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Biological Control

Proceedings of a Conference: Training in the Control of *Sirex noctilio* by the Use of Natural Enemies

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Preface

In South America, the rate of afforestation with exotic pines has dramatically increased during the last two decades. The countries of South America are dependent on plantations of fast-growing trees to help meet their national needs for lumber, pulpwood, fuelwood, and other wood products. Also, these plantations alleviate the pressure on some naturally occurring species in areas such as the Amazon Basin, Atlantic Forest, and Auraucaria Forest. There are presently 5.0 million hectares of forest plantations in Brazil, of which 2.0 million hectares consist of various species of pines.

Pines in South America were relatively pest-free; however, in the early 1990s, several species of insects and fungi were accidentally introduced into the continent. These pests have caused widespread, serious damage. Several pest species now threaten the future viability of pine, as well as tree biodiversity as a component of South American forestry programs.

Sirex noctilio F. (Hymenoptera: Siricidae), is native to southern Europe, the Near East, and north Africa, where it is a secondary invader in the boles of weakened and dying pines. It is not considered a pest in its native habitat. This horntail is associated with a fungus, *Amylostereum areolatum*, which is toxic to certain pines. By the mid 1980s, *S. noctilio* was causing extensive mortality in New Zealand, Tasmania, and Australia.

Sirex noctilio was first reported in South America (in Uruguay in 1980). In 1988 it was found in the southern part of Brazil. It has caused widespread losses, and, in some local cases, has resulted in over sixty-percent mortality in pine plantations in Brazil and neighboring countries. In Brazil, the insect presently occurs in the southern states of Rio Grande do Sul, Santa Catarina, and Paraná, and covers an area of approximately 200,000 hectares of pine plantations. This region contains approximately sixty percent of the country's pine plantations. Current annual losses attributed to *S. noctilio* in this region are estimated at US$ 5 million.

There is a tremendous potential for further spread of this pest in South America, especially into Chile, which has in excess of 1.3 million hectares of Monterey pine (*Pinus radiata* D. Don.) plantations. Additionally, countries such as the United States are potentially threatened by *S. noctilio* as international trade increases.

During the first meeting of the Permanent Working Group on Silvo-Agricultural Health, held in Brazil in 1992, the southern cone countries (Argentina, Brazil, Chile, and Uruguay) identified *S. noctilio* as the pest that poses the greatest threat to conifer plantations in South America. Also in 1992, a regional conference on *Sirex noctilio* was held in Florianópolis, Brazil. It was attended by representatives from Argentina, Brazil, Chile, Colombia, Paraguay, Uruguay, United States, and Venezuela. This was the first South American Regional Conference held to address a forest pest. Recommendations from the conference included creation of a national program to control *S. noctilio* that emphasizes biological control, using a complex of parasites, nematodes, and silvicultural methods (Ciesla 1993).

Brazil is a key country for U.S. Department of Agriculture Forest Service international activities, because of its large area of forested land (13 percent of the world's closed natural forest area, more than 30 percent of the closed broad-leaved forest of the tropics, and 33 percent of the total plantation area). The U.S. Department of Agriculture Forest Service has a unique capacity to advance the science and practice of sustainable forest management. U. S. Department of Agriculture Forest Service activities within Brazil are carried out through Memorandums of Understanding (MOU) with the National Resources Institute (IBAMA) and the Brazilian Agricultural Corporation (EMBRAPA). One aspect of these MOUs is to advance restoration and maintenance of forest health by assisting in reducing the spread of insects, diseases, and weeds that could impact Brazil and the United States.

In 1994, the U.S. Department of Agriculture Forest Service formed a comprehensive agreement with CABI Bioscience, Ascot, U.K. (formerly the International Institute of Biological Control) and several Australian organizations, in order to take advantage of other international expertise in the biological control of *S. noctilio*. Through this collaboration, and recognizing the recommendation of the 1992 workshop, a program of shipments of *S. noctilio* parasitoids from Australia to Brazil was begun in 1996. This international workshop on biological control, held at EMBRAPA, Colombo, PR State, Brazil, in November 1996, provided technical underpinning for this activity. The main purpose of the workshop was to provide a forum for countries to update the exchange of information on *S. noctilio* and to provide training in parasitoid rearing, release, and evaluation methods. Participants included representatives from Brazil, Argentina, Chile, Uruguay, South Africa, Australia, and the U.K. This Proceedings provides a record of the presentations at the workshop.

In 1997, a three-year participating agreement between the EMBRAPA and the U.S. Department of Agriculture Forest Service (97-PA-002) was signed. This agreement allows the parties to continue to work cooperatively on the development of an integrated pest management program for *Sirex noctilio*.

