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Sirex noctilio: Report on its occurrence within South Africa and the progress with biological control up until June 1996

Introduction: The woodwasp *Sirex noctilio* Fabricius is endemic to Eurasia and North Africa and almost 76 % of its distribution range is in the Mediterranean bioclimatic zone. It is almost exclusively associated with *Pinus* species although living trees attacked by *S. noctilio* in Europe are rarely killed, in contrast to the losses caused to *Pinus radiata* D. Don grown commercially in Australasia (Spradbery & Kirk 1978), where up to 70 % of a compartment may be destroyed (Neumann et al. 1987).

Pinus species confirmed as hosts thus far in South Africa include *P. canariensis*, *P. elliottii*, *P. patula*, *P. pinaster*, *P. pinea* and *P. radiata*. *Pinus taeda* is also recorded in the literature as a host of *S. noctilio*.

Mode of attack: *Sirex noctilio* woodwasps are attracted to stressed trees which they kill by injecting a phytotoxic mucus and the symbiotic fungus *Amylostereum areolatum* (Fr.) Boidin into the wood during oviposition. *Sirex noctilio* larvae feed on the fungus within the wood and pupate just under the bark layer of the tree. *Pinus radiata* is particularly susceptible to *S. noctilio*, and although neither the fungus nor the mucus alone are capable of killing trees, they are lethal in combination (Coutts 1969).

History in South Africa: In April 1994, two disintegrated steel-blue wasps were discovered under the bark of a discarded 44-year-old *P. radiata* log in a clear-felled compartment (C18b) in Tokai Plantation. The number of distinctive round exit holes in discarded logs revealed that a minimum of 3772 wasps had emerged from this clear-felled compartment the previous season. From the number of exit holes in dead, standing trees in the unfelled part of this compartment it was estimated that a further 5000 wasps had emerged. When taking into account the number of exit holes found subsequently in trees in other plantations, an estimate of about 15 000 wasps could have emerged the previous season throughout the south-western Cape.

Even before adult wasps became available for identification, core samples were taken from dying trees from which the symbiotic fungus *A. areolatum* was positively identified by Alice Baxter (Division of Systematics, PPRI, Pretoria). Later the wasp itself was positively identified by F. Kock in Berlin.

Distribution: The epicentre of the *S. noctilio* infestation is centred in Tokai Plantation and adjoining Cecilia and Silvermine plantations judging from the number of trees killed by the woodwasp and the number of old exit holes, which also indicate that they had been there for at least two seasons. Because *S. noctilio* has an annual life-cycle, the woodwasp has been in the Cape Peninsula at least two years before its discovery in 1994. It probably arrived in wood used for crates because the woodwasp pupates just under the bark and usually the cant of a log is used for this purpose. There must have been several wasps which emerged for a female (which occurs usually in a ratio of 3 males: 1 female) to have been mated on a host tree which must be independently found by both sexes.

Several trips were made to plantations in the South Western Cape and with the aid of the foresters the following distribution of *S. noctilio* in South Africa was determined. Live *S.*

noctilio larvae were extracted from dying *P. radiata* trees in Tokai, La Motte, Kluitjieskraal, Jonkershoek and the adjacent plantations of Grabouw and Nuweberg, all within a 90 km arc around Cape Town. Other than at Tokai, exit holes from the previous season were also present at Grabouw Plantation. In February 1996 an additional site of *Sirex* infestation was found on private land opposite Cape Point Nature Reserve where about 36 *P. pinaster* trees had died or were dying. In the Stellenbosch district, exit holes were also found in *P. radiata* trees at Papegaaiberg, Lourensford Estate and Paradyskloof.

The report by a visiting Australian scientist that he had observed *Sirex*-killed trees at Mariepskop near Klaserie could not be confirmed.

Seasonal emergences: By coincidence the first wasps to emerge from infested logs collected in Tokai plantation and placed in the large cage in both 1994 and 1995 was on 15 November. Records taken in the 1994/5 season showed that the peak period of emergences occurred in March. The period during which the wasps emerged was 24 weeks and extended until the end of April.

Purchase of nematodes: Biological control in Australasia had been successfully achieved by importing the parasitic nematode *Deladenus siricidicola* Bedding and four parasitic wasp species of which two, *Ibalia leucospoides* and *Megarhyssa nortoni*, made a significant addition to parasitism levels.

