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Nematode vectors of plant viruses in New Zealand

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Abstract A survey of virus vector nematodes based on a total of 320 published and recent records revealed that 3 *Longidorus*, 1 *Paralongidorus*, 6 *Xiphinema*, 2 *Trichodorus*, and 3 *Paratrichodorus* species are present in New Zealand. *Xiphinema diversicaudatum* and *Paratrichodorus minor* are the most common and widespread species. *Longidorus orongorongensis*, an undescribed *Paralongidorus* species and *Trichodorus cottieri* appear to be endemic species, and *Longidorus taniwha*, *Paratrichodorus lobatus* and probably one (still unidentified) species of the *X. americanum* group are also indigenous to New Zealand. Most of the other species (e.g. *Longidorus elongatus*, *X. diversicaudatum*, and *Trichodorus primitivus*) were probably introduced from Europe. Maps showing the

distribution of the 15 species in New Zealand, and illustrations and tables of the morphological characters for species identification, are presented. Several species are of economic importance through direct damage they cause to cultivated plants, and all can be considered potential vectors of plant viruses.

Keywords Nematoda; virus vector; *Longidorus*; *Paralongidorus*; *Xiphinema*; *Trichodorus*; *Paratrichodorus*; New Zealand

INTRODUCTION

The discovery that species of Longidoridae and Trichodoridae are vectors of plant viruses (Hewitt et al. 1958; Sol et al. 1960) aroused great interest in these nematodes worldwide. The number of described species drastically increased from 25 Longidoridae (*Longidorus* and *Xiphinema*) and 15 *Trichodorus* species in 1960 to currently more than 400 Longidoridae (*Longidorus*, *Paralongidorus*, *Xiphinema*, *Xiphidorus*, *Paraxiphidorus*) and about 90 Trichodoridae (*Trichodorus*, *Paratrichodorus*, *Monotrichodorus*, *Allotrichodorus*). In particular, studies in individual countries in Europe contributed greatly to knowledge of the distribution of the species and their taxonomy and ecology (Alphey & Taylor 1986; Brown & Taylor 1987; Brown et al. 1990; Navas et al. 1990).

The earliest record of known or potential virus-transmitting nematodes from New Zealand is by Clark (1963a). Since then, several new *Longidorus* and *Trichodorus* species have been described (Clark 1963b, c; Yeates 1967) and new finds recorded (Dale 1971, 1972; Thomas & Procter 1972; Yeates 1973; Yeates & Prestidge 1986; Grandison 1991; Hay & Close 1992).

In this paper results are presented of a survey of longidorid and trichodorid species in New Zealand. Our own data, from material collected over many years in various parts of the country, were combined with data from various New Zealand collections and information published on species and species

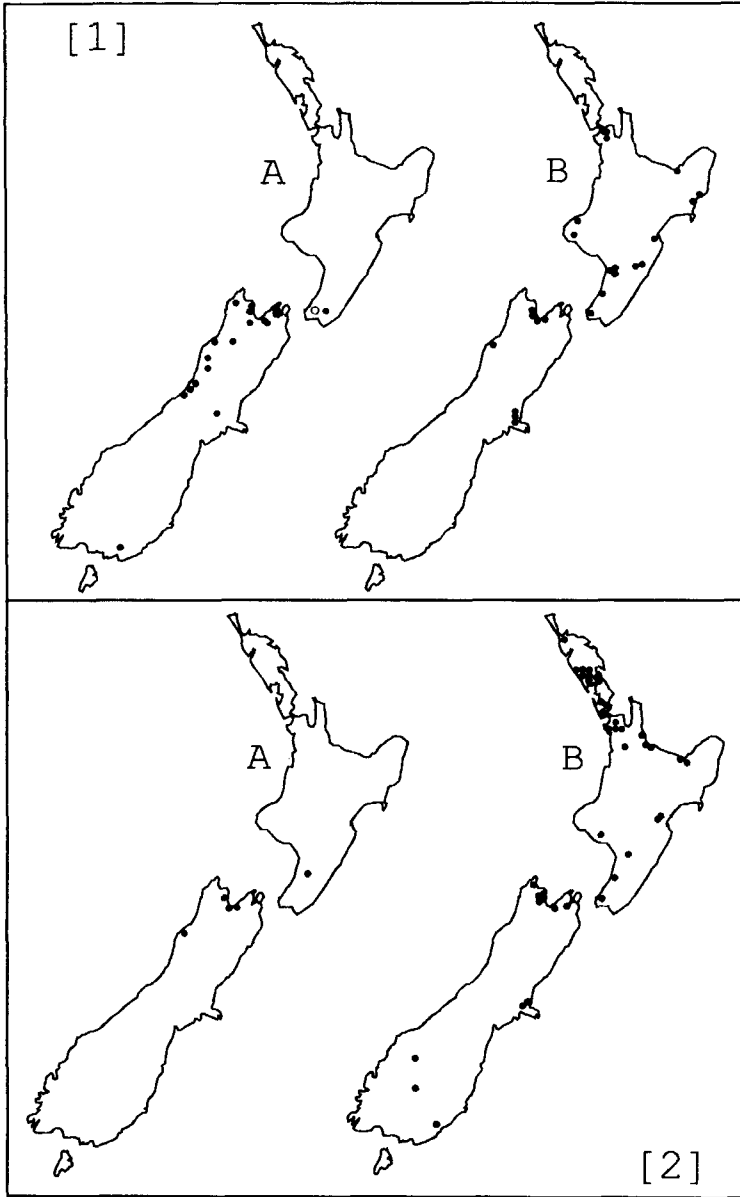


Fig. 1 Distribution of virus-transmitting nematode species in New Zealand: A, *L. taniwha* (●) and *L. orongorongensis* (○); B, *Longidorus elongatus*.

Fig. 2 Distribution of: A, *Paralongidorus* sp. (undescribed); B, *Xiphinema diversicaudatum*.

distribution. The only data considered was that based on identified species or species that could still be identified from preserved material. A total of 228 longidorid and 92 trichodorid records were available for the present survey. Maps showing the distribution of each observed species are presented and morphological characters important for species identification are given.

