	1							
X. americanum	7				1			
Xiphinema sp.	1							
Longidorus elongatus							1	
Tylenchida								
Meloidogyne hapla†	11							
M. trifoliophila	1							
Meloidogyne sp.	2							
Heterodera sp.	1							
Pratylenchus crenatus	3‡							
Pratylenchus sp.	1				1			
Paratylenchus elachistus	9			1‡	1			
P. nanus	2‡							
P. projectus				1‡				
Tylenchulus semipenetrans						1		
Helicotylenchus dihystera	6‡							
H. labiatus	16‡		1	1‡	3		1‡	
*H. paraplatyurus**		1						
H. pseudorobustus	3						1	
Helicotylenchus sp.	9	1						
Rotylenchus uniformis	1‡							
*Scutellonema brachyurus**	2‡				1‡			

*Nematodes not previously recorded in New Zealand.
†Proposed new pest:host relationship.
‡Extension to known distribution.

to a 1 ml sample in a Baermann funnel type apparatus (Hooper 1986a). At the time that the nematodes in the samples were live and fresh a 5% subsample was heat killed and immediately examined under phase contrast with 10 or 40× objective. Initial identifications were made for later reference. The remaining 95% of the sample was heated to 60°C for 1 min and added to an equal volume of 6% formalin (37% formaldehyde). After a period of fixing in formalin of not less than 4 weeks the samples were examined under 50× binocular magnification, and any plant parasitic nematodes of interest were hand picked into cold lactophenol. The original "fresh" observations were used either to direct selection to include nematodes that could not be confidently identified under initial water mounts or to ignore those that had been identified already. The lactophenol was then heated to a temperature sufficient to cause it to give off visible vapour. Once cool, the nematodes were transferred to permanent mounts of glycerol and examined under high power interference contrast.

Root samples were washed in cold tap water and blotted dry before being finely chopped with clean scissors. No attempt was made to standardise the amount of roots used. Nematodes were extracted by placing the chopped roots into a single-ply paper tissue supported by a plastic mesh in an open ended funnel suspended over a glass boiling tube. These were placed in a Seinhorst mistifier chamber (5 s on : 4 min 55 s off mist cycle) for 48–72 h (Hooper 1986b). The funnel was not sealed onto the boiling tube so that excess water overflowed the tube allowing the nematodes to accumulate undisturbed in the bottom of the tube. The lower 5 ml of this extraction was transferred to a smaller tube where the nematodes could be condensed to a

Table 2 Plant parasitic nematodes associated with feijoa (*Feijoa sellowiana*) in New Zealand, 1998–99.

	Number of sites surveyed (total = 23)								
	5	5	1	1	3	1	3	4	
	Crosby et al. (1976) district								
Nematode	AK	WO	CL	BP	TK	WI	NN	MB	Source of association info.
Triplonchida									
Paratrichodorus minor	1	1			3		1		
P. porosus					1				
Dorylaimida									
Xiphinema diversicaudatum					1‡				
X. americanum		1			1				
Tylenchida									
Meloidogyne hapla	1				1			1‡	
Pratylenchus crenatus	1								
Pratylenchus penetrans					1‡			1	
Paratylenchus projectus	1								
Gracilacus straeleni							1‡		
Criconema californicum	1‡				1‡	1‡			
Mesocriconema sp.							1		
Ogma palmatum							1‡		
Hemicycliophora sp.	1								
Helicotylenchus dihystera	1‡								
H. labiatus			1		1	1	1		Yeates & Wouts (1992)
H. pseudorobustus	2								
H. varicaudatus							1		
Helicotylenchus sp.		1							
Rotylenchus uniformis						1‡	1‡		

‡Extension to known distribution.

Table 3 Plant parasitic nematodes associated with kiwifruit (*Actinidia deliciosa*) in New Zealand, 1998–99.

