CONTROL OF *SIREX NOCTILIO* F. WITH *DELADENUS SIRICIDICOLA* BEDDING

PART II. INTRODUCTIONS AND ESTABLISHMENTS IN THE SOUTH ISLAND 1968-75

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ABSTRACT

The nematode, **Deladenus siricidicola** Bedding, which sterilises adult female **Sirex noctilio** F. and is regarded as being the most important controlling agent of the woodwasp in the North Island, has been successfully introduced into several South Island forests. It is well established in the northern parts of Nelson Conservancy and there has spread naturally to forests where it was not introduced. In Canterbury Conservancy it has been recovered from two of the six forests in which it was introduced, and in Southland Conservancy from five of the eight forests.

Details are given of the methods used for the introductions and the establishment checks.

INTRODUCTION

The nematode *Deladenus siricidicola* Bedding (Neotylenchidae), which is a parasite of the introduced woodwasp *Sirex noctilio* F., was first discovered in the North Island in 1962 (Zondag, 1969). The initial discovery was in adult female sirex from Rotoehu State Forest and subsequent surveys revealed its presence in nearly all of the North Island pine forests.

Deladenus siricidicola is an entomophagous-mycetophagous nematode, the infective stage of which parasitises sirex larvae and subsequent adults. In sirex adults the ovaries and eggs are atrophied and the testes hypertrophied; the fertility of the males is not impaired but the females are sterilised. Infection levels of about 90% have been found in many North Island forests.

Infected female woodwasps transmit the nematode and for this to happen these females have to attack the same trees as uninfected females. In the wood of successfully attacked trees the nematodes are in a free-living form which feed on the sirex fungal symbiont, and in a parasitic form, the females of which penetrate the sirex larvae. These infective females produce young ovoviviparously at the time of host pupation and the juvenile nematodes then invade the sirex reproductive organs. Further details of the

complex life cycle and symptoms in the host can be found in Bedding (1967; 1972) and Zondag (1969).

Because of the undoubted potential of the nematode as a biocontrol agent it was decided to attempt to introduce it into South Island pine forests. To this end, a trial was set up in 1967 to test the efficiency of four different methods (Zondag, 1971). One of the methods proved superior and was adopted for further introductions described below.

METHODS

Rearing and Introduction

The simplest method of introducing the nematode into new locations would have been to place logs containing a high percentage of infected sirex larvae in the forests. The emerging females would then spread the infection. However, because of the attendant risks of introducing insects that do not occur in parts of the South Island (eg. *Arhopalus ferus* Mulsant, *Xyleborus saxeseni* Ratzeburg) and the non-sterilising strain of the nematode which occurs only in the northern part of the North Island (New Zealand Forest Service, 1974; Zondag and Nuttall, in prep.) it was decided not to use this method.

From 1969 until 1970 the nematodes were introduced into South Island forests using the method that had proved most successful in the 1967 trials (Zondag, 1971). Nematodes were extracted from the wood of recently sirex-killed trees, stored in vials filled with moistened wood shavings (from sirex-killed trees), and the contents were then inserted into holes drilled in trees that contained sirex larvae. The main disadvantage of this method was that, because of their short storage life, the nematodes had to be used within ten days of extraction.

From 1971 onwards the method developed by Bedding in Australia was used (Bedding and Ackhurst, 1974). The nematode was mass-reared on the sirex fungus, initially on potato-dextrose agar and later on grain, and cool-stored in flasks lined with malt agar. Prior to introduction, the nematodes were washed from the flasks and mixed into cooled gelatine. The gelatine mixture was then inserted with hypodermic syringes into holes made by punch- and chisel-hammers in trees containing sirex larvae. The main advantage of this method is that millions of nematodes can be reared and held in cold storage for up to four months. It also allows the operator to make the holes with one hand and immediately insert the gelatine mixture with the other.

With both these methods the nematodes were inserted into the stems of felled sirex-killed trees at intervals of about 30 cm. All introductions were made between March and November.