SPECIES RECORDED IN NEW ZEALAND, THEIR DISTRIBUTION AND DIAGNOSTIC CHARACTERS

LONGIDORIDAE

***Longidorus taniwha* Clark, 1963**

Clark (1963b) reported this species from three localities on the West Coast of the South Island. We have

found it in 37 additional samples from sites on the West Coast and in the Nelson district, the centre of the South Island, and Southland. There is only a single record from the North Island: Yeates et al. (1992) found *L. taniwha* in virgin forest at the type locality of *L. orongorongensis* east of Wellington (Fig. 1A). The species is generally present in native bush, in loamy soil or sandy loam; there is one record from wet pasture close to bush, and one from the rhizosphere of kowhai (*Sophora microphylla*) growing on the edge of a pasture along a river.

In South Australia, *L. taniwha* has been reported from seven localities, six of them in national parks, associated with a variety of plants but mostly *Eucalyptus* species (McLeod et al. 1994).

Records of this species from Egypt (Tarjan 1964; Oteifa & Tarjan 1965; Aboul-Eid 1970) and Israel (Cohn 1969) probably refer to other *Longidorus* species. Loof (1982) mentioned that *L. taniwha* from Egypt is probably *L. orientalis* Loof, 1982. We have observed that specimens from France identified as *L. taniwha* (Dalmaso 1969) are not identical with this species.

L. taniwha is thicker than the other longidorid species present in New Zealand and can be further differentiated by its odontostyle length, the position of the guiding ring, and the short and almost hemispherical tail, which is also broadly rounded in the juvenile stages (Table 1; see Fig. 5A, B, 6A). The lip region is generally less rounded than illustrated by Clark (1963b), and the variation in morphometrics is obviously greater than reported by Yeates & van Etteger (1991) and Robbins et al. (1995). Males appear to be absent in some populations.

Longidorus orongorongensis Yeates, van Etteger & Hooper, 1992

This species has been described from the Orongorongo Valley near Wellington, where it was found

in a conifer/broadleaved forest in silt loam at a depth of 60–80 cm (Fig. 1A).

L. orongorongensis resembles *L. taniwha* in most morphological characters, such as shape of cephalic region and tail and position of the guide ring (see Fig. 5C, 6B), but can be distinguished by its longer body and odontostyle and higher “a” ratio (Table 1). In this species, too, the tail is broadly rounded in all juvenile stages.

Longidorus elongatus (de Man, 1876) Thorne & Swanger, 1936

Dale (1971) reported this species from strawberries at Levin and from soil around peach and apple trees at Havelock North and Auckland. Yeates (1973) reported it from lucerne near Mt Taranaki. Our 28 more recent records are from pasture, bowling turf, cultivated plants such as tobacco, strawberries and various flowers, and from *Salix* sp. Most records are from sites in the North Island; in the South Island it was found in the Nelson district, at Westport, and in the Christchurch area (Fig. 1B).

Longidorus elongatus is widespread in Europe and is also present in North America and South Africa (Hooper 1973). It is reported from a single location in South Australia (McLeod et al. 1994) and has also been reported from Thailand, India, and Pakistan.

Morphological characters differentiating *L. elongatus* from the other *Longidorus* and *Paralongidorus* species present in New Zealand are the almost truncate cephalic region, which is continuous with or only slightly set off from the neck contour, and the bluntly conoid tail (Table 1; see Fig. 5D, 6C). In the four juvenile stages the tail is more slender than in the females.

Paralongidorus sp.

A *Paralongidorus* species was found in nine samples

Table 1 Diagnostic characters of New Zealand *Longidorus* and *Paralongidorus* species.

Species	Females			a	Males
	Odontostyle (µm)	Guide ring (µm)	Length (mm)		
<i>L. orongorongensis</i> ¹	152–166	63–73	6.0–8.0	81–127	present
<i>L. taniwha</i> ²	106–122	56–66	3.2–5.0	46–65	present in most populations
<i>L. elongatus</i> ³	72–102	29–36	4.5–6.4	76–123	absent in most populations
<i>P. sp.</i> (undescribed) ⁴	92–100	34–38	5.9–8.1	114–148	unknown

Measurements after: ¹Yeates et al. (1992); ²Clark (1963b), Yeates & van Etteger (1991), and Robbins et al. (1995); ³Hooper (1973); ⁴original.

from locations in northern and western regions of the South Island and at Woodville near Palmerston North in the North Island, mostly in native bush (Fig. 2A). This species is different from the three species of the genus recorded from Australia and the Pacific islands (Orton Williams 1980; Bridge 1988; McLeod et al. 1994) and is new to science. At three sites the species occurred together with *Longidorus taniwha*.

The New Zealand *Paralongidorus* is long and slender and has a broad, conoid tail with a broadly rounded terminus. The lip region set off by an incisure, and the wide, slit-like amphidial openings, are characteristics of the genus (Table 1, see Fig. 5E, F, 6D).

***Xiphinema diversicaudatum* (Micoletzky, 1927) Thorne, 1939**

In the first record of this species for New Zealand, Dale (1971) reported it from Te Puke and Riverhead. *X. diversicaudatum* is the virus vector nematode most frequently recorded in New Zealand (99 records available). The species is widely distributed in the North Island. In the South Island it is common in the Nelson and Marlborough area and in Christchurch, and is present around Wanaka and Alexandra in the south (Fig. 2B). It occurs almost exclusively in cultivated soils, where it has been found associated with roses, carnations, and other flowers, *Rubus ursinus*, *Thuja* and other ornamentals, strawberries, vegetables and in hop gardens, and in the rhizosphere of apple, apricot, olive, tamarillo and *Citrus* trees. It is also common in turf and *Cotula* soil from bowling greens.

Xiphinema diversicaudatum is widespread in Europe, and has also been recorded from other temperate regions of the world, including Victoria, Australia (McLeod et al. 1994).

Xiphinema diversicaudatum can be differentiated from the other New Zealand *Xiphinema* species by its body size, the ventrally located terminal tail peg (see Fig. 7A, peg rarely absent), and males being common. The morphometrics of a *X. diversicaudatum* population from Alexandra, studied by Brown & Topham (1985), were well within the range of variation for this species, and females of this population interbred with males from a Scottish population (Brown 1986).

***Xiphinema radiculicola* Goodey, 1936**

Xiphinema specimens identified as *X. radiculicola* (= *X. australiae* McLeod & Khair, 1971) were collected from *Cotula* bowling green soil at Motueka, Nelson district, in July 1978 and again in January 1996 (Fig. 3A).