Richard C. Reardon
Sean T. Murphy

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Exotic invasive species: a threat to forest health

Richard C. Reardon

During the early 1990s, both members of the U.S. Congress and representatives of various land management agencies expressed concerns about the present and future health of America's forests, mainly because of several catastrophic pest outbreaks and fire episodes in the West. In an effort to address these concerns, in 1990 Congress amended the Cooperative Forestry Assistance Act of 1978 to strengthen U.S. Department of Agriculture Forest Service programs concerned with forest health. Specifically, Congress amended the authorising section in the act for the Forest Health Protection program to include forest health monitoring, technology development, and promotion of management measures to protect forest health. In response, the U.S. Department of Agriculture Forest Service and the U.S. Environmental Protection Agency, in cooperation with state forestry agencies and others, implemented a nationwide Forest Health Monitoring Program. Also, in 1993, the Forest Service updated its strategic plan for addressing forest health concerns. *Healthy Forests for America's Future, A Strategic Plan* outlines goals and actions for maintaining or restoring healthy forests on national and private lands.

Forest health is recognised as a matter requiring international cooperation. Both the threat exotic forest pests pose for the U.S. and the threat forest pests native to the U.S. pose for other countries, are of concern. The United States is taking action to improve international cooperation in forest health, specifically to strengthen cooperation in operational technologies for management of insects and diseases, to provide technical assistance to strengthen program capabilities, to enhance research capabilities for protecting forest health, and to develop a knowledge base on foreign pests. For example, in 1990, the U.S. Department of Agriculture received an industry proposal to import larch logs from Siberia. In 1991, the Forest Service completed a pest risk analysis of importing Russian larch (*Larix* spp.) logs. It showed that potential damage could occur from one of several forest pests in Russia. Similar proposals were received for log importations from New Zealand and Chile. The pest risk assessment completed for New Zealand logs also found pests of concern if logs of Monterey pine (*Pinus radiata* D. Don) were to be imported without appropriate quarantine measures.

Meanwhile, land managers detected three new exotic forest pests in the United States in 1991 and 1992: the Asian strain of gypsy moth (*Lymantria dispar*), common European pine shoot beetle (*Tomicus piniperda*), and Eurasian poplar leaf rust. At the October 1993 meeting of the Insect and Disease Study Group of the North American Forestry Commission, the Study Group endorsed a proposal to prepare an exotic forest pest list for North America. Canadian, Mexican, and U.S. representatives are coordinating the development of this list, which identifies organisms significant for regulation; provides a basis for harmonisation of activities among North American countries; allows for a pro-active stance concerning new pest introduction by providing information on the biology, damage potential, and control options for a given pest; and provides the basis for developing strategies for dealing with newly introduced forest and wood pests.

Large areas of forests will continue to be susceptible to pests and will require future suppression efforts. Recent emphasis has focused on the use of biological control as the cornerstone of an integrated management approach to suppressing forest pests. For example, International Forestry Operations and the U.S. Department of Agriculture Forest Service, Forest Health Protection, are working together with Brazilian counterparts (e.g., Empresa Brasileira de Pesquisa Agropecuaria [EMBRAPA]) to develop methods for controlling, and to assist in reducing the spread of, insects, diseases, and weeds that could impact United States economic interests. Our current focus is the horntail *Sirex noctilio* F., which is native to the pine forests of Europe and has been identified as the pest that poses the greatest threat to conifer plantaions in South America.

Biological control of tropical forestry and agroforestry insect pests: a review

Sean T. Murphy

Introduction

Within the tropical region, defined here as the area lying between 27° north and south of the equator (Evans 1982), an increasing amount of land has been devoted to large- and small-scale tree plantations during the course of this century. In fact, during the last 30 years or so, afforestation and agroforestry programmes involving softwoods, hardwoods, and multipurpose trees have escalated in all parts of the tropics. This is largely because of the demands of forest industries, soil stabilisation programmes, and local fuelwood and fodder needs (Anon. 1985; Evans 1986).

Despite the fact that many tropical countries have invested in, and continue to invest in, forest monocultures, there is much evidence to show that plantations of this type seem to be at high risk from insect and other pests (Gibson and Jones 1977). To address these problems, many national forestry programmes have turned to biological control methods involving the use of natural enemies. This has been for a number of reasons. Firstly, forested regions are usually large, and thus the application of insecticides for the control of insect pests has been too expensive to contemplate by some countries. In contrast, some biological control strategies (for example, the introduction or "classical" technique) are cheap in comparison, and seem appropriate for large areas because natural enemies can usually disperse effectively by themselves. Secondly, and more generally, the long rotation time for most tree crops (30-100 years) and the infrequent application of silvicultural practices are, in principle, conducive to the use of natural enemies.

In view of the increasing economic importance of plantations to tropical countries and the problems posed by insect pests, it is necessary that pest management strategies be critically reviewed so that their value in crop protection can be properly assessed.

Several authors (for example: Hall and Ehler 1979; Hall et al. 1980; Greathead 1986; Waage and Greathead 1988; Greathead and Greathead 1992) have used the historical records of the introduction technique in biological control to assess the success of this method in agriculture and forestry on a global basis, and to determine what factors, if any, influence the chance of success. Although these broad analyses have generated some useful statistics about the introduction technique in general, they provide little information about the success of this technique under particular environmental conditions. In this paper, we review the biological control projects of all types that have been implemented against tropical forest and agroforestry insect pests and discuss the opportunities and challenges for the further use of this form of pest management in tropical forestry.