Deladenus siricidicola may occur in two distinct forms: a free-living form which feeds on the *A. areolatum* fungus in the wood and a parasitic form which has a stylet which is used to penetrate the cuticle of the *Sirex* larva. When the free-living form encounters a larva, the high CO2 and low pH levels around the larva induces the adult to produce the parasitic form. The nematodes eventually find their way to the ovaries or testes of the emergent wasp. Sterile eggs full of nematodes are deposited into stressed trees visited by other unparasitised wasps and in this way the nematodes are spread between trees. The male is neither made sterile by the nematodes nor are the nematodes transferred to the female during copulation.

Following the *Sirex* outbreak in South Australia in 1987, it was found that the virulence of the nematode culture had significantly diminished due to the continuous maintainance of the culture in the easier-to-rear free-living form. Hence a search was made at the original release site in Tasmania and the virulent Kamona strain is now used in Australia. It is this strain which was purchased from the the Australian CSIRO for release in South Africa. The licence to use this strain only extends as far as the Cape Provincial boundaries. Care must be taken that the inferior strain of *D. siricidicola* does not become established in South Africa because results from South Australia have shown that the Kamona strain is able to hybridise with it. The outcome is that the Kamona hybrid so formed is inferior to the pure Kamona strain.

A visit to Dr. Robin Bedding's laboratories at the CSIRO in Canberra allowed first-hand experience in the mass-rearing procedures of *D. siricidicola* and a report on this was compiled in South Africa in the event that this should become necessary for mass-rearing locally. A second course conducted by Dr. Robert Eldridge on the field inoculation of the nematode into trees was held at Bathurst (NSW) and was also attended.

Ten second-hand *Sirex* inoculation hammers with spare punches were purchased from the forestry department of South Australia for use in South Africa. These hammers are especially designed to make a clean cut through the tracheid vessels so that the nematodes can enter them directly.

Inoculations in the Cape (1995): Three consignments of nematodes were received from the CSIRO in 1995. A test consignment of 100 000 nematodes was sent directly to the Division of Plant and Quarantine Control in Pretoria where their identity was confirmed and a clean bill of health was received. A sample from each of the subsequent consignments was also withdrawn for inspection by the Division's Stellenbosch laboratories.

The number of nematodes imported on the relevent dates is given in Table 1. below:

Table 1.	Consignment 1.	20 May 1995	25 million nematodes
	Consignment 2.	3 June 1995	15 million nematodes
	Consignment 3.	7 July 1995	10 million nematodes
		Total	50 million nematodes

The nematodes arrived in sealed plastic sachets each containing five million nematodes. A source of poly-acrylamide gel with the trade name "Synpol" was secured from Kynoch Soil Services in Randburg. The nematodes were suspended in a Synpol/water mixture before being squirted from plastic sauce bottles into the punched holes during inoculation of the tree. Using the specially made hammer, two rows of holes, with 30 cm between each hole, were punched into the tree into which the nematodes were squirted. One gram of gel was added to 100 ml of water and the nematodes were added to the mixture as the gel absorbed the water. This supplied both the oxygen and water needed for the nematodes to survive before being inoculated into the stem.

Ideally there must be 2000 nematodes per millilitre of water i.e. 25 g of gel added ot 2500 ml water into which a sachet of five million nematodes has been added. With 2000 nematodes per hole and 50 holes per tree, five million nematodes are sufficient to inoculate 50 trees.

All trees showing signs of Sirex infestation within the 90 km arc of their distribution around Cape Town were inoculated (see Table 2.)

Table 2. **The number of *P. radiata* trees inoculated with *Deladenus siricidicola* in the different plantations during May - June 1995.**

Tokai	51 + 36 + 14 + 12	=	113
Cecilia	49	=	49
La Motte	7	=	7
Jonkershoek	9 + 4	=	13
Grabouw	41	=	41
Kluitjieskraal	11	=	11
Papegaaiberg	3	=	3
Lourensford	2 + 4	=	6
Somerset West	4 + 3	=	7
Total			250

Most of these trees were over 30 years old (with many over 40 years old) and thus several additional rows of holes were punched into these trees to ensure saturation of the entire stem with nematodes. The identification of *Sirex*-infested trees (as opposed to trees suffering from other stresses) was perfected so that a success rate of 99 % was achieved. Since all trees had to be felled before they could be inoculated, this resulted in almost no wastage. Inoculation takes place about 3 months after the nematodes would naturally have been deposited by an infested *Sirex* female and hence the necessity of the high number of nematodes to be inoculated for saturation of the stem to occur.