Xiphinema radiculicola is a tropical species which is known from several countries in central Africa and southern and south-east Asia (Luc 1981). In Australia it is the most commonly recorded *Xiphinema* species (McLeod et al. 1994). It has not been observed elsewhere in the South Pacific (Bridge 1988).

The conical and mostly slightly digitate tail (see Fig. 7B), anterior position of the vulva, and absence of an anterior genital tract are characters easily differentiating *X. radiculicola* from the other *Xiphinema* species known from New Zealand (Table 2).

***Xiphinema krugi* Lordello, 1955**

This species appears to have limited distribution in New Zealand. It has been found only in samples from *Cotula* bowling greens at Auckland and Otorohanga and around New Zealand flax (*Phormium tenax*) in the South Island, near Nelson (Fig. 3A).

Xiphinema krugi (= *X. denoudenii* Loof & Maas, 1972, *X. loosi* Southey & Luc, 1974) is known only from warmer countries of the world, Australia (New South Wales), Fiji, Samoa, and Norfolk Island (Orton Williams 1980; Bridge 1988; McLeod et al. 1994). It can be differentiated from the other species of the genus present in New Zealand mainly by the anterior position of the vulva, the shape of the tail, and the length of the body and odontostyle (Table 2; see Fig. 7C).

***Xiphinema americanum* group**

Dale (1971) reported *X. americanum* from grapes at Henderson, Auckland. Subsequently it has been found associated with various cultivated plants and turf at different sites (C. J. Barber in Dale 1971). *X. americanum* is considered to be a complex of more than 50 species, many of them difficult to identify, and several of uncertain taxonomic status. Therefore, the identity of Dale's *X. "americanum"* is uncertain. Members of this group are mainly characterised by a small body, a vulva position between 50 and 60%, a short tail, and bacteria-like inclusions in the genital tract. In our survey of material in the National Nematode Collection of New Zealand, the collection of the N.Z. Plant Protection Centre – Lynfield, and a recent collection, the following three species of the *X. americanum* group were identified.

Xiphinema species "a"

This species appears to be identical with *X. americanum* Cobb, 1913 *sensu stricto* as redescribed by Lamberti & Golden (1984). It was found in 12 samples from the North Island: in soil from boysenberry in Auckland, from *Cotula* bowling greens in Auckland, Tauranga, Rotorua and Katikati,

Fig. 3 Distribution of: A, *Xiphinema krugi* (●) and *X. radicolica* (○); B–D, species of the *X. americanum* group: B, *Xiphinema* sp. “a”; C, *Xiphinema* sp. “b”; D, *Xiphinema* sp. “c”.

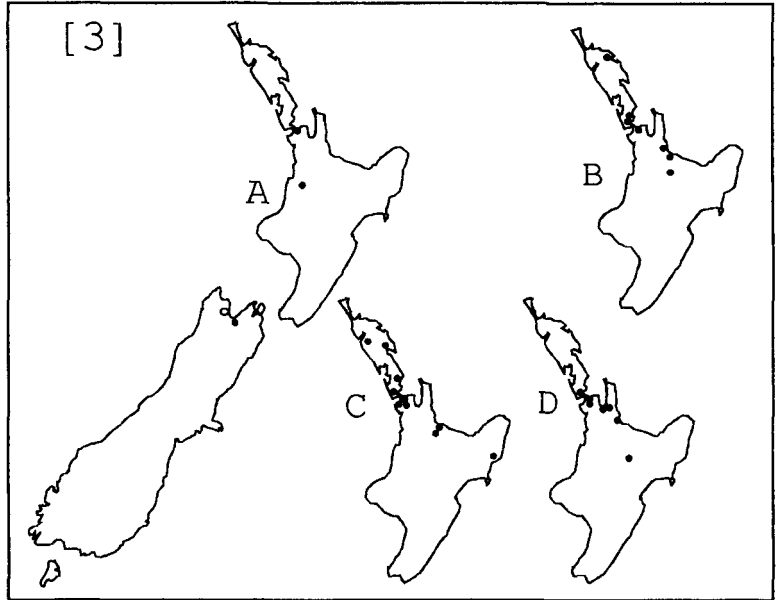
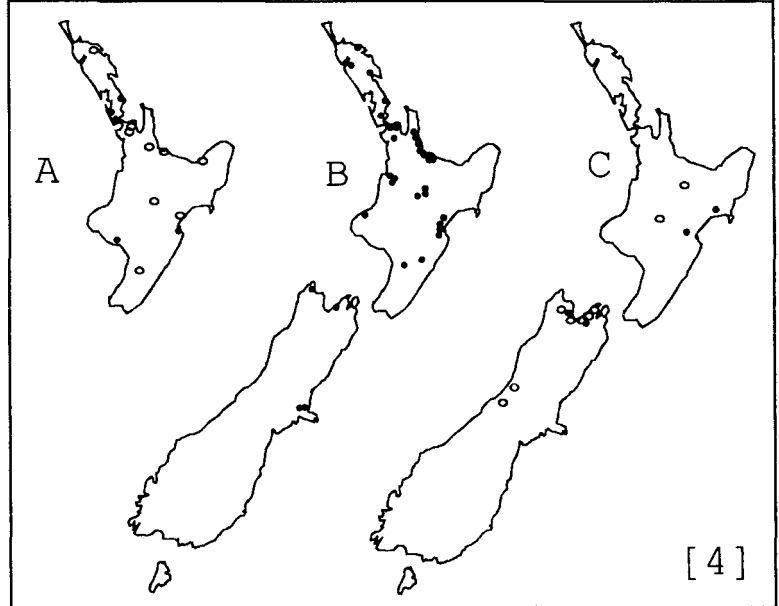


Fig. 4 Distribution of: A, *Paratrichodorus lobatus* (●) and *P. porosus* (○); B, *Paratrichodorus minor*; C, *Trichodorus cottiieri* (○) and *T. primitivus* (●).



from peach at Albany, and from *Citrus* and tamarillo at Kerikeri (Fig. 3B).

Xiphinema species “a” can be distinguished from the other New Zealand species of the *X. americanum* group by its short odontostyle and the more or less slender conoid tail, which is generally ventrally curved (Table 2; see Fig. 7D). Males were present in some of the samples.