Biological control projects

Traditionally in biological control, the introduction approach (i.e., the importation and release of specialised natural enemies from the area of origin of the pest) is the preferred method for exotic pests (see DeBach 1964) whereas all approaches (introduction, inoculation, and inundation) are used for native pests. One or more of these techniques is particularly suitable for pests of seedlings, saplings, or mature trees. Here we review the different types of biological control that have been implemented against native and exotic tropical forest insect pests in turn. Information about biological control projects was obtained in two ways. First, a search was made of the database BIOCAT (Greathead and Greathead 1992). This database, put together at the

International Institute of Biological Control (IIBC, now CABI-Bioscience), contains published information (source, pest, agent, and outcome) on all introductions to date of insect natural enemies against arthropod pests. In BIOCAT, every introduction of an agent species is treated as a separate record: thus in cases where several agents have been used against a particular pest species, BIOCAT will contain an equivalent number of records. Some of the limitations of the dataset that BIOCAT is based on have been discussed by Greathead and Greathead (1992). Second, a more general search was made of CAB International's (CABI's) vast database on agriculture and forestry, to locate projects on biological control involving other agents (e.g., pathogens) and techniques (e.g., augmentation projects involving native natural enemies).

Native pests

The search on native pests showed that the number of projects that have been implemented is small; on a worldwide basis not more than about 20 species have been targeted. This is obviously only a very small proportion of the native pest spectrum worldwide. Despite the small number of projects undertaken, most regions of the tropics seem to have been active in the use of biological control methods against native pests. Most projects have been directed against pests of saplings and mature trees.

The biological control projects that have been conducted can be conveniently divided into two groups:

1. The introduction of exotic insect and microbial agents.

2. The augmentation of native insect and microbial agents.

Very few introductions of exotic insect agents seem to have been made (see Table 1).

Table 1. Introduction of agents against native tropical forestry insect pests

Agents	Pest	Tree	Country	Outcome
Insects				
Cedria paradoxa Wilkinson	*Eutectona machaeralis* (Walker)	Teak	India	Not known
C. paradoxa	*E. machaeralis*	Teak	Burma	Not known
Telenomus alsophilae (Viereck)	*Oxydia trychiata* Guenee	Cypress	Columbia	Successful control
Hymenopterous parasitoids	*Hypsipyla grandella* (Zeller)	Mahogany	Brazil & several Caribbean countries	Failed
Hymenopterous parasitoids	*Hyblaea puera* (Cramer)	Teak	India	Not known/failed
Hymenopterous parasitoids	*H. puera*	Teak	India	Not known/failed
Bacteria				
Bacillus thuringiensis Berliner	*Pachypasa capensis* (Linnaeus)	Pines	South Africa	Still being researched
B. thuringiensis	*Euproctis terminalis* Walker	Pines	South Africa	Still being researched
B. thuringiensis	*Dendrolimus punctatus* (Walker)	Pines	China	Still being researched?
Viruses				
Cytoplasmic polyhedrosis virus	*D. punctatus*	Pines	China	Still being researched

In Columbia, the geometrid defoliator *Oxydia trychiata* (Lepidoptera) has moved over from natural hardwood trees to plantations of exotic cypress where it has caused substantial damage. However, in 1975, an egg parasitoid, *Telenomus alsophilae* (Hymenoptera: Scelionidae), was imported from the USA, released, and brought the pest under control (Bustillo and Drooz 1977). A number of biological control projects undertaken in 1960s and 1970s have been attempted against the mahogany shoot borer, *Hypsipyla grandella* (Lepidoptera: Pyralidae), in various Caribbean countries and in Brazil. Twelve parasitoid species have been collected from the more diverse natural enemy complex of *Hypsipyla robusta* (Moore) in India and have been tried against the pest. Most of the parasitoids failed to establish. A few species established but failed to control the pest, and in the remaining cases the results of the releases are unknown. The reasons for the failures of these projects are unknown, but only a small proportion of the parasitoids recorded from *H. robusta* have been tried. Similar attempts were made to control teak defoliators in India and Burma in the 1930s and 1940s using parasitoids from India, but again the projects either failed or results are unknown (Rao et al. 1971).

There seem to be only two well-documented records of the augmentation of native insect natural enemies. Both these projects were undertaken in China and have involved the seasonal inoculative releases of parasitoids. In the first case (see Table 2, bottom of this page) inoculative releases of the bethylid *Sclerodermus guani* (Hymenoptera: Bethylidae) have been made for the control of the cerambycid borer *Semanotus sinoauster* (Coleoptera), a serious pest of the Chinese fir (*Cumminghamia lanceolata*) (Zhang et al. 1989). In the second case, inundative releases of the parasitoid *Trichogramma dendrolimi* (Hymenoptera: Trichogrammatidae) have been made against the widespread lasiocampid defoliator *Dendrolimus punctatus* (Lepidoptera) (Yan and Lui 1992). Both projects claim the successful seasonal control of these pests.