Inoculations in the Cape (1996): Two consignments of *Deladenus siricidicola* were purchased from the CSIRO in 1996.

Consignment 1.	20 May 1996	10 million nematodes
Consignment 2.	(yet to arrive)	10 million nematodes

The following number of trees were inoculated with the nematodes from the first consignment.

Cape Point (private)	*P. pinaster*	= 18
Papegaaiberg	*P. radiata*	= 2
Newlands forest	*P. radiata*	(proceeding)
Kluitjieskraal	*P. radiata*	(proceeding)

Loss assessment: A survey of the number of trees killed by *Sirex* in Tokai Compartment C17b consisting of 8.1 ha planted at 362 s.p. ha was 96 trees. This represented 3.3 % mortality due to *Sirex* at a cost of R20 943 (where the average tree volume was 2.16 m and the average price R101 per m).

Percentage parasitism: During August 1995 sections of trees that had been inoculated with *Deladenus siricidicola* were brought back to the Rosebank laboratories. Here they were individually fitted with nylon gauze sleeves and checked every day for emergences. Both male and female wasps were dissected and examined for the presence of *D. siricidicola* nematodes and the percentage parasitism was determined. The results can be seen in Tables 3 & 4.

Of the 402 wasps which emerged 91 (22.6 %) were parasitised. The sex ratio of the wasps was 335 males to 67 females. Of the males 74 (22.0 %) were parasitised and so were 17 (25.4 %) of the females. There was no significant increase in the percentage of wasps parasitised as the season progressed. The decrease in the ratio of males to females from 10.17 males: 1 female in 1994, to 5 males: 1 female in 1996 is presumably indicative of the fact that the numbers of the wasp population had increased and more females were finding mates. Unfertilised wasps lay male eggs only, while fertilised wasps can lay both female or male eggs. Meeting of the sexes usually takes place either in the air above suitable host trees or on the trees themselves. Table 3 indicates that from the logs where parasitised wasps did emerge, only 24.2 % of the wasps emerging from these logs inoculated with *D. siricidicola* had been parasitised. This low percentage is indicative of a lack of dispersal of the nematodes within the logs, probably influenced greatly by the age and hence dryness of the log at the time of inoculation.

Table 3. Ratio of parasitised *Sirex noctilio* wasps to unparasitised wasps emerging from logs inoculated with *Deladenus siricidicola* (excluding those from which unparasitised wasps alone emerged)

Plantation & Compartment	Number of Sirex		%
	parasitised	Unparasitised	parasitism
Grabouw E18	4	9	30.8
Grabouw B21	1	34	2.9
Lourensford	4	12	25.0
Cecilia E19a	20	30	40.0
Tokai B9	16	15	51.6
Mixed localities	46	185	19.9
Total	91	285	24.2

Table 4. Logs inoculated with *Deladenus siricidicola* from which only unparasitised *Sirex* wasps emerged

Plantation & Compartment	No. of unparasitised wasps
Kluitjieskraal	0
Jonkershoek	6
La Motte	1
Tokai A19a	9
Tokai C64	2
Tokai C11	4
Papegaaiberg	4
Total	26

The total ratio (tables 3 & 4 combined) of parasitised to unparasitised wasps was 91: 311 (22.6 %).

Origins of Sirex in S.A.: The low percentage of parasitised wasps obtained in South Africa is very similar to that in South America where 24 % parasitism was recorded in the first year of inoculation. The initial response was that this could be due to the failure of the virulent Kamona strain of the nematode due perhaps to an incompatibility of the Australian and South African fungal strains on which the nematodes feed. This was tested by Bernard Slippers under the direction of Prof. Mike Wingfield and it was found in initial studies that the nematodes feed equally well on both strains of the fungus. It was also ascertained that the *Sirex* wasps present in South Africa did not originate from Australia because the fungal spores extracted from wasps in South Africa and those present in the nematode consignments from Australia were incompatible when plated onto the same agar dish. Further comparisons are to be made against the fungus extracted from wasps collected in various localities throughout Europe so that the origin of the wasp present in South Africa can be established.