	Number of sites surveyed (total = 117)										
	5	12	7	2	63	1	3	1	1	22	
	Crosby et al. (1976) district										
Nematode	ND	AK	WO	CL	BP	GB	HB	WI	WN	NN	Source of association info.
Triplonchida											
Paratrichodorus minor	1				20		1			3	
P. porosus			2		4		1			1‡	
P. lobatus										1‡	
Paratrichodorus sp.										2	Watson et al. (1992)
Dorylaimida											
Xiphinema diversicaudatum										4	
X. americanum					2						
Longidorus elongatus					1					2	
Longidorus sp.					1						
Tylenchida											
Meloidogyne hapla	5	9	4	2	55	1	2	1	1	16	Dale (1971a)
Meloidogyne sp.					1					1	
Heterodera sp.					1						Watson et al. (1992)
Pratylenchus crenatus	1				2					2	
P. penetrans					4					1	
Pratylenchus sp.		1	2		1						Watson et al. (1992)
*Paratylenchus elachistus**			1‡		7‡					4‡	
P. nanus				1					3		
Paratylenchus sp.					4					1	Watson et al. (1992)
*Criconema annuliferum**										1‡	
Helicotylenchus dihystera					1‡						
H. labiatus	1				9					2	Yeates & Wouts (1992)
H. paraplatyurus			1		2‡					1‡	
H. pseudorobustus	1	1			3						
Rotylenchus uniformis		1								1	
Scutellonema brachyurus					2						

*Nematodes not previously recorded in New Zealand.
‡Extension to known distribution.

1 ml volume. From this point a procedure similar to that described for the soil samples was followed.

All nematodes species that yielded material suitable for identification were identified to species level. Where a new record (new pest:host relationship, new distribution, new to New Zealand) was suspected, the material was sent to a recognised expert for validation of the identification. All such material was placed in the NPPRL Nematode Collection as physical evidence of the new record, and the information was entered into the New Zealand Ministry of Agriculture and Forestry PPIN (Plant Pest Information Network) database. Where a nematode species was found in the presence of a subtropical subject but a pest:host relationship was not proven, a record was also made in PPIN, in compliance with the greater survey procedure. Validation of the nematode identification was not sought in these cases.

RESULTS AND DISCUSSION

The results of 319 investigations are shown in Tables 1–6. Where a nematode has previously been recorded in association with the specified host, reference to the original information source is provided. This does not necessarily indicate a pest:host relationship is proven. The original reference should be consulted to ensure the nematode:plant association is sufficiently established for the purposes of the reader. Other nematodes listed in these tables are considered to be new associations. If there is sufficient evidence (e.g., a combination of the following factors: high numbers of nematodes in the sample including gravid females and/or numerous juveniles; extraction from the roots; frequent occurrence with the host in weed free sites) new pest:host relationships are proposed. These are indicated in the Tables, as are extensions to

Table 4 Plant parasitic nematodes associated with passionfruit (*Passiflora edulis*) in New Zealand, 1998–99.

	Number of sites surveyed (total = 28)							
	3	9	1	4	8	2	1	
	Crosby et al. (1976) district							
Nematode	ND	AK	WO	BP	TK	WN	NN	Source of association info.
Triplonchida								
Paratrichodorus minor	2		1	3	2			Dale et al. (1972)
P. porosus	2							
Dorylaimida								
Xiphinema diversicaudatum	1			1				
Tylenchida								
Meloidogyne hapla		1			2	1		
M. trifoliophila	1							
Meloidogyne sp.	1			1				
Pratylenchus crenatus†		1	1	1	2‡			
P. penetrans†	1‡	1		2‡	4			
Pratylenchus sp.		1			2			
*Zygotylenchus guevarai**†					1‡			
Paratylenchus elachistus			1	1				
Ogma palmatum					1‡			
*Crossonema civellae**					1‡			
Tylenchulus semipenetrans	1							
Helicotylenchus dihystera	1			1	1‡			
H. labiatus	1	1		1	2			
H. paraplatyurus			1‡					
H. vulgaris		1‡						
Helicotylenchus sp.		2						
Rotylenchus uniformis				1‡	2‡			

*Nematodes not previously recorded in New Zealand.
†Proposed new pest : host relationship.
‡Extension to known distribution.

distributions and nematodes not previously known to occur in New Zealand.