Table 2. Augmentation of native agents against native tropical forestry insect pests

Agents	Pest	Tree	Country	Outcome
Insects				
Sclerodermus guani Xiao and Wu	*Semanotus sinoauster* Gressit	Chinese fir	China	Successful control
Trichogramma dendrolimi Matsumura	*Dendrolimus punctatus* (Walker)	Pines	China	Successful control
Fungi				
Beauveria bassiana (Bals.) Vuill.	*D. punctatus*	Pines	China	Successful control
Metarhizium anisopliae (Metsch.)	Termites	Eucalyptus	Australia	Failed but still being researched
Viruses				
Nuclear polyhedrosis virus	*Hyblaea puera*	Teak	India	Still being researched
Nematodes				
Steinermema feltiae (Filipjev)	*Zeuzera multistrigata* Moore	*Casuarina*	China	Successful control

Attempts at using microbial agents in the tropics against forest pests are still in their infancy. The focus, to date, has been on microbial agents that can be applied as biopesticides. South Africa and China (see Table 1, page 4) are both researching the use of the bacterium *Bacillus thuringiensis* for the control of lasiocampid and lymantriid defoliators (Anon. 1993a; 1993b); China is also investigating the use of a Japanese cytoplasmic polyhedrosis virus for the control of *D. punctatus* (Chen 1992). Unfortunately, the cost of production of some of these microbes is sometimes too high for their use to be economical (Chen 1992; Anon 1993b). However, recent advances in cheap production techniques for native microbial agents has opened up ways for these agents to be augmented in a practical and economic way (see Table 2, preceding page).

In India methods are being investigated for utilising natural epizootics of a nuclear polyhedrosis virus of the teak defoliator, *Hyblaea puera* (Lepidoptera: Hyblaeidae), to control the pest in areas where the virus is absent (Nair, pers. comm.). These viruses can, for example, be applied by ground spraying crude aqueous suspensions of diseased insect larvae. This method has been effectively employed for the control of diprionid sawflies in Canada (Cunningham and De Groot 1980). Similar work is being conducted in China for the control of lepidopterous defoliators (Anon. 1993b). Research on local fungal pathogens for the control of tropical forest insects is also being conducted in some countries; these pathogens can very often be cheaply produced using local raw materials. For example, in China, aerial applications of a local strain of *Beauveria bassiana* have been used to control outbreaks of *Dendrolimus punctatus*. A mortality of 42% to 92.9% of larvae in the field was achieved (Anon 1993b).

The fungal pathogen *Metarhizium anisopliae* is being investigated in Australia for the control of termites on eucalypts. Initial trials were not successful (Hanel and Watson 1983), but a new, more pathogenic, isolate of the fungus has now been selected and is being field tested (Milner 1992). There is one example where successful control has been achieved by the use of a nematode. In China, the carpenter worm, *Zeuzera multistrigata* (Lepidoptera: Cossidae), causes damage to *Casuarina* trees by boring into the bole of the tree. To control the moth, a water suspension of the nematode *Steinernema feltiae* is applied to the frass-ejecting holes made in the tree by the pest (Xiao 1991).

In conclusion, the different techniques of biological control that have been implemented or are being researched for the control of native tropical forest pests can be considered encouraging. However, it seems that much work still needs to be done to enable insect agents to be properly utilised. Furthermore, initial work with exotic microbes suggests that production costs may limit the use of some species.

Exotic pests

An examination of the dataset in BIOCAT and additional literature indicated that projects for biological control of exotic pests have involved introductions of exotic insect natural enemies only, and these have been mostly against pests of saplings and mature trees. A summary of these introductions of agents taken from the BIOCAT database is shown in Table 3.

Table 3. Introduction of insect agents against exotic tropical forestry insect pests

Number of countries	20
Number of pest species	17
Number of agent species imported	43
Number of separate introductions of agents of all species	59
Number of establishments	20

Data from BIOCAT: Greathead and Greathead (1992)

The figures in Table 3 reflect the facts that some pests are present in more than one country, and that, in some countries, several agent species have been introduced against a single pest species. A high proportion of agent introductions has been made in Africa and the surrounding islands; in contrast, very few introductions have been made in Latin America. Of the 59 introductions, 20 (34%) have resulted in the establishment of the agent. This figure disregards whether or not the agent also brought about, or contributed to, the control of the pest in question.

Of course, of more importance to the current analysis is the success rate of projects on a pest-country basis; i.e., whether or not a particular pest in a country has been successfully controlled by the introduction of one or more agent species. Table 4 shows that a total of 35 projects have been undertaken.

Table 4. Outcome of introduction projects against exotic pests on a pest-country basis

Number of projects	35
Number of successful projects	15
Number of unsuccessful projects*	9
Number of projects where state of pests (i.e., controlled or not controlled) is unknown	11
Percentage of successful projects where outcome is known	62.5%

*Some agents may have established in these projects but not brought about control of pests. Data derived from BIOCAT: Greathead and Greathead (1992)

Of these, the outcomes are unknown in a high proportion (31%) of cases. Where the outcome is known, approximately 62% of introduction projects can be counted as successful.