Checking on Introduction and Establishment

To check on the success of the nematode inoculations samples were taken from the nematode-treated trees a few months after treatment. The samples consisted of short billets (usually about 1.2 m long) which were held in cages at FRI until the adult sirex emerged. These insects were dissected to determine whether the nematode was present or not.

Checks to see whether or not the nematode had become established were made in the season following inoculation and, of course, samples were taken from trees other

than those that had been treated with the nematode. In most instances these checks were continued for several seasons and were also made in forests where no nematode introductions had been made to determine if any natural spread between forests had occurred.

The establishment checks were made by three different methods, viz.

1. Sample logs from sirex killed trees were brought to FRI and held in cages or insectaries where the adults were allowed to emerge. These adults were then dissected. In some cases sample logs were held in insectaries at regional Forest Biology Observer Headquarters and the emerging adults forwarded to FRI for dissection. These sample logs were taken at different heights up the stem wherever sirex larvae were found. Past experience had shown that there is variation in the percentage of nematode infection at different heights (Zondag, 1973).

2. Sirex larvae were split out of the wood of recently killed trees and dissected.

3. Nematodes were extracted from the wood of sirex-killed trees in Baermann-type funnels.

The dissection of adult sirex was the preferred method because it was the most reliable and the least time-consuming. Larval dissection was used mainly when there was difficulty in forwarding sample billets to FRI. Larvae that were damaged when the wood was being split had to be examined as soon as possible before they began to putrefy, and larvae examined early in the season usually had a low rate of infection which could give rise to erroneous negative results (Zondag, 1969).

Attempts to extract nematodes from the wood were usually only made when larval dissection revealed no nematodes. In a few cases all three methods were used.

RESULTS AND DISCUSSION

The forests in which the nematode was introduced between 1967 and 1974 (including the 1967 trial, *see* Zondag, 1971) are given on the left side of Table 1. The results on the checks on the introductions (*not* establishment checks) are given on the right side of Table 1. In some of the forests samples for checks on the introductions were not taken; this was for a variety of reasons but usually because insufficient material was treated with the nematode. In all but three of the forests that were checked (Hochstetter, Eyrewell and Alexandra) the checks showed that the inoculations were successful. There did not seem to be any common factor linking these three failures but they can probably be explained individually. The parcel containing the nematodes for inoculation at Hochstetter went missing in the mail system for a week and the nematodes were probably dying or dead when inserted into the tree. At Eyrewell, because no other suitable material was available, the nematodes were inserted into poisoned trees and at Alexandra, because of a limited amount of material treated, only a small sample was taken from which no sirex emerged.

Table 2 shows the South Island forests from which the nematode has been recovered. Of particular note is the presence of the nematode in forests where it has never been introduced. After the successful trials in Rai-Whangamoa State Forest in 1967 (Zondag, 1971) the nematode was recovered from Motueka State Forest and Pigeon Valley (Baigent's Plantation) in 1970, a natural spread of some 50 km (Fig. 1). Following these recoveries it was decided not to make any further nematode introductions in Nelson Conservancy or in the northern part of Canterbury so that the natural spread of the

TABLE 1—Introductions of **Deladenus siricidicola** in the South Island 1968-1974