Six nematodes not previously recorded in New Zealand were identified in this survey. They are: *Criconema annuliferum* (de Man, 1921) Micoletzky, 1925; *Crossonema civellae* (Steiner, 1949) Mehta & Raski, 1971; *Paratylenchus elachistus* Steiner, 1949; *Helicotylenchus paraplatyurus* Siddiqi, 1972; *Scutellonema brachyurus* (Steiner, 1949) Andrassy, 1958; and *Zygotylenchus guevarai* (Tobar Jimenez, 1963) Braun & Loof, 1966.

Two adult, female *C. annuliferum* (identification: Knight; validated: W. Wouts) were found in soil from one commercial kiwifruit crop in Appleby (NN) (Knight 2000).

A single specimen of *C. civellae* (identification: Knight; validated: W. Wouts) was extracted from soil from a commercial passionfruit crop on the outskirts of New Plymouth city (TK). No pest:host relationship is proposed for these Criconematids for the same reasons given for *P. elachistus* below.

Paratylenchus elachistus (identification: Knight; validated: E. Van den Berg) is here offered as the first record in New Zealand, although an earlier observation had been made in Auckland. The specific identity of the earlier find was only confirmed concurrently with this survey. The distribution of *P. elachistus* includes the Crosby et al. (1976) districts ND, AK, CL, WO, BP, NN, and was found associated with avocado, kiwifruit, and passionfruit. *P. elachistus* are ectoparasites that rarely produce significant disease in their plant hosts, consequently there is little information on their pest:host relationships. No attempt is made here to create such a record, since in all cases the nematodes were extracted from the soil, numbers were only moderate to low; and the possibility of feeding from the roots of other species in the area could not be excluded.

The spiral nematode, *H. paraplatyurus* (identification: Knight; validated: W. Wouts), has not previously been reported in New Zealand. It was found in 10 sites in this survey in six Crosby et al. (1976) districts (ND, AK, WO, BP, WN, NN), where it was associated with five of the six crops surveyed (avocado, kiwifruit, persimmon,

Table 5 Plant parasitic nematodes associated with persimmon (*Diospyros kaki*) in New Zealand, 1998–99.

	Number of sites surveyed (total = 27)					
	3	16	3	1	2	2
			Crosby et al. (1976) district			
Nematode	ND	AK	WO	BP	GB	HB
Triplonchida						
Paratrichodorus minor			1	1		
P. porosus		1				
Paratrichodorus sp.		1				
Dorylaimida						
Xiphinema diversicaudatum		1				
Tylenchida						
Meloidogyne hapla			2	1		
M. naasi		1‡				
Pratylenchus crenatus		3	1			
P. penetrans		1	1			
Paratylenchus projectus			1‡			
Tylenchulus semipenetrans†	1	3			1	
Helicotylenchus dihystera		1				
H. labiatus		1	1			
H. paraplatyurus		2‡				
H. pseudorobustus		2				
Scutellonema brachyurus		1‡				

†Proposed new pest host relationship.
‡Extension to known distribution.

passionfruit, and tamarillo). No pest:host relationship is proposed between this nematode and any of the crops surveyed. It is not charateristic of *Helicotylenchus* spp. to enter the roots to feed (Siddiqi 2000), therefore they cannot be extracted from root tissues, making it difficult to draw accurate conclusions about their feeding relationships with hosts. However, in at least half of the observations, the site of sampling was considered to be weed free.

Scutellonema brachyurus (*S. brachyurum*) (identification: Knight; validated: W. Wouts) is here offered as the first record of this nematode in New Zealand. Earlier observations of an unidentified species of *Scutellonema*, in cultivated orchard soils (Egunjobi 1968), may have been *S. brachyurus*. In this survey, *S. brachyurus* was found in the soil samples from avocado (ND and BP), kiwifruit (BP), and persimmon (AK). *S. brachyurus* is a known parasite of woody hosts (Siddiqi 1974) but has not previously been recorded in association with these crops. The low frequency of observations, presence in soil only, and the low numbers observed do not support the proposition that a pest:host relationship is proven with any of these crops.