Some examples of particularly successful introduction-type biological control projects against exotic tropical forestry pests are summarised in Table 5 .

Table 5. Examples of successful introduction projects against exotic tropical forestry insect pests

Agents	Tree	Agent	Country	Reference
Cinara cronartii Tissot & Pepper	Pines	*Pauesia cinarovora* Marsh	South Africa	van Rensburg (1992)
Coniperus scutellatus Gyllenhal	Eucalypts	*Anaphes nitens* (Girault)	Kenya South Africa St. Helena Madagascar Mauritius	Greathead (1971)
Orthesia insignis Browne	Ornamental Trees	*Hyperasis patherina* (Fursch)	Kenya Tanzania	Greathead (1971)
Pineus sp.	Pines	*Leucopsis tapiae* Blanchard	Uganda	Culliney et al (1988)
Trachymela tincticullis Blackburn	Eucalypts	*Enoggera reticulata* Naumann	Hawaii South Africa	Tribe (1992)

In an analysis of all BIOCAT records (agricultural and forestry), Greathead and Greathead (1992) showed that the Homoptera have been the most frequently targeted order for the introduction technique. It is within this order that most successes (success being judged on the basis of the number of cases where the introduction of an agent resulted in control) have been achieved. Unfortunately, the dataset on introduction against tropical forest insect pests is not large enough to conduct a similar, meaningful analysis. Further examination of the dataset indicates, however, that most introductions (see Table 6) have been focused on pines, eucalypts, and Leucaena. This is because tree species within these genera have been widely planted throughout the tropics and have, therefore, attracted more pest species than other tree genera.

Table 6. Introduction of agents against exotic insects in relation to tree genera

Pines	17
Eucalyptus	9
Leucaena	10
Other (some 7 genera)	23

Data from BIOCAT: Greathead and Greathead (1992)

The insect agents used in introduction projects against tropical forest insect pests have most been species from the orders Hymenoptera and Coleoptera (seeTable 7). This is consistent with more general analyses of natural enemy introductions (Greathead and Greathead 1992).

Table 7. Agents used in introductions against tropical forestry insect pests

Order	Number of species	Number of introductions
Hemiptera	5	6
Neuroptera	1	5
Diptera	5	8
Coleoptera	14	25
Hymenoptera	14	20

Data from BIOCAT: Greathead and Greathead (1992)

A summary of some less successful introduction projects is shown in Table 8 (bottom of this page).

All of the less-successful cases concern homopteran pests. In the first three, successful control of the pest has been achieved in another part (or several other parts) of the world. Possible reasons for failure in the particular instances listed seem to include the selection of an inferior agent or an inadequate release method. In the case of the project against *Orthezia insignis* in Malawi, the actual success of the project is somewhat in dispute, largely because the impact of the agent, *Hyperaspis patherina*, was inadequately monitored (Greathead 1971).

Table 8. Examples of 'unsuccessful' introduction projects against exotic tropical forestry insect pests

Pest	Tree	Agent	Country	Reference	Comments on project
Heteropsylla cubana Crawford	Leucaena	*Curinus coeruleus* Mulsant	India Indonesia	Jalahi & Singh (1989) Waterhouse & Norris (1987)	Try another agent? (parasitoid)
Icerya purchasi Maskell	Pines	*Cryptochetum iceryae* Williston	Sao Tome India	Greathead (1971) Rao et al (1971)	Try another agent? [Rodolia cardinalis (Mulsant)]
Orthezia insignis Browne	Ornamentals	*Hyperaspis patherina* (Fursch)	Malawi	Greathead (1971)	Success/failure in dispute. Precise monitoring required.
Pineus ?boerneri Annand	Pines	*Leucopis* spp.	Kenya	Owuor (1991)	Agents successful elsewhere. New release method required.

In summary, it seems that the introduction approach for exotic tropical forestry pests has been a particularly successful strategy. An examination of "failed" projects has indicated a number of reasons why these projects might have failed, but none of the problems identified pose a constraint on the further use of the introduction technique. One shortcoming of past work, though, is the large number of projects where the results of the releases are unknown.

Discussion

Native pests of tropical plantation trees are extremely numerous in many parts of the tropics. In some regions, notably Asia, some species are regional in distribution and cause a vast amount of damage to their host trees. It is ironic, therefore, that so little work on biological control has been undertaken. Given that the different methods of biological control implemented against some of these pests show much promise, there is a vast opportunity to apply these techniques to other forestry pests throughout the tropics. The use of exotic insect agents for the control of native pests is, in itself, an under-exploited technique, but in principle has great potential (Carl 1982). Clearly, though, more emphasis needs to be placed on agent selection. The opportunity for developing the use of local microbial agents (for example, fungal pathogens) also looks promising, but given that these agents have to be mass produced before application, their use over large forested areas may be limited. They may have more potential for the control of pests of seedlings or pests of trees grown in small woodlots such as in agroforestry systems. Such an approach may also be useful for the control of exotic pests in these systems. Examples of native pests where urgent work on their biological control is needed include: the teak defoliator (*Hyblaea puera*), the teak skeletonizer *Eutectona machaeralis* (Lepidoptera: Pyraustidae), and pine shoot borers, *Dioryctria* spp. (Lepidoptera: Phycitidae), in Asia; and the pan-tropical mahogany shoot borers (*Hypsipyla* spp.) and termites of various species (Isoptera: Macrotermitinae) which are problematic throughout the tropics.