Conservancy & Forest	Nematode Introductions: Month & year	No. trees treated	Approximate stem length treated (cm)	Checks on Introductions: No. trees checked	No. samples taken	No. Sirex checked	Mean % Sirex infected
Nelson Conservancy							
Golden Downs S.F.	Aug. 1973	10	100	10	10	280	51
Rabbit Island	May 1970	4	n.m.	0	—	—	—
*Rai-Whangamoa S.F.	Mar/ Sep. 1967	13	72	9	21	624	40
Tawhai S.F.	Aug. 1973	5	26	5	5	4	100?
Westland Conservancy							
Hochstetter S.F.	Nov. 1974	5	15	5	5	42	0
Canterbury Conservancy							
Ashley S.F.	Sep. 1968	18	135	17	17	2801	24
	Sep. 1969	21	150	12	12	679	24
Burwood	Aug. 1973	7	25	0	—	—	—
Eyrewell S.F.	Sep. 1969	5	n.m.	3	3	28	0
Hinds	Sep./ Oct. 1972	3	30	3	3	37	59
Kakahu S.F.	Sep. 1971	2	10	2	2	7	71
*Omihi S.F.	Feb/ Sep. 1967	14	92	11	29	1034	29
	Sep. 1969	1	4	0	—	—	—
Southland Conservancy							
Alexandra	Jun. 1971	3	15	3	3	7	0
Berwick S.F.	Mar./ Jun. 1968	6	4	1	1	51	88
	Nov. 1969	9	30	0	—	—	—
	Jun. 1971	8	n.m.	7	7	150	10
Dusky S.F.	Jun./ Sep. 1968	8	28	8	8	260	72
Herbert S.F.	Sep. 1968	12	50	11	11	640	74
	Oct. 1973	?	n.m.	5	5	174	18
	Oct. 1972	3	n.m.	0	—	—	—
Longwood S.F.	Nov. 1969	5	24	0	—	—	—
Otago Coast S.F.	Oct. 1973	2**	28	1	1	20	45
*Rankleburn S.F.	Feb./ Mar/ 1967 Sep.	17	150	14	25	801	76
	Oct. 1973	1**	20	0	—	—	—
Tapanui S.F.	Jun. 1968	2	10	2	2	176	82

* 1967 trial (see Zondag 1971).

** Inoculated logs from Herbert placed in stands.

n.m. Not measured.

Since 1971 mass-reared nematodes were used for introductions.

TABLE 2 — **Recoveries of D. siricidicola in the South Island 1968-1975**

Conservancy and Forest	Year Introduced	Recoveries					Negative results and remarks
		Season	Adults		Larvae		
			No. checked	% infected	No. checked	% infected	
Nelson Conservancy							
Baigent's Plantations							
Harakeke Block	-	1973-74	5	40	-	-	Orinoco Block 72/73
Mahana Block	-	1972-73	238	34	-	-	Tasman Block 73/74
		1973-74	157	87	24	75	
Pigeon Valley	-	1970-71	-	-	79	1	
		1971-72	190	44	57	18	
		1972-73	47	38	-	-	
Sunrise Block		1753-74	38	53	-	-	
Waiwhero Block	-	1972-73	16	86	-	-	
Braeburn Plantation	-	1972-73	24	54	-	-	
Fletcher's Plantation	-	1973-74	9	100	3	0	
Golden Downs SF		1971-73	2425	22	-	-	Golden Downs 69/70, 70/71, 71/72
		1972-73	162	6			In 1971/72 one tree found with
	1973	1973-74	4197	87	37	32	infected Sirex (1%). In 1972/73 another tree.
Motueka SF							
(Kaiteretere Block)	-	1970-71	-	-	110	8	
		1971-72	569	51	219	42	
		1972-73	208	65	44	39	
		1973-74	151	78	15	47	
Rabbit Island	1970	1971-72	654	14	194	12	Rabbit Island 69/70; 70/71 Figures west and east side combined
		1972-73	601	33	103	6	
		1973-74	166	20	27	4	
		1974-75	267	84	-	-	
*Rai-Whangamoa	1967	1968-69	284	93	-	-	
		1969-70	234	56	-	-	
		1970-71			27	70	
Tawhai SF	1973	-					Tawhai 73/74
Westland Conservancy							
Hochstetter SF	1974	-					
Canterbury Conservancy							
Ashley SF	1968	1969-70	2787	8	42	0	Lots of logs. With and without exit holes
	1969	1970-71	2930	3	778	1	
		1971-72	2677	13	861	8	Ashley 1972/73
Burwood	1973	-					Burwood 73/74. 74/75
Hinds	1972	-					
Kakahu SF	1971	-					Kakahu 73/74
*Omihi SF	1967	1968-69	21	5	-	-	
	1969	1969-70	27	4	-	-	
		1970-71	453	0	233	<1	
		1971-72	753	>1	-	-	
Southland Conservancy							
Alexandra	1971	-					Alexandra 70/71, 71/72, 72/73, 73/74
Berwick SF	1968	1973-74	916	18	42	0	Berwick 70/71, 71/72
	1969	1974-75	164	97	-	-	
	1971						
Dusky SF	1968	1974-75	-	-	22	36	Dusky 69/70, 70/71, 73/74
Herbert SF	1968	1972-73	5	40	-	-	Herbert 70/71, 71/72
		1973-74	300	0	40	5	
	1973	1974-75	223	66	-	-	
Longwood SF	1972	-					Longwood 71/72, 72/73, 73/74
Otago Coast SF	1969	1974-75	823	6	-	-	Otago Coast 70/71, 71/72, 72/73, 73/74
	1973						
Tapanui SF							
Tapanui SF	1968	1970-71	-	-	64	4	Tapanui 71/72
*Rankleburn SF	1967	-					Rankleburn 68/69, 70/71, 71/72, 73/74

