NEMATODES IN NEW ZEALAND FOREST NURSERIES

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ABSTRACT

A survey of nine nurseries (36 blocks) yielded no nematode populations at damaging levels. *Rotylenchus robustus* (de Man) Filipjev was recorded, as were total populations of root-feeding, fungal-feeding, bacterial-feeding, and omnivorous nematodes. Current management practices of rotation and tillage appear to be keeping populations of *Trichodorus, Rotylenchus, Pratylenchus*, and *Paratylenchus* spp. below levels at which they may cause economic damage.

Keywords: forest nurseries; cultivation; root-feeding nematodes; management; *Rotylenchus robustus*; *Pinus radiata*.

INTRODUCTION

Soil nematodes may produce economic loss in forest tree nurseries but there is no evidence of their pathogenicity to forest trees in plantations or natural stands (Ruehle 1973). While death of mature trees may follow infection with the *Bursaphelenchus* (pine wilt nematode) : *Ceratocystis* (fungus) complex through the vector *Monochamus* spp. (long horn beetle) (OEPP 1986), there is no evidence for soil transmission of *Bursaphelenchus* (Mamiya & Shoji 1989). Glasshouse and nursery studies have shown significant reduction in seedling growth caused by a range of root-feeding nematodes (Gowen 1971; Hijink 1969; Viglierchio & Maggenti 1975), and infestations in overseas nurseries have been surveyed (Boag 1978; Maeseneer 1964; Mamiya 1969; Mancini *et al.* 1981).

In New Zealand some 40 000 ha were planted with *Pinus radiata* D. Don in 1988 (Turland & Novis 1990). This paper reports an initial survey of soil nematodes in nine of the nurseries producing seedlings for such plantings.

MATERIALS AND METHODS

In each nursery, three to six blocks were sampled and both root and soil samples taken. The soil sample was composed of 10–20 cores, each 25 mm in diameter and 0–15 cm deep, taken at random from the block. Duplicate 200-g (field moist) samples were extracted by the tray method (Southey 1986) and total nematodes counted. After fixation with F.A.4:1, an average of 106 nematodes/block were mounted in glycerol (Southey 1986) and identified to genus. Root samples were composed of two seedlings from each block which were shaken gently to remove adhering soil. The roots were then stained for 3 min in boiling lactophenol cotton blue and differentiated in lactophenol (Southey 1986); 20 min were spent teasing and cutting these root systems under a stereomicroscope at ×25 magnification, and all nematodes found were identified to genus.

One nursery was sampled in April 1987, the other eight in June-July 1989. Site information is given in Table 1. The normal management regime for production of *P. radiata* seedlings involves: October planting of seeds in rows 12.5 cm apart, with eight rows along each bed, with superphosphate and potassium, calcium, magnesium fertilisers; foliar sprays or side-dressings of nitrogen, phosphorus, potassium, magnesium, and iron applied as necessary; spraying of fungicides and insecticides as required; wrenching and lateral pruning; undercutting at c. 8 cm depth in February/March. Machinery passes over the blocks and soil is disturbed at least monthly. Seedlings are transplanted to forests typically in May/September. After c. 6 years of seedling production a grass or grass/legume fallow is grown for c. 3 years, principally for maintenance of soil structure (Knight 1981; van Dorsser 1981).

TABLE 1–Location and characteristics of the nurseries sampled

Site Location	Trees grown	Soil type*	10-cm soil temperature† (°C)	Rainfall‡ (mm)	Lat. (°S)	Long. (°E)
1 Whakarewarewa	Forest trees	Yellow-brown pumice/ yellow-brown loam	12	1509	38°9'	176°16'
2 Ngongotaha	General nursery	Yellow-brown pumice/ yellow-brown loam	12	1790	38°4'	176°12'
3 Te Teko	Forest trees	Recent soil from volcanic ash	13	1586	38°2'	176°49'
4 Owhata	Forest trees (previously general nursery)	Yellow-brown pumice/ yellow-brown loam	12	1510	38°8'	176°18'
5 Athol	Forest trees	Yellow-brown pumice	11	1652	38°16'	175°52'
6 Bulls	Forest trees	Recent alluvial	13	905	40°11'	175°23'
7 Rangiora	Forest trees, ornamentals	Gley	10	697	43°19'	172°35'
8 Eyreton	Forest trees	Gley	10	697	43°25'	172°34'
9 Ashburton	General nursery	Recent alluvial	11	752	43°55'	171°44'

* NZ Soil Bureau 1968

† Mean annual value (N.Z. Meteorological Service 1984)

‡ Annual total (N.Z. Meteorological Service 1980)

Because of the limited nature of this initial survey, no statistical analysis has been carried out. Over-all trends in the data are discussed.