Workers on the biological control of native pests face several major challenges. First, there is an increasing need for biological control to be integrated with silvicultural and tree-breeding approaches to pest control; in other words, for biological control to become part of an integrated pest management (IPM) approach to pest problems. Reasons for this are:

1. Very often different approaches to pest control run tangetially to one another, which results in conflicting advice about which strategy should be best adoped for a particular pest problem.

2. Some silvicultural practices and some resistant tree types can be detrimental to insect natural enemies (Hebert et al. 1989; Speight and Wainhouse 1989). For this reason alone, it is necessary to integrate research projects that focus on different techniques.

3. Some degree of resistance within a tree species, together with the right silvicultural practices and the introduction and/or augmentation of natural enemies, may provide acceptable levels of control where any one method alone is not effective by itself (Speight and Wainhouse 1989).

Second, although introduction and augmentation strategies appear attractive for the control of native pests of tropical plantations, these activities are, nonetheless, reactive; i.e., action is only taken once a problem has developed. A better goal might be to try to prevent the risks of native pest outbreaks from occurring in the first place through the conservation of natural enemies. This subject has received little attention in forestry.

Many opportunities exist for the further use of the introduction technique for the control of exotic pests. Some initiatives are already underway. For example, two regional pests of conifers in southern and eastern Africa, the cypress aphid, *Cinara cupressi*, and the pine woolly adelgid, *Pineus ?boerneri* (Homoptera: Adelgidae), are the subjects of a regional classical biological control project being undertaken by CABI-Bioscience (formerly IIBC) (Murphy et al. 1994). Other examples include projects against the neem scale, *Aonidiella orientalis* (Newstead) (Homoptera: Diaspidae), in Nigeria, and the leucaena psyllid, *Heteropsylla cubana*, in East Africa. However, much more remains to be done. For pan-tropical pests, insect agents that have been successfully employed in one region or continent could be transferred to other regions where the pest remains uncontrolled. For example, the wood wasp, *Sirex noctilio* Fabricius (Hymenoptera: Siricidae), has been successfully controlled in Australia by the use of a nematode and ichneumonid parasitoids (Berryman 1986). *Sirex noctilio* is still, however, a major problem in many pine-producing countries in South America (Pedrosa-Macedo 1990). Although some agents have been introduced into Brazil and Uruguay for trial (Vibrans 1991), efforts need to be made to introduce all of the agents that are known to be important; otherwise the successful control of the wood wasp is unlikely to be achieved.

There are also several exotic pests which are excellent targets for biological control through the use of insect natural enemies against which no action seems to be have been taken. The reasons for this are unclear, but one reason might be that the impact of these pests on their tree hosts has not been quantified. Examples include the Australian eucalyptus psyllid, *Ctenarytaina eucalypti* (Maskell) (Homoptera), in Africa (Kenya Forestry Research Institute, unpublished data), the North American scolytid bark beetles, *Ips calligraphus* (Germar) and *Ips grandicollis* Eichhoff (Coleoptera), that attack pines in Jamaica (Garraway 1986), and pyralid shoot borer, *Rhyacionia frustrana* (Comstock) (Lepidoptera), that originates from the eastern USA and attacks pines in Central America (Ford 1986). All of these species, apart from *I. calligraphus*, have been or are currently the subjects of very promising biological control projects in temperate regions.

Another opportunity that may be appropriate to the introduction approach relates to the use of mirobes. To date, the focus of introduction projects has been on the use of insect agents, mostly hymenopterous parasitoids and coccinellid beetles. However, recent research has demonstrated the potential of microbial agents for the control of insect and other pests. Some of these agents, e.g., entomophthoralis fungi, are particularly suitable for the introduction approach because they do not need to be mass cultures. These fungi may be useful against forest pests such as aphids or defoliators. Consideration should also be given to the possible augmentation of local microbes against exotic pests of seedlings.

A number of challenges exist which future introduction projects against exotic pests need to take into account. For example, although this technique has been very successful, an analyses of "failed" projects has indicated that improvements in the success rate of projects might be made if greater effort were put into factors such as agent selection and the monitoring of releases. Pschorn-Walcher (1977), in a review of the introduction approach in forest insect pest management, argues that pre-introduction studies on agents for the control of these types of pests are particularly appropriate, because of the complex nature of the structure and diversity of the natural-enemy complexes associated with forest insects. Besides this, the fact that the results of a high proportion of introduction projects are unknown suggests that a much greater effort needs to be channelled into the monitoring of releases. In addition to these points, and as already discussed for native pests, there is an increasing need for the introduction approach to be integrated with silvicultural and tree-breeding approaches to pest control.