*1967 trial (Zondag, 1971). Sirex from the following areas, in which no introductions were made were checked also; Canterbury Conservancy, Hanmer SF 73/74; Southland Conservancy, Conical Hill SF 70/71, 73/74; Gimmerburn SF 72/73; Invercargill C.C. Plantation 71/72, 72/74; Naseby SF 70/71, 71/72, 72/73; Otautau SF 73/74; Pebbly Hills SF 70/71; Pukerau SF 71/72; Roxborough Plantation 72/73; Slopedown SF 71/72; Tisbury (a shelterbelt) 71/72.

nematode could be followed. In subsequent seasons the nematode was found to be established in other plantations in the Nelson region (Fig. 1; Table 2). In 1973 further introductions were made in Golden Downs State Forest although the nematode had been found there in the 1971-72 seasons.

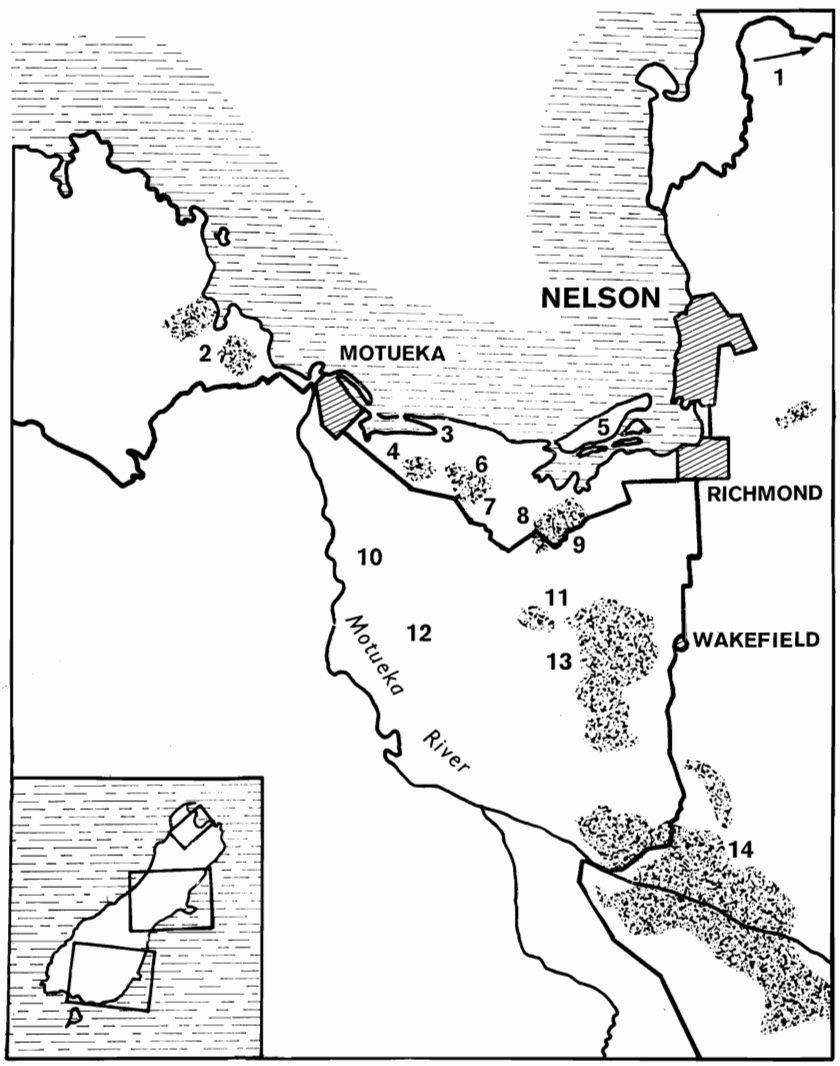