Zygotylenchus guevarai (identification: Knight; validated: W. Wouts) was extracted in low numbers from the roots of passionfruit in New Plymouth (TK) (Knight 2000). It was not found in the soil samples of this orchard, including soil taken from under the infested vine. *Z. guevarai* is known to have a fairly broad host range (Siddiqi 1975), and although it has not previously been reported as parasitising passionfruit, it is likely that a feeding relationship does exist as the nematodes were found within the roots, but could not be detected in the soil. A new pest:host relationship is proposed for *Z. guevarai* and passionfruit.

Table 6 Plant parasitic nematodes associated with tamarillo (*Cyphomandra betacea*) in New Zealand, 1998–99.

	Number of sites surveyed (total = 29)									
	11	3	2	2	1	2	1	1	6	
	Crosby et al. (1976) district									
Nematode	ND	AK	WO	BP	GB	TK	WI	WN	NN	Source of association info.
Triplonchida										
Paratrichodorus minor		7	1	1						Dale (1971b)
P. porosus	1									Dale (1971b)
Dorylaimida										
Xiphinema diversicaudatum	1								1	Dale (1971b)
X. americanum		1		1‡						Knight et al. (1997)
Tylenchida										
Meloidogyne hapla	5	2	1	2			1		2	Dale (1972)
M. incognita										Sale (1984)
Meloidogyne sp.			1							
Pratylenchus crenatus†	1	1			1			1‡	2	
P. penetrans	1								1	
Pratylenchus sp.					2					
Paratylenchus elachistus	1‡	1‡								
P. nanus									1	
Paratylenchus sp.	1									
Helicotylenchus labiatus	1							1	2	
H. paraplatyurus	2‡									
H. pseudorobustus	1							1	1	
Helicotylenchus sp.									1	
Tylenchorhynchus sp.								2		

†Proposed pest:host relationship.
‡Extension to known distribution.

Five additional new probable pest:host relationships for New Zealand are proposed as a result of this survey.

The citrus nematode, *Tylenchulus semipenetrans* Cobb, 1913, was recovered from the soil in five out of 27 persimmon sites. High numbers in the roots of persimmon in one weed-free Kerikeri (ND) site is offered as proof of parasitism. Persimmons are a known host of *T. semipenetrans* in the United States (Nesbitt 1956).

The root lesion nematodes, *Pratylenchus crenatus* Loof, 1960 and *P. penetrans* (Cobb, 1917) Filipjev & Schuurmans Stekhoven, 1941, were found in five and eight of the 28 passionfruit sites examined, respectively. In the case of each nematode, large numbers were extracted from the root tissue and soil, where good weed control had been practised by the grower.

Pratylenchus crenatus was present in six out of 29 tamarillo sites, including 150 nematodes, mostly juveniles, extracted from the root tissues of one Whangarei (ND) sample.

Ten out of 95 avocado sites yielded *M. hapla*. Five of these sites were considered to be weed free. In one of the weed-free sites *M. hapla* females and egg masses were visible on the roots. In two other weed-free sites juveniles were extracted from the roots using mist extraction. The identity of *M. hapla* in avocado samples from this survey have been verified using PCR techniques (Marshall et al. 2001). It is probable that a pest:host relationship exists between *M. hapla* and avocado, although it does not seem to be a strong parasitic relationship, based on the low numbers observed at each site and the low frequency of positive sites.

In each of the new pest:host relationships proposed from observations in this survey, all were nematode species that form close physical associations with the host roots. In each case the nematodes were either fully contained within or partially embedded in the roots. In the cases of hoplolaimids (*Helicotylenchus*, *Scutellonema*, *Rotylenchus*), criconematids (*Criconema*, *Crossonema*, *Paratylenchus*, *Gracilacus*), longidorids (*Xiphinema*, *Longidorus*), and triplonchids (*Paratrichodorus*), which generally feed ectoparasitically, the observations even of repeated associations, in high numbers, cannot prove a pest:host relationship exists without further ecological study.

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