RESULTS

Nematode Populations in Soils

Soil populations of nematode genera recovered from the four sites at which both typical *P. radiata* seedling production and fallow blocks were sampled are given in Table 2. Total nematode abundance at each site was lower beneath *P. radiata* (average 707 nematodes/100 g) than in fallow blocks (4324 nematodes/100 g). The number of genera under the two treatments was similar on the two volcanic soils (18–21 genera), but on the gley soils the nematode fauna was more diverse under *P. radiata* (11.5 genera) than in fallow blocks (7.5 genera).

The root-feeding nematodes found under *P. radiata* (*Rotylenchus, Pratylenchus, Paratylenchus, Trichodorus*) could individually reduce seedling growth, either if the plant were subject to other stress or if the nematodes were sufficiently abundant. As *Rotylenchus* is uncommon in New Zealand and certain species may be of economic importance in conifer nurseries, the specific status of this material is discussed below.

The fungal-feeding genera (*Tylenchus, Ditylenchus, Aphelenchus, Aphelenchoides, Tylencholaimus, Diphtherophora*) were more abundant in the fallow blocks than in the *P. radiata* blocks. This could be attributed to hyphal abundance under grass and the ability of such nematodes to feed on root hairs as well as fungi. Although large numbers of *Tylenchus* (*Cephalenchus*) *emarginatus* may damage some seedlings, and some *Ditylenchus* spp. may be plant-pathogenic, their numbers in this study were negligible. *Tylencholaimus* and *Diphtherophora* have been found to comprise 50% of the 20 nematodes/100 g soil recovered from 50–80 cm soil depth in a mature *P. radiata* stand (unpubl. data).

Bacterial-feeding nematodes were the most diverse, being represented by 14 genera, four of which (*Acrobeles, Cervidellus, Teratocephalus, Chronogaster*) have delicate head structures and typically inhabit soils with open textures (Table 2).

Except for the site at Eyreton, the relatively large-sized omnivorous genera were more abundant in the fallow than in the disturbed *P. radiata* blocks.

Nematode populations for 32 sites and treatments are aggregated by feeding groups in Table 3. Under *P. radiata* seedlings with typical management, root-feeding nematodes averaged 14 nematodes/100 g soil, being most numerous at Te Teko (46 nematodes/100 g soil) and below the level of detection at five sites. Over the nine sites there were no consistent effects of growing P. radiata cuttings or seedlings into a second or third year on the abundance of root-feeding nematodes. At Owhata, Bulls, and Eyreton, where there were blocks of *P. radiata* seedlings growing under atypical production conditions, root-feeding nematodes were more abundant than under typical conditions. Populations below other tree species were similar to those under *P. radiata*.

Populations of fungal-feeding nematodes showed no consistent differences between tree species. This presumably reflects the importance of mycorrhizas as a food source.

Nematode Populations in Roots

Examination of stained roots for nematodes gave only two positive results from the 36 blocks with trees listed in Table 3. Both blocks at Bulls which represent the first year after a grass/clover fallow had a few root-lesion nematodes (*Pratylenchus*) within the *P. radiata*

TABLE 2–Populations of nematode genera per 100 g field-moist soil under typical *Pinus radiata* seedling production conditions and under green fallow; except for Rangiora where n = 1, *P. radiata* values are means of two blocks; for fallow n = 1 at all sites; – indicates genus not detected; + in *P. radiata* indicates genus not detected in typical *P. radiata* blocks but found in other blocks growing trees.