FIG. 1—Localities in Nelson region. 1, Rai-Whangamoa State Forest; 2, Motueka S.F.: 3, Tasman Forest; 4, Braeburn Plantation; 5, Rabbit Island; 6, Machine Gulley; 7, Harakeke Block; 8, Mahana Block; 9, Fletcher's Block; 10, Waiwhero Block; 11, Sunrise Block; 12, Orinoco Block; 13, Pigeon Valley; 14, Golden Downs S.F.

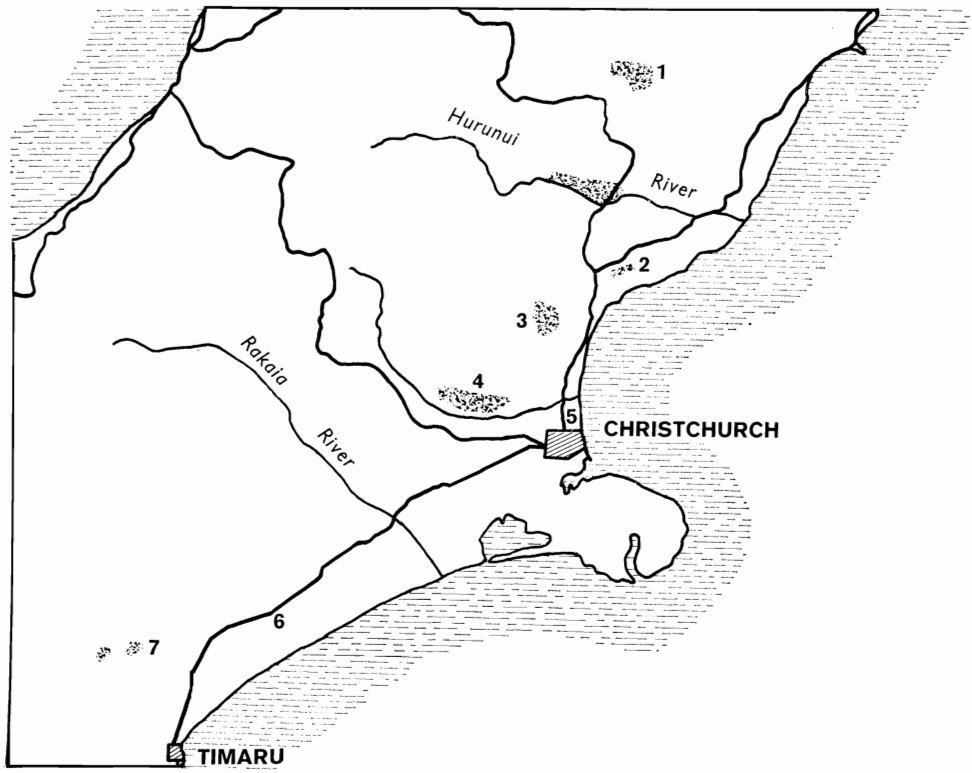

FIG. 2—Localities in Canterbury. 1, Hanmer S.F.; 2, Omihi S.F.; 3, Ashley S.F.; 4, Eyrewell S.F.; 5, Burwood Plantation; 6, Hinds (Railway Plantation); 7, Kakahu S.F.

In Canterbury the nematode has been introduced into six forests but recovered from only two, Ashley and Omihi State Forests (Fig. 2). At Ashley spread occurred throughout the forest but infection levels were low. At Omihi only small numbers of infected sirex were found in the four years since the initial introduction in 1967 and none of these were far from the site of introduction. In both these forests sirex-killed trees were very scarce and in some years none at all could be located.