Xiphinema species “b”

This species, which is in morphological characters

close to *X. brevicolle* Lordello & Da Costa, 1961, was present in 10 samples from Auckland, Waiuku, Tauranga, Opononi, Whangarei, Albany, and Gisborne (Fig. 3C). In Opononi/Northland it was found under grass at the coast and at Waiuku in a bowling green; at the other sites it was always associated with woody plants (grape, *Citrus*, *Poncirus trifoliata*, peach, walnut, *Araucaria* sp.). Among the slides examined were two with specimens ex grapes from Penfold’s Wines, Henderson, Auckland, collected 24 July 1968 and 25 March 1971. We believe

that these are the *X. "americanum"* specimens reported by Dale (1971).

Diagnostic characters of this small, rather thick species are given in Table 2. The tail is short and bluntly conoid (see Fig. 7E).

Xiphinema species "c"

This species, which appears to be new to science, was present in 10 samples. It was found under trees at One Tree Hill, Auckland, and under *Dicksonia squarrosa* at Titirangi Beach, Auckland, under trees at the Manukau Heads, in tamarillo soil at Tauranga, and in native bush at three sites on the Coromandel Peninsula and in the Kaingaroa Forest (Fig. 3D). An additional record is from *Meliccytus ramiflorus* from Raoul Island.

This rather slender species has the longest body and odontostyle of the New Zealand species of the *X. americanum* group (Table 2). The tail is broadly conoid (see Fig. 7F); a few males were also found.

From the South Pacific islands six species of the *X. americanum* group have been recorded: *X. americanum*, *X. brevicolle*, *X. pachtaicum*, *X. pseudoguirani*, *X. opisthohystrum*, and *X. rivesi* (Bridge 1988). The first three are present also in Australia (McLeod et al. 1994). For most of these records the species identity requires confirmation. Likewise, a detailed comparative study is required for species identification of the New Zealand *X. "americanum"* populations.

Xiphinema sp.

A member of the *X. americanum* group resembling *X. species "c"* from New Zealand but distinguished by a longer stylet and greater distance of the guide ring from the anterior end, and differing from all six species of the *X. americanum* group recorded from the South Pacific islands so far, we isolated from the

rhizosphere of a coconut tree on Manihiki Island, Cook Islands.

In a soil sample from a shipment of taro (*Colocasia esculenta*) from Western Samoa, intercepted at the port of Wellington, we found *X. ensiculiferum* (Cobb, 1893) Thorne, 1937. This appears to be the most widely distributed *Xiphinema* species in the South Pacific (Bridge 1988). It has been observed by us in samples from several sites in the Cook Islands and the Solomon Islands.

TRICHODORIDAE

Trichodorus cottieri Clark, 1963

This species was described from regenerating shrubland between Awatuna and Stafford, Westland (Clark 1963a). It was found by us in Hokitika, Westland, and at Brooklyn, Ngatimoti, Wai-iti, Rai Saddle, and Tennyson Inlet, Nelson. There are only two records from the North Island: Kaingaroa Forest and near Whakapapa, Mt Ruapehu (Fig. 4C). The specimens were found in the rhizosphere of *Carpodetus serratus*, *Nothofagus menziesii*, *N. solandri*, *Myrsine* sp., *Olearia* sp., grasses, and other vegetation in native bush or forests.

The only record of this species outside New Zealand is from Florida (Esser 1993). This identification requires confirmation.

Morphological characters of diagnostic significance are given in Table 3. The vagina is almost cylindrical and the vaginal sclerotisations in lateral view are rather large, more or less rectangular, and parallel to the longitudinal body axis (Fig. 8A). The body of adult specimens is rather long (700–1010 µm), the oesophageal bulb is set off from the intestine, and males have only one cervical pore anterior to the excretory pore.

Table 2 Diagnostic characters of New Zealand *Xiphinema* species.

Species	Females		Males		
	Odontostyle (µm)	Length (mm)	Vulva	a	
<i>X. diversicaudatum</i> ¹	130–157	4.0–5.5	39–48	57–92	common
<i>X. radiccicola</i> ²	100–152	1.6–3.0	25–33	36–72	very rare
<i>X. krugi</i> ³	102–125	1.8–2.6	32–36	35–50	very rare
<i>X. "americanum"</i> sp. c ⁴	115–129	2.4–3.0	51–55	49–61	rare
<i>X. "americanum"</i> sp. b ⁴	84–100	1.5–2.0	51–54	31–46	unknown
<i>X. "americanum"</i> sp. a ⁴	74–82	1.5–1.7	50–53	45–49	present

Measurements after: ¹Pitcher et al. (1974); ²Luc (1981); ³Frederick & Tarjan (1974); ⁴original.