Genus*	Feeding group†	Whakarewarewa		Te Teko		Rangiora		Eyreton	
		P. radiata	Fallow	*P. radiata*	Fallow	*P. radiata*	Fallow	*P. radiata*	Fallow
Enoplia									
Enoplidae	B	1	142	–	–	–	–	–	–
Alaimus	B	11	107	11	–	68	–	–	–
Mononchus	O	3	54	24	257	+	–	20	54
Dorylaimus	O	–	–	–	343	–	–	–	–
Eudorylaimus	O	–	–	7	–	+	–	–	–
Aporcelaimus s.l.	O	5	268	140	343	68	115	225	126
Sectonema	O	–	18	3	86	–	–	+	–
Tylencholaimus	F	20	107	4	–	–	–	11	–
Diphtherophora	F	27	18	31	86	–	–	–	–
Trichodorus	R	17	–	14	429	–	–	–	–
Nygolaimus	O	+	–	–	–	–	–	3	–
Chromadoria									
Plectus	B	+	54	7	–	171	–	8	90
Chronogaster	B	6	178	14	–	34	–	–	–
Wilsonema	B	–	–	–	–	–	–	–	108
Chromadoridae	B	3	72	7	–	+	–	–	–
Monhysteridae	B	1	–	7	172	34	–	+	–
Rhabditia									
Rhabditidae	B	5	53	14	1372	516	2183	29	36
Cephalobus	B	93	357	88	257	274	115	19	–
Heterocephalobus	B	–	–	+	–	205	–	–	–
Acrobeles	B	–	–	7	429	–	–	–	–
Cervidellus	B	6	125	+	86	–	–	–	–
Panagrolaimus	B	–	160	–	600	+	3675	4	108
Teratocephalus	B	–	–	4	–	–	–	–	–
Diplogasteria									
Aphelenchina									
Aphelenchus	F	16	179	–	86	+	230	11	36
Aphelenchoides	F	87	–	11	–	68	115	5	–
Tylenchina									
Tylenchus s.l.	F	74	89	45	1542	137	–	16	36
Ditylenchus s.l.	F	–	–	3	–	+	–	–	–
Pratylenchus	R	–	89	–	86	–	–	+	–
Helicotylenchus	R	–	89	4	172	–	–	3	–
Rotylenchus	R	19	–	–	–	–	–	–	–
Heterodera	R	–	36	–	772	–	–	–	–
Meloidogyne	R	3	18	–	–	–	–	–	–
Paratylenchus	R	–	125	28	600	+	–	28	214
TOTAL		397	2338	473	7718	1575	6433	382	808

* Genera grouped by classification of Maggenti (1981)

† Dominant feeding habit of species encountered is denoted by R = obligate root feeder, F = facultative fungal feeder, B = bacterial feeder, O = omnivore (including predators).

TABLE 3–Abundance of nematodes by feeding groups per 100 g field-moist soil (Table 2 gives allocation of genera to feeding groups); for each nursery the first line refers to an annual crop of seedlings with typical cultivation, root-pruning, and fungicide sprays; only one bulk sample per treatment except where noted.

Nursery	Crop	Nematode feeding group				Total nema-todes
		Root feeding	Fungal feeding	Bacterial feeding	Omniv-orous	
Whakarewarewa	*P. radiata* seedlings (n = 2)	39	224	126	8	397
	P. radiata cuttings	3	232	73	25	333
	P. taeda seedlings	10	31	57	8	106
	Grass/clover fallow	357	393	1248	340	2338
Ngongotaha	*P. radiata* seedlings	–	231	644	82	957
	P. radiata cuttings	146	373	569	115	1203
	3 year *P. radiata*	102	169	610	238	1119
	2 year *Cryptomeria*	25	78	155	95	353
Te Teko	*P. radiata* seedlings (n = 2)	46	92	159	174	473
	P. radiata seedlings poor	39	97	170	39	445
	3 year *P. radiata*	–	171	362	85	618
	Ryegrass/clover fallow	2059	1714	2916	1029	7718
Owhata	*P. radiata* seedlings	–	204	1628	270	2102
	P. radiata seedlings —previously ornamentals	–	931	415	311	1657
	P. radiata seedlings (n = 3) —breaking area in	62	142	428	206	838
Athol	*P. radiata* seedlings (n = 3)	12	1206	1140	14	2132
	2 year *P. radiata*	28	469	639	128	1264
	Eucalyptus fastigata	–	226	328	82	636
Bulls	*P. radiata* seedlings	–	59	133	14	206
	P. radiata seedlings (n = 2) —first year after fallow	29	48	102	36	215
Rangiora	*P. radiata* seedlings	–	205	1302	68	1575
	Eucalyptus nitens seedlings	–	656	1427	327	2410
	Cupressus macrocarpa seedlings	20	36	65	52	173
	Pseudotsuga menziesii seedlings	–	71	63	10	144
	Mixed native tree seedlings	–	93	511	139	743
	Grass fallow	–	345	5973	115	6433
Eyreton	*P. radiata* seedlings (n = 2)	31	43	60	248	382
	P. radiata coated seeds	67	120	133	40	360
	Pseudotsuga menziesii seedlings	–	2	14	38	54
	Grass fallow	214	72	342	180	808
Ashburton	*P. radiata* seedlings (n = 2)	–	42	43	27	112
	2 year *P. radiata* (n = 2)	–	27	87	117	232

roots, but there was no necrosis, egg-laying, or mature specimens. These were also the only blocks to yield any *Pratylenchus* from amongst the mass of roots. As well, they were unique in that the soil contained the large dorylaimid *Pungentus maorium*, whose populations although widespread and abundant under pastures are very susceptible to cultivation (Yeates 1990). Genera such as *Tylenchus, Aphelenchoides, Rhabditis, Panagrolaimus, Cephalobus, Acrobeloides, Cervidellus, Acrobeles, Plectus*, and *Aporcelaimus* occurred amongst the roots at all sites except Whakarewarewa and Ngongotaha. In every *P. radiata* block roots appeared well infected with mycorrhizal fungi.