In conclusion, tropical plantations, large and small, are important to the economies of many countries and to the livelihoods of rural people. In many instances, the plantations have been established or developed with the support of international funding, and thus cheap and efficient ways must be found to help protect these man-made forests against the invasions of insect and other pests. On the basis of general considerations and examination of the records of the use and outcome of biological control in tropical forestry, we suggest that this method of control is appropriate for the management of many native and exotic insect pests. However, there is a need, in some instances, to integrate biological control with other methods of control. For native pests there is also a need to look more closely at the conservation of natural enemies so that pest management for this group of pests becomes more a proactive rather than a reactive exercise.

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References

Anon. 1993a. Annual report of the Plant Protection Research Institute. Pretoria, South Africa: Plant Protection Research Institute. 11 p.

Anon. 1993b. A general introduction to the research achievements on the major forest insects in China. Report. Beijing, China: Chinese Academy of Forestry. 8 p.

Berryman, A. A. 1986. Forest insects. New York and London: Plenum Press. 279 p.

Bigger, M. 1988. The insect pests of forest plantation trees in the Solomon Islands. Chatham, UK: Overseas Development Natural Resources Institute. 190 p.

Bustillo, A. E.; Drooz, A. T. 1977. Co-operative establishment of a Virginia (USA) strain of *Telenomus alsophilae* on *Oxydia traychiata* in Colombia. Journal of Economic Entomology. 70: 767-770.

Carl, K. P. 1982. Biological control of native pests by introduced natural enemies. Biocontrol News and Information. 3:191-200.

Chen, C. 1992. A general survey using cytoplasmic polyhedrosis virus to control masson pine caterpillar *Dendrolimus punctatus* in China. Report. Beijing, China: Chinese Academy of Forestry. 112 p.

Cock, M. J. W., ed. 1985. A review of biological control of pests in Commonwealth Carribean and Bermuda up to 1982. Technical Comunication No. 9 of the Commonwealth Institute of Biological Control. Slough, UK: Commonwealth Agricultural Bureaux. 218 p.

Cunningham, J. C.; De Groot, P. 1980. *Neodiprion lecontei* (Fitch) redheaded pine sawfly (Hymenoptera: Diprionidae) In: Kelleher, J. S.; Hulme, M. A., eds. Biological control programmes against insects and weeds in Canada. Slough, UK: Commonwealth Agricultural Bureaux. 323-239.

Culliney, T. W.; Beardsley, J. W., Jr.; Drea, J. J. 1988. Population regulation of the Eurasion pine adelgid (Homoptera: Adelgidae) in Hawaii. Journal of Economic Entomology. 81: 142-147.

DeBach, P., ed. 1964. Biological control of insects pests and weeds. London: Chapman and Hall. 844 p.

Evans, J. 1982. Plantation forestry in the tropics. Oxford, UK: Clarendon Press. 432 p.

Evans J. 1982. Plantation forestry in the tropics: trends and prospects. The International Tree Crops Journal. 4: 3-15.

Ford, L. B. 1986. The Nantucket pine-tip moth. Turrialka. 36: 245-248.

Garraway, E. 1986. The biology of *Ips calligraphus* and *Ips grandicollis* (Coleoptera: Scolytidae) in Jamaica. Canadian Entomologist. 188: 113-121.

Gibson, I. A. S.; Jones, T. 1977. Monoculture as the origin of major forest pests and diseases, especially in the tropics and southern hemisphere. In: Cherrat, J. M.; Sagar, G. R., eds., Origin of pests, parasite, disease and weed problems. Oxford, UK: Blackwell Scientific Publications. 413 p.

Greathead, D. J. 1971. A review of biological control in the Ethiopian region. Technical Communication No. 5. of the Commonwealth Institute of Institute of Biological Control. Slough, UK: Commonwealth Agricultural Bureaux. 162 p.

Greathead, D. J. 1986. Parasitoids in classical biological control. In: Waage, J. K.; Greathead,

D. J., eds. Insect parasitoids. 13th Symposium at the Royal Entomological Society of London. London, UK: Academic Press. 389 p.

Greathead, D. J.; Greathead, A. H. 1992. Biological control of insect pests by insect parasitoids and predators: the BIOCAT database. Biocontrol News and Information. 13: 61-68.

Hall, R. W.; Ehler, L. E. 1979. Rate of establishment of natural enemies in classical biological control. Bulletin of the Entomological Society of America. 25: 280-282.

Hall, R. W.; Ehler, L. E.; Bisabri-Ershadi, B. 1980. Rate of success in classical biological control of arthropods. Bulletin of the Entomological Society of America. 26: 111-114.

Hanel, H.; Watson, J. A. L. 1983. Preliminary field tests on the use of *Metarhizum anisopliae* for the control of *Nasutitermes exitiosus* (Hill) (Isoptera: Termitidae). Bulletin of Entomological Research. 73: 305-313.