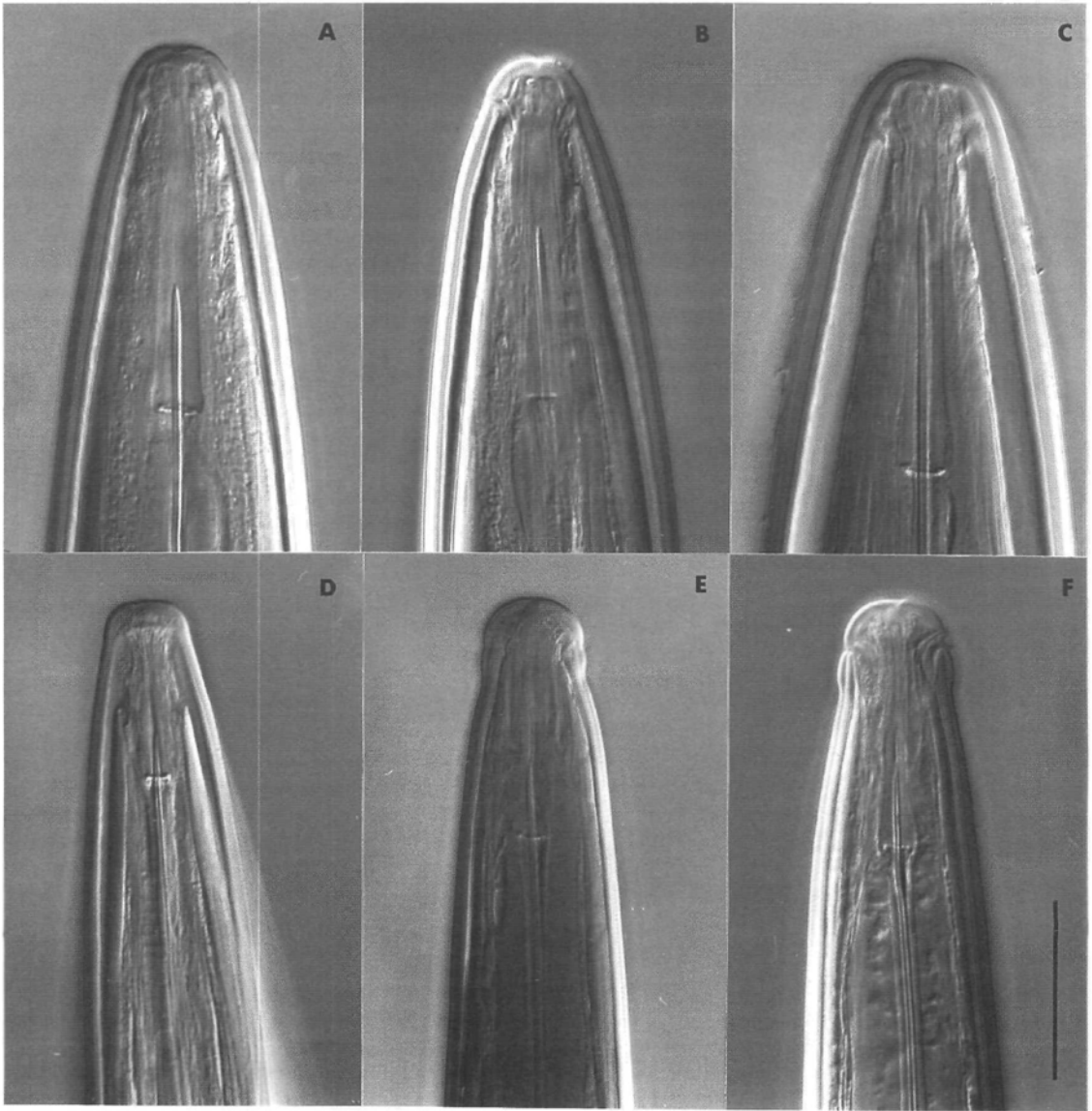


Fig. 5 Anterior end of: **A, B**, *Longidorus taniwha*; **C**, *L. orongorongensis*; **D**, *L. elongatus*; **E, F**, *Paralongidorus* sp. (undescribed) in lateral and dorsoventral view. Scale bar: 30 μ m.

***Trichodorus primitivus* (de Man, 1880)
Micoletzky, 1922**

This species was recorded from New Zealand for the first time by Decraemer (1995). It was found by us in the North Island under grass on a river bank near Napier and under cabbage at Gisborne, and in the South Island in the Nelson area in samples from around the roots of *Myoporum laetum*, *Ginkgo biloba* (in arboretum), celery (*Apium graveolens*), and New Zealand flax (*Phormium tenax*) (Fig. 4C).

Trichodorus primitivus is common in the cool temperate regions of Europe and is occasionally reported from the United States.

The species is easily identified by its rod-shaped vaginal sclerotisations parallel to the vaginal lumen (Fig. 8B) and the characters listed in Table 3. The oesophageal bulb is set off from the intestine. The distal part of the spicule is very slender. As in other *Trichodorus* species, the cuticle generally does not swell upon fixation.

***Paratrichodorus minor* (Colbran, 1956) Siddiqi, 1974**

This is the most common trichodoridae species of New Zealand (present in 57 records). Dale (1971) recorded it as *Trichodorus christiei* from Kerikeri, Auckland, Te Puke, and Turangi. It has since been identified from many other places in the North Island and a few sites in the Nelson and Christchurch areas of the South Island (Fig. 4B). The species was found associated with apple, peach, tamarillo, tangelo, grapefruit, *Citrus*, kiwifruit, passionfruit, grape, silver beet, lucerne, tobacco, lily, *Rhododendron* and other cultivated plants, New Zealand flax, *Cotula* sp. and grasses in bowling greens, and in pastures and in sandy soil along a river bank.

Paratrichodorus minor is a cosmopolitan species which has been recorded mainly from warmer regions; it is widespread, for example, in the United States and South Africa, common in Australia, and has been reported also from Fiji and New Guinea (Bridge 1988; McLeod et al. 1994).

The species is characterised mainly by its short onchiostyle and small body (440–700 µm), the excretory pore located close to the pharyngo-intestinal junction, the oesophageal glands mostly overlapping the intestine, absence of body pores, and the shape of the vaginal sclerotisations (rod-shaped in lateral view and parallel to body axis) (Table 3; Fig. 8C). Males have not been found among the New Zealand material.

***Paratrichodorus porosus* (Allen, 1957) Siddiqi, 1974**

Dale (1971) recorded this species from soil around roots of tamarillo and *Citrus* at Kerikeri. It was found by us in 12 samples from under various trees, including *Cyphomandra betacea*, apple and *Citrus* at One Tree Hill (Auckland), Opotiki, Kerikeri, New Ply-

mouth and Waitahanui (Lake Taupo), around grapes in Hawke's Bay, and in soil from bowling turf at Waiuku, Matamata, Tauranga and Palmerston North. So far, all records are from the North Island (Fig. 4A).

Paratrichodorus porosus is widespread in Australia, Japan, South Africa, and the United States and is present also in Hawaii, Brazil, the Azores, Madeira, India, and Korea (Decraemer 1995) and in New Guinea and on Norfolk Island (Bridge 1988).

The species is easily identified by one or two ventromedian body pores anterior and posterior to the vulva (Table 3; Fig. 8D). Males are mostly absent. As in other *Paratrichodorus* species, the cuticle may strongly swell upon fixation.

***Paratrichodorus lobatus* (Colbran, 1965) Siddiqi, 1974**

This species was described as *Trichodorus clarki* by Yeates (1967) from sand under *Ammophila arenaria* at Castlecliff Beach, Wanganui, and was synonymised with *P. lobatus* by Siddiqi (1974). Recent records are from sandy soil under *Cotula* at Orewa Beach, coastal dunes under *Ammophila arenaria* at Karekare Beach, regenerated native bush in the Waitakere Ranges, and garden soil at Havelock North (Fig. 4A).