Morphometric Characterisation of *Rotylenchus robustus* (de Man, 1876) Filipjev, 1936 Nematoda : Tylenchoidea : Hoplolaimidae

Whakarewarewa

Females (n = 4): L = 1.57 (1.44–1.70) mm; a = 37.5 (34–41); b = 11.0 (10–11); b' = 7.5 (7–8); c = 72 (65–76); c' = 0.66 (0.57–0.76); V = 55 (54–57)%; stylet = 46 (41–50) μm; m = 51 (48–52)%; head annules = 6.0 (5–7); tail annules = 12.8 (12–14); midbody annule width = 1.9 (1.6–2.4) μm.

Males (n = 5): L = 1.31 (1.22–1.47) mm; a = 38.0 (36–41); b = 9.6 (8–12); b' = 7.0 (6.1–8.3); c = 37 (34–40); c' = 1.8 (1.8–1.9); stylet = 44 (43–46) μm; m = 55 (54–56)%; head annules = 7.3 (7–8); midbody annule width = 1.7 (1.5–1.9) μm; spicule chord = 37 (34–39) μm; gubernaculum = 20 (17–23) μm.

The material from under *P. radiata* conforms with the description of Siddiqi (1972) who summarised taxonomic and ecological information. The pathogenicity of *R. robustus* to conifer seedlings has been reported by Boag (1978) and Hijink (1969). Clark (1963) listed *Rotylenchus* as occurring in New Zealand, and Dale (1972) recorded *Fragaria* sp. as a host of *R. robustus*. *Rotylenchus robustus* has been reported from vegetables and herbaceous ornamentals in Victoria, Australia (Suatmadji 1988).

DISCUSSION

With the known effects of tillage on nematodes (Yeates 1990) and the known role of nematodes in enhancing the cycling of plant nutrients (Coleman *et al.* 1983) the abundance and diversity of the nematode fauna in the nursery blocks was as expected.

The maximum populations of root-feeding nematodes were compared with average values found in three other surveys of conifer nurseries (Table 4). While the occurrence of various genera is dependent on biogeographic, climatic, soil, and plant hygiene conditions, it is clear that the populations found in New Zealand are similar to those found in other studies. With most nematode infestations, secondary infections and physical or chemical stress on the host plant are common in yield loss situations.

The three root-feeding genera found in this survey have each been associated, in other studies, with depressed growth of conifers. Pot trials using 500 or 5000 *Trichodorus christiei* in 20-cm pots significantly reduced growth of *Pinus palustris* Miller, *P. taeda* L., and *P. elliottii* var. *elliottii* Engelm. (Ruehle 1969). In Australia *Pratylenchus penetrans* has been associated with major mortality of *Pinus radiata* seedlings and, as is characteristic of this endoparasitic nematode, while the population in soil was 4 nematodes/250 ml, diseased roots yielded over 8000 nematodes/10 g (Suatmadji & Marks 1983). After field trials in a sandy soil Hijink (1969) considered field populations of 2000 *Rotylenchus robustus*/100 ml soil to be of practical importance in retarding growth of *Picea abies* (L.) Karsten, and Boag (1978) reported that as few as 10 reduced the growth of *Picea sitchensis* (Bong.) Carr.

TABLE 4—Maximum populations of root-feeding nematodes (per 100 g soil) found under *P. radiata* seedlings in this survey, together with mean populations (per 100 ml soil) from three other surveys of conifer nurseries.

Nematode group	New Zealand	Belgium*	Italy†	Scotland‡
Longidoridae	–	–	7	10
Trichodorus s.l.	123	–	10	121
Pratylenchus spp.	130	100	21	–
Tylenchorhynchus s.l.	–	179	27	26
Rotylenchus robustus	30	390	–	88
Rotylenchus total	30	390	34	127
Paratylenchus spp.	55	–	7	–
Criconemoides s.l.	–	–	16	6

* Maeseneer 1964 Table 1
† Mancini *et al.* 1981 Table 2
‡ Boag 1978 Table 2

Under current management regimes root-feeding nematodes are not causing management problems in these New Zealand nurseries. The effect of the mycorrhizal flora of *P. radiata* (Chu-Chou 1979), green fallowing, and the significant mortality of nematodes at soil disturbance (Boag 1986; Spaull & Murphy 1983) are likely to be important factors in keeping populations low. Change in or reduction of the genetic diversity of planting material (Carson 1986) [Hancock (1988) has reviewed interactions between potato genotypes and nematodes of the genus *Globodera*] or change in cultivation practice could result in root-feeding nematodes exceeding the economic damage threshold. Knowledge of nematode biology would permit nonchemical solutions to such problems.

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