Reasons for initial low parasitism rate: *Sirex* wasps emerging from the same logs which had been inoculated with *D. siricidicola* consisted both of parasitised and unparasitised individuals (see table 3). This indicates that the nematodes did not saturate the logs but were concentrated locally in certain sections only. This was probably a result of the logs being fairly dry at the time of inoculation and then drying out even more rapidly after felling.

Possibly also having an influence on the drying out of the logs and affecting the quantity of food available to the nematodes are the secondary invasion of *Sirex* killed trees by the European bark beetle *Orthotomicus erosus* and the long-horned borer *Arhopalus* (*Criocephalus*) *pinetorum*.

Usually the bottom third of a log is inhabited by the larvae of *A. pinetorum* whilst *O. erosus* in addition is responsible for introducing blue-stain fungi into the wood. The blue stain fungi are antagonistic to *A. areolatum*. However, the *Sirex* larvae which also feed on this fungus emerge normally after completing their cycle and the blue-stain fungi do not thus appear to significantly affect the amount of food available to them. Both these secondary beetle species are not present in Australia.

Other nematode species discovered in *P. radiata*: Several wood core samples were taken from a dying *P. radiata* tree in Tokai in 1994 and sent to Pretoria to confirm the presence of *S. noctilio* through the presence of its sybiotic fungus. However two unsuspected saprophagous nematode species were also found in these samples by Dr. Antoinette Swart and are the first such records in South Africa. *Cryptaphelenchus* sp. is a known associate of bark beetles and has until now only been recorded from the northern hemisphere. It could possibly have been brought into South Africa with *Orthotomicus erosus*. *Aphelenchoides* sp. nr. *haguei* is also of interest because *A. haguei* has only been recorded in Antarctica on moss. Two further species of *Aphelenchoides* spp. were isolated from the wood of *P. elliottii* in Lottering Plantation by Dr. Swart in April 1996. No systematic search has been made for the presence of nematodes in South African plantation trees and the isolation of them in stressed trees could possibly explain the cause for stress.

Trap trees: Trap trees, made by injecting the herbicide Dicambra into holes drilled into the stem, are set out in groups of five trees and used in Australia to attract *Sirex* wasps to oviposit. They are used as a way of determining whether *Sirex* has moved into an area ahead of the front, and as a source of trees for inoculation. Several such trap trees were established in Tokai, Cecilia, Grabouw, Kluitjieskraal, Jonkershoek and La Motte Plantations. However, these trap trees proved to be of varying success. Some did not attract *Sirex* wasps possibly due to the presence of *O. erosus* which colonised several of the trees. Trials were also carried out comparing Dicambra injected trees with trees severely ring-barked either just below the crown or at the base of the stem. The trap trees at La Motte and Grabouw plantations proved successful in attracting *Sirex* wasps.

Corresponding increase in *Arhopalus pinetorum*: There has been a dramatic increase in the number of *A.* (*Criocephalus*) *pinetorum* beetles since the arrival of *Sirex*. Unfortunately this increase cannot be quantified because no records exist of the population levels of *A. pinetorum* prior to 1994. *Arhopalus pinetorum* is a secondary long-horned (Cerambycidae) beetle species originating in the USA and was previously found only in semi-decaying pine logs lying on the plantation floor. This situation has now changed with the beetle larvae being found in large numbers in the bottom two metres of *Sirex* attacked trees. The drying of the tree due to the dry rot fungus introduced by the female *Sirex* during oviposition obviously creates ideal conditions for *A. pinetorum*. The beetle lays its eggs in the crevices in the bark and, upon hatching, the larvae bore into the bark where they feed on the cambium before penetrating the wood. Trees inhabited by *A. pinetorum* degrade the wood to such an extent that they are of no commercial value.

The population level of the European bark beetle, *Orthotomicus erosus*, has also increased locally due to the presence of *Sirex*. *Sirex*-stressed trees are ideal for secondary bark beetles such as *O. erosus* which colonise the trees usually when the *Sirex* larvae are still actively feeding within the wood.

Future Developments: The consensus amongst Australian researchers who have worked on the *Sirex* problem is that it is unlikely to be restricted to the mediterranean climate of the Cape. They maintain that wherever its hosts, especially *P. radiata*, can be grown, the woodwasp will become established. In both Australia and South America *Sirex* is established in the winter rainfall and all year rainfall areas respectively but has begun to spread into summer rainfall regions.