Paratrichodorus lobatus is common in Australia (Colbran 1965) and has also been observed in South Africa and Chile (Decraemer 1995).

In addition to the diagnostic characters listed in Table 3 and the characteristic vaginal sclerotisations, which are small, oval and well separated (vulva longitudinal!) (Fig. 8E, F), the oesophageal glands ventrally overlapping the intestine and the swelling of the cuticle on fixation may be useful for identification.

Table 3 Diagnostic characters of New Zealand *Trichodorus* and *Paratrichodorus* species.

Species	Females			Males		
	Onchiostyle (µm)	Shape of vulva	Body pores	Abundance	Bursa	Ventral cervical papillae
<i>T. cottieri</i>	53–68	transverse	1 lateral postvulvar	present	absent	1
<i>T. primitivus</i>	42–59	transverse	1 lateral postvulvar, 2 prevulvar	common	absent	3
<i>P. lobatus</i>	42–58	longitudinal	1 lateral postvulvar	common	present	0
<i>P. porosus</i>	39–58	pore-like	ventral prevulvar and postvulvar, no lateral	rare	present	1
<i>P. minor</i>	26–47	transverse	absent	rare	present	0

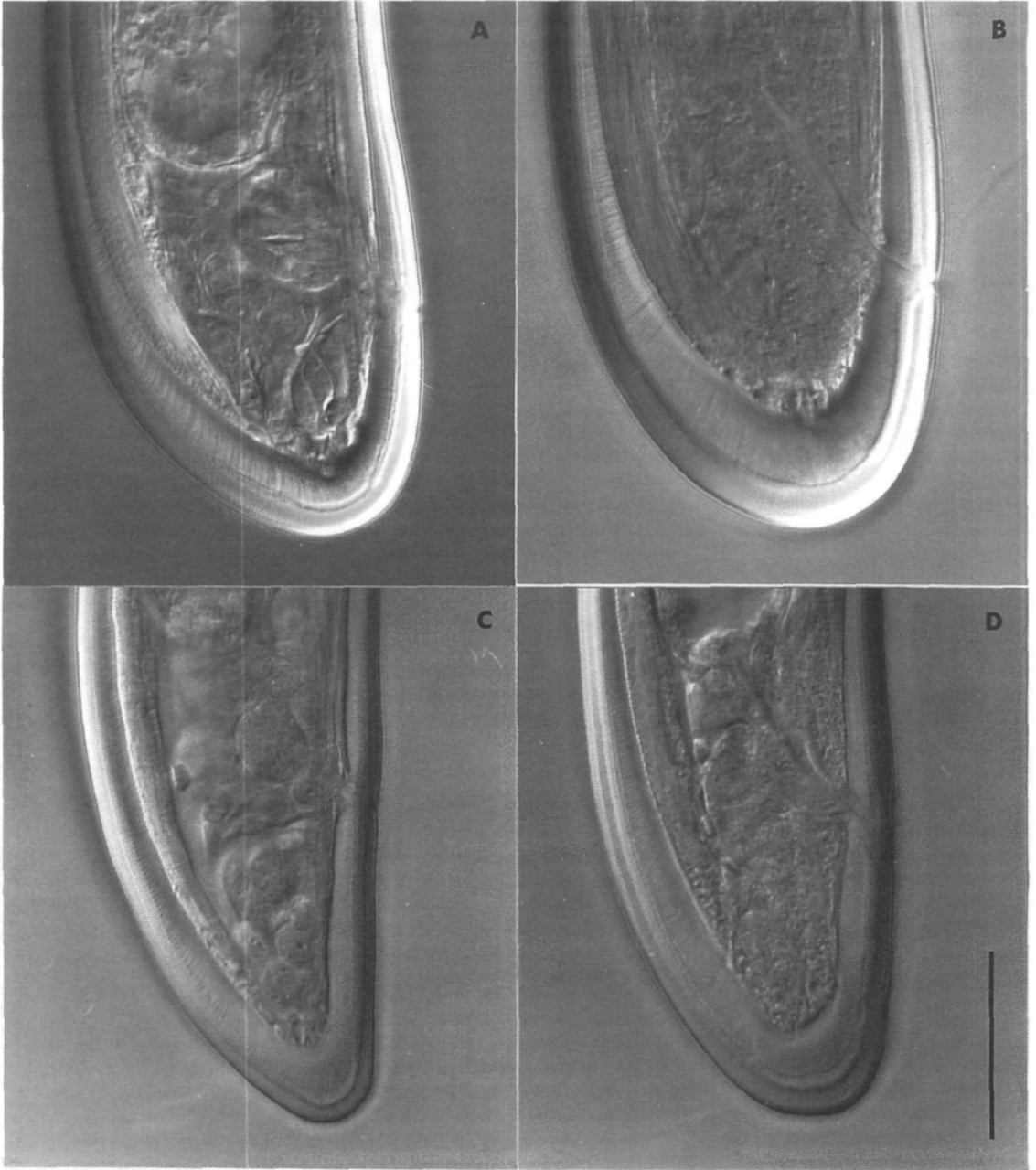


Fig. 6 Posterior end of: **A**, *Longidorus taniwha*; **B**, *L. orongorongensis*; **C**, *L. elongatus*; **D**, *Paralongidorus* sp. (undescribed). Scale bar: 30 μ m.