In Southland the nematode has been recovered from five of the eight forests (Fig. 3) in which it was introduced. In nearly all of these five forests the nematode was not recovered until several years after the introductions; the exception was Tapanui State Forest where it was recovered in the 1970-71 season after being introduced in 1968. In all forests the number of trees found with infected sirex was low.

There is no apparent correlation between the number of trees treated with the nematode and the eventual establishments. In Tapanui State Forest only two sirex-attacked trees were treated but the nematode established itself and was recovered two seasons later. The main factor influencing the chances of establishment is undoubtedly the level of sirex activity in the forest at the time of introduction and in the following season(s). Where sirex is at a very low level, which it was in most of the Canterbury and Southland forests when the introductions were made, the chances of establishment must be considerably reduced.

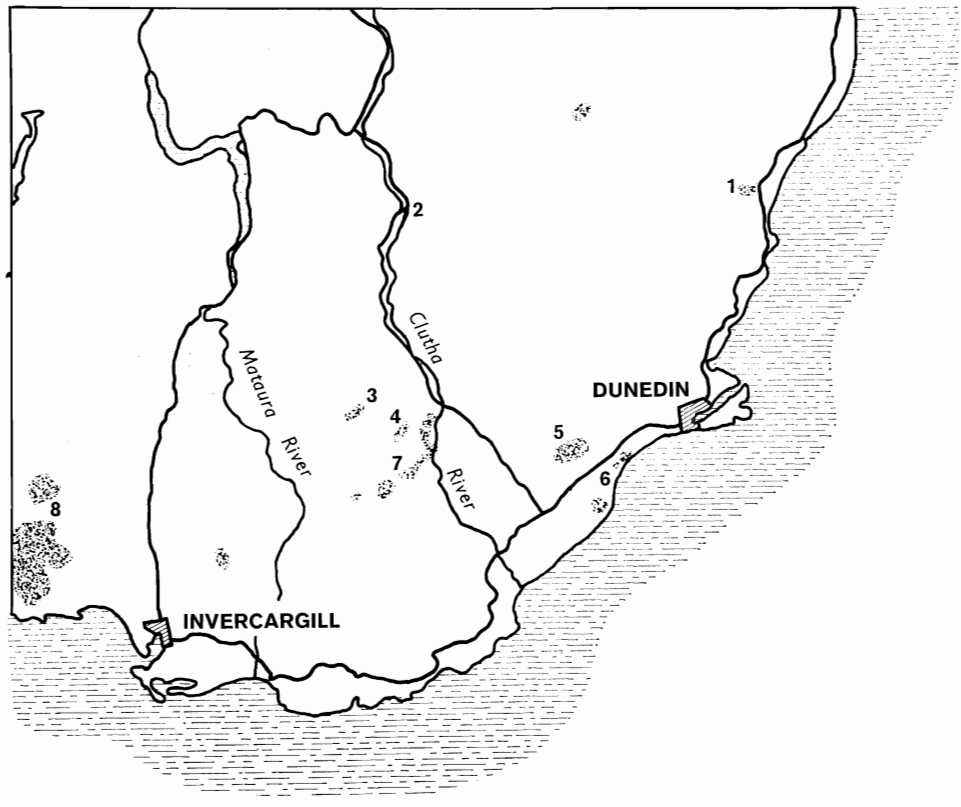

FIG. 3—Localities in Southland: 1, Herbert S.F.; 2, Alexandra B.C. Plantation; 3, Dusky S.F.; 4, Tapanui S.F.; 5, Berwick S.F.; 6, Otago Coast S.F.; 7, Rankleburn S.F.; 8, Longwood S.F.

CONCLUSIONS

In Nelson Conservancy the nematode introductions can be recorded as being highly successful. Not only have infection rates of over 75% been recorded but natural spread has accounted for establishment in several forests. In Canterbury and Southland the known establishments are, by comparison, rather disappointing but it is believed that this is because of very low levels of sirex activity in most of these forests. It has been demonstrated that *D. siricidicola* can quickly and effectively be introduced into forests where it does not occur naturally. Introductions are being continued.

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