The use of the present license to use the Kamona strain of *D. siricidicola* pertains only to the Cape Province. Should *Sirex* extend beyond this border, a new license will have to be negotiated. The nematode should with time be distributed naturally by the *Sirex* wasp to all areas of South Africa. Where the problem lies is that the larger the wasp and the healthier the wasp, the further she flies. Thus the wasp can cause up to 70 % loss of a plantation before the nematode brings it under control. This is presently the situation in Australia and as the *Sirex* front moves forward at about 30 km/year, the nematodes are released in the newly colonised areas to minimise losses. Only once the whole continent is totally colonised by both the wasp and its parasites, will a stable balance be possible. This balance could however be disrupted locally if an incident, such as a major fire, should give a temporary advantage to the wasp.

Sirex noctilio need not systematically spread gradually up the east coast from Cape Town but could be accidentally spread by the transport of infested wood. Timber is currently being transported from the eastern Cape to a mill in the Transvaal for example, and although safe at the moment, the situation could change if *Sirex* had to appear there. Hence *Sirex* could appear in plantations far removed from its present distribution.

Importation of additional parasites. Over the 50 or so years that *Sirex* has been in New Zealand and Australia, initially seven hymenopterous parasitoid species were introduced both from Europe and North America. One species indigenous to Tasmania also changed hosts and began to parasitise *S. noctilio*. Only the following two species warrant introduction into South Africa as additional biological control agents:

Species	Origin	% parastism Average	Max.	Stage parasitised
Ibalia leucospoides	Europe	12.7 - 28.9	40	1st & 2nd instar larva
Megarhyssa nortoni	N. America	>12	22.7	late instar larva

A maximum 34 % mortality of immature *Sirex* was recorded by the combined affect of these two species in Australia. Even if *Sirex* larvae have already been parasitised by *D. siricidicola*, the hymenopterous parasites are unaffected by this and do not become sterilised.

An arrangement was made for the 1995/6 season with the Australian National Sirex Coordinating Committee to supply these two species to South Africa if they had excess wasps after their commitment to their industry had been met. Unfortunately no wasps were forthcoming. This arrangement still stands for 1996/7 and an alternative source for *I. leucospoides* has been found in South America. Negotiations are currently underway to procur some wasps in 1996/7. These wasps will have to spend one generation (approximately 12 months) in quarantine before they can be released into the plantations. This will entail the rearing of large numbers of *Sirex* in cages for this purpose.

Publications: The following articles dealing with the *Sirex* problem in South Africa have been published:

Tribe, G.D. 1995. The woodwasp *Sirex noctilio* Fabricius (Hymenoptera: Siricidae), a pest of *Pinus* species, now established in South Africa. African Entomology 3(2): 215 - 217.

Baxter, A.P., Rong, I.H. & Schutte, A.L. 1995. *Amylostereum areolatum* (Aphyllophorales: Stereaceae) in South Africa. South African Journal of Botany 61(6): 352 - 354.

Swart, A. & Tribe, G.D. 1996. Nematodes in pine trees in South Africa. Poster to be presented at the Symposium of the Zoological Society of South Africa, Pretoria 8 - 12 July.

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Neumann, F.G., Morey, J.L. & McKimm, R.J. 1987. The *Sirex* wasp in Victoria. In: Meagher, D. (Ed.) Bulletin, Lands and Forests Division, Department of Conservation, Forests and Lands, Melbourne 29: 1 - 41.

Spradbery, J.P. & Kirk, A.A. 1978. Aspects of the ecology of siricid woodwasps (Hymenoptera: Siricidae) in Europe, North Africa and Turkey with special reference to the biological control of *Sirex noctilio* F. in Australia. Bulletin of Entomological Research 68: 341 - 359.

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22 May 1996

Was Criocephalus pinetorum
then Arhopalus pinetorum
now Arhopalus syriacus

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Dear Geoff

RE: IDENTIFICATION OF CERAMBYCIDAE - JOB NO. 1995/141

Having recently received a letter from overseas, I am now in a position to provide you with the correct name for the cerambycid specimens you submitted for identification. Although they do belong to the genus *Arhopalus* as predicted, the species is *A. syriacus* (Reitter). It is apparently widespread but not very common in the Mediterranean Basin (from Spain to Turkey and North Africa).

May I also make use of this opportunity to thank you for your letter as well as the specimens and literature on the genus *Trachymela*. They will be put to good use!

Kind regards

E. Grobbelaar (Miss)
BIOSYSTEMATICS DIVISION
for DIRECTOR: PPRI