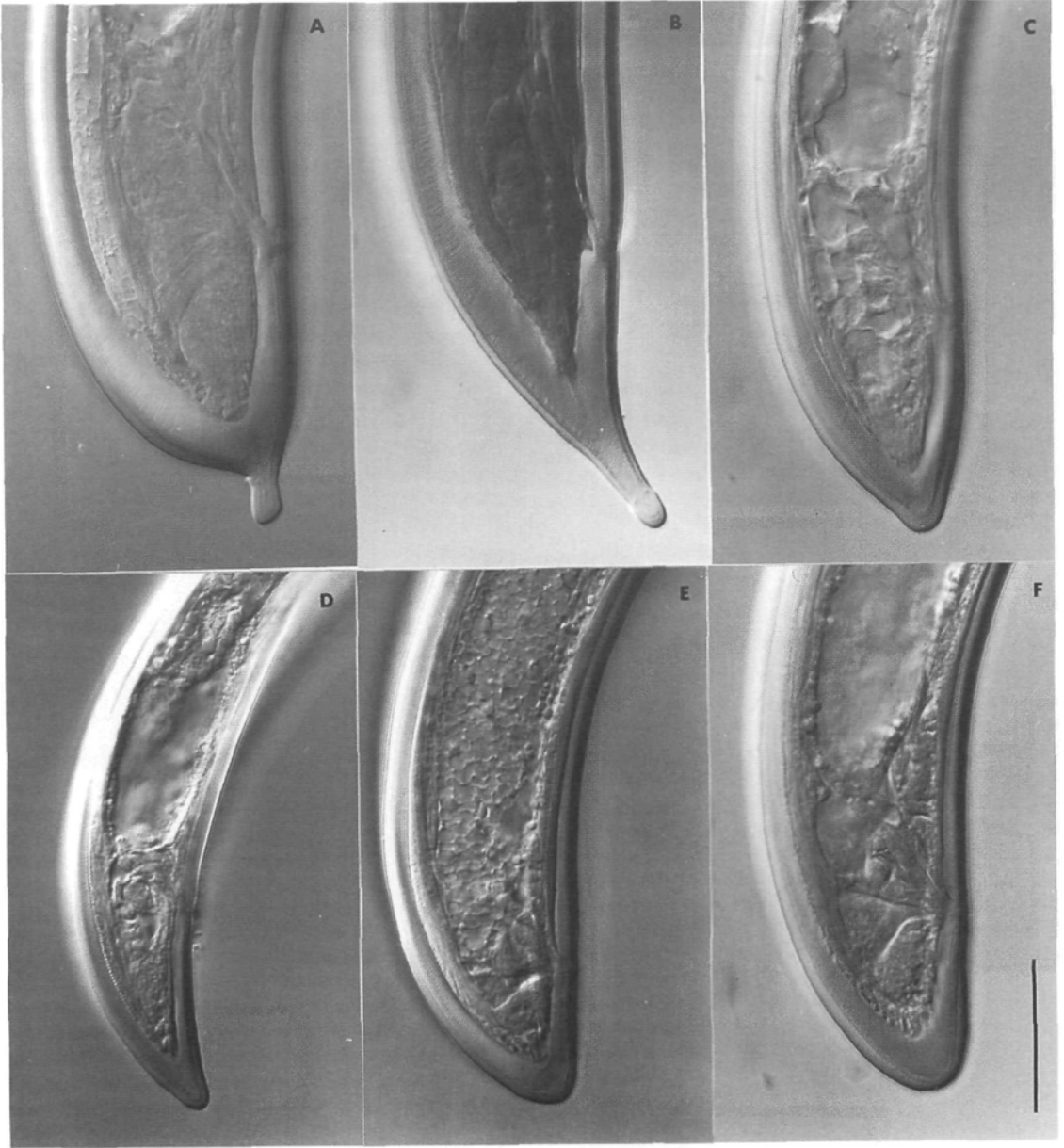


Fig. 7 Posterior end of: **A**, *Xiphinema diversicaudatum*; **B**, *X. radicolica*; **C**, *X. krugi*; **D–F**, species of the *X. americanum* group (**D**, sp. "a"; **E**, sp. "b"; **F**, sp. "c"). Scale bar: 30 μ m.

GENERAL REMARKS

Fifteen species of known or potential virus transmitting nematodes have been found and differentiated in New Zealand so far. This number is rather low in comparison to the 20 longidorid and 7 trichodorid

species recognised from Australia (Decraemer & Reay 1991; McLeod et al. 1994) and the 20 longidorid and 4 trichodorid species reported from other South Pacific islands (New Guinea, New Caledonia, Samoa, Fiji, Tonga, etc.) (Orton Williams 1980; Bridge 1988; Germani 1990).

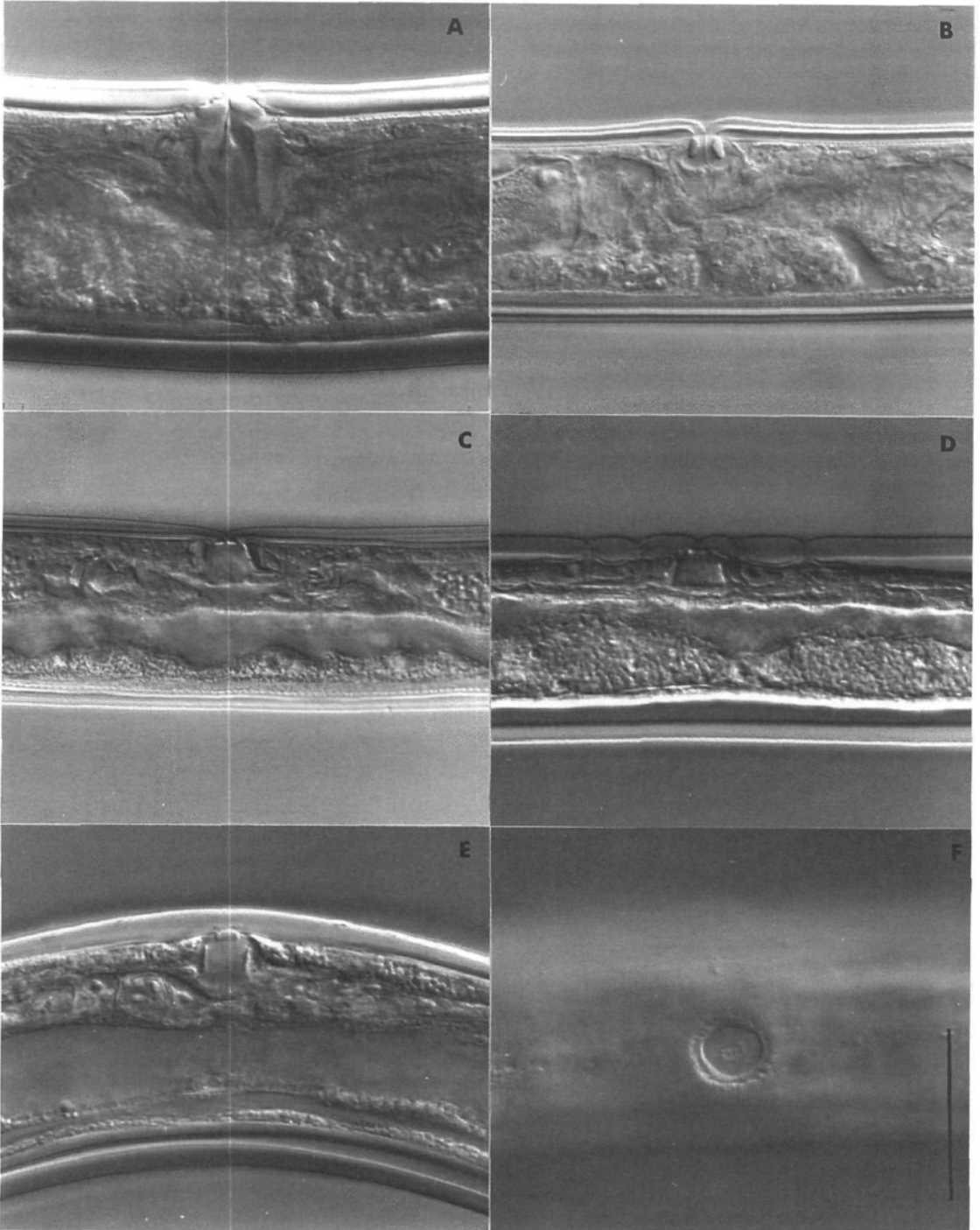


Fig. 8 Vulva-vagina region of: **A**, *Trichodorus cotti*; **B**, *T. primitivus*; **C**, *Paratrichodorus minor*; **D**, *P. porosus*; **E**, **F**, *P. lobatus* in lateral and ventral view. Scale bar: 30 μ m.

Longidorus orongorongensis, *Paralongidorus* (undescribed sp.), and *Trichodorus cottieri* are obviously endemic to New Zealand. *L. taniwha* is also known from Australia, and *Paratrichodorus lobatus* from Australia, South Africa and South America, showing Gondwana connections. In New Zealand, these species have been exclusively found in non-arable soil in the presence of native vegetation.

Longidorus elongatus, *X. diversicaudatum*, and *T. primitivus* may be considered "European" species introduced to New Zealand by humans. Their almost exclusive presence in cultivated soil supports this assumption. They have been recorded rarely from Australia. *Paratrichodorus minor*, *P. porosus*, *X. krugi*, and *X. radiculicola* are widely distributed in warmer regions of the world. Among species of the *X. americanum* group, *X. species "c"* may also be indigenous to New Zealand, an assumption supported by its almost exclusive occurrence in non-cultivated soil and its presence on Raoul Island. The other two species of the group may have been introduced, because almost all records are from cultivated plants.

X. diversicaudatum appears to be the most common longidorid species in New Zealand (43% of the total of 228 records) and *P. minor* the most common trichodorid (62% of all 92 trichodorid records available for this study). Both species together amounted to more than two-thirds of all records from cultivated soils. Often two species of the virus vector nematodes occurred together at a sampling site (e.g., *T. primitivus* + *P. minor*, *P. porosus* + *P. minor*, *L. taniwha* + *Paralongidorus* (undescribed sp.), *X. diversicaudatum* + *X. radiculicola*, *X. "americanum" species "a"* + *species "b"*), occasionally three species (*L. elongatus* + *P. minor* + *P. porosus*, *X. diversicaudatum* + *X. species "b"* + *P. porosus*), and once even four species could be differentiated (*L. elongatus* + *X. diversicaudatum* + *X. species "a"* + *P. minor*).

The majority of our records come from the North Island. This, in part, may be due to more intensive sampling and surveying in this part of the country, but may also be an indication that the majority of species need or prefer warmer climatic conditions and a mild winter. Some of the species introduced from temperate regions may not yet have dispersed sufficiently to reach the South Island. Assuming a rather recent introduction of *X. diversicaudatum* to New Zealand, the rapid spread and wide distribution of this species are particularly remarkable. On the other hand, *X. radiculicola* possibly has not spread beyond Motueka/Riwaka in the Nelson district, where it was found in 1978 and again in 1996.

Several of the species reported here are of economic importance through the direct damage they cause to plant roots. For *L. elongatus*, for example, "severe damage to the roots of strawberries" was reported by Dale (1971). Additional observations of root damage and poor growth of a wide variety of cultivated plants and bowling green turf by dense populations of *Longidorus*, *Xiphinema*, and *Paratrichodorus* species (often in combination with plant parasitic tylenchids) have been reported (Yeates & Prestidge 1986). Symptoms of *Xiphinema* infestation in bowling green *Cotula* commences as localised small yellow patches. Over the years these patches increase in size, coalescing to occupy large areas. The yellow foliage gradually turns brown and plants die, leaving large bare areas. The root ends of affected plants are stunted and slightly swollen. Introduction of the nematode into the bowling greens is probably via infected planting material used in green renovation. Recovery after treatment with organophosphate nematicides is very slow, taking many years (unpubl. pers. obs.).

Of the species found in New Zealand, *L. elongatus*, *X. diversicaudatum*, *X. americanum*, *T. primitivus*, and *P. minor* are recognised to have the ability to transmit plant viruses (nepoviruses and tobnaviruses). The other species are potential vectors. Hay & Close (1992) found *X. diversicaudatum* in hop gardens infected with Arabis Mosaic Virus (AMV) at Riwaka and suggested that this species is a vector in New Zealand. At Te Puke this species has also been found regularly associated with tamarillo plants (*Cyphomandra betacea*) infected with AMV (Thomas & Procter 1972). Under experimental conditions, a New Zealand population of *X. diversicaudatum* transmitted two serologically distinct strains of AMV as efficiently as did populations of various European origins (Brown et al. 1988). *Xiphinema index*, the vector of the economically most important grape virus, Grapevine Fanleaf Virus (GFV), has not yet been found in New Zealand, though the virus is present (Chamberlain et al. 1970; Dale 1971; Grandison 1991). Two species of the *X. americanum* group have been recorded repeatedly from vineyards where GFV was present. There is no evidence of nematodes transmitting the virus in these instances.

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