Hebert, C.; Cloutier, C.; Regnierre, J. 1989. Factors affecting the flight activity of *Winthemia furniferanae* (Diptera: Tachinidae). Environmental Entomology. 19: 293-302.

Jalali, S. K.; Singh, S. P. 1989. Release and recovery of an exotic coccinellid predator *Curinus coeruleus* (Huls.) on subabul psyllid, *Heteropsylla cubana* Crawf. in India. Journal of Insect Science. 2: 58-159.

Milner, R. J. 1992. Selection and characteristics of *Metarhizium anisopliae* for control of soil insects in Australia. In: Lomer, C. J.; Prior, C., eds. Biological control of locusts and grasshoppers. Proceedings of a workshop, International Institute of Tropical Agriculture. Cotonou, Benin; 29 April-1 May 1991. Wallingford, UK: CAB International. 200-207.

Murphy, S. T.; Chilima, C. J.; Cross, A. E.; Abraham, Y. J.; Kairo, M. T. K.; Allard, G. B.; Day, R. K. 1994. Exotic conifer aphids in Africa: ecology and biological control. In: Leather, S. R.; Watt, A. D.; Mills, N. J.; Walters, K. F. A., eds., Individuals, populations and patterns in ecology. Andover, UK: Intercept. 233-242.

Owuor, A. L. 1991. Exotic conifer aphids in Kenya, their current status and options for management. In: Exotic aphid pests for conifers: a crisis in African forestry. Proceedings of a workshop, Kenya Forestry Research Institute. Muguga, Kenya; 3-6 June 1991. Rome, Italy: Food and Agriculture Organisation of the United Nations. 58-63.

Pedrosa-Macedo, J.H. 1990. Protection of forests in the tropics: regional priorities for Latin America. Unpublished report presented at IUFRO's XIX congress. Montreal, Canada; August 1990. 8 p.

Pschorn-Walcher, H. 1977. Biological control of forest insects. Annual Review of Entomology. 22: 1-22.

Rao, V. P.; Ghani, M. A.; Sankaran, T.; Mathur, K. C. 1971. A Review of the biological control of insects and other pests in south-east Asia and the Pacific region. Technical Communication No. 6 of the Commonwealth Institute of Biological Control. Slough, UK: Commonwealth Agricultural Bureaux. 49 p.

Speight, M. R.; Wainhouse, D. 1989. Ecology and management of forest insects. Oxford, UK: Clarendon Press. 374 p.

Tribe, G. D. 1992. Neutralisation of the eucalyptus tortoise beetle. Plant Protection News. 29: 5.

Van Rensburg, N. J. 1992. The black pine aphid: a success story. Plant Protection News. 28: 5-6.

Vibrans, A. 1991. Zur biologischen bekanpfung der holwespe (*Sirex noctilio* F.) In: Brazilien Forstarchiv. 62: 97-99.

Waage, J. K.; Greathead, D. J. 1988. Biological control: Challenges and opportunities. Philosophical Transactions of the Royal Society of London, B. 318: 111-128.

Waterhouse, D. F.; Norris, K. R. 1987. Biological control: Pacific prospects. Melbourne, Australia: Inkata Press. 454 p.

Xiao, G., ed. 1991. Forest insects of China. Beijing, China: China Forestry Publishing House. 1362 p.

Yan, J.; Lui, H. 1992. A review of development of studies on utilising parasites and predators of forest pests in China. Shaami Forest Science and Technology. 2: 24-28.

Zhang, L.; Sung, S.; Huang, H.; Li, X.; Qui, L. 1989. Biological control of a wood borer in China. IPM Practitioner. XI: 5-7.

Sirex management: Silviculture, monitoring, and biological control (an introduction)

John Madden

Although the subject of this workshop is "Training in the Control of *Sirex noctilio* by the use of parasitoids", nematodes play a complementary role, and the rigorous execution of silvicultural practices and management at the correct time is necessary. It is appropriate therefore to reflect on the early attempts to control *Sirex* within the context of the host tree and the dynamics of *Sirex* infestation and outbreak behavior. This discussion is extended to highlight key strategic aspects of *Sirex* management which, in practice, are considered more fully in subsequent contributions.

A number of hypotheses have been advanced as to the cause of *Sirex* outbreaks. Rawlings and Wilson (1949) feature the incidence of drought and tree suppression as causal factors. These authors also stress the importance of sound silviculture. In a review of major outbreaks in Australasia, Madden (1988) found that most outbreaks were characterized by managerial or environmental events which preceded the damage attributed to *Sirex* and which negatively affected plantation performance at the individual tree level. Such events included thinning and harvest operations during the *Sirex* flight season, fire (in the case of outbreaks at Mt. Gambier), and wind damage, as experienced at two sites in Tasmania.

The capacity of the host tree, Monterey pine (*Pinus radiata* D. Don), to progressively reduce the activity of its physiological systems to basal metabolic levels in response to increasing soil-water deficits (Rook et al. 1976) strongly suggests that drought per se is not a causal factor. The response of the tree to either progressive drought or low availability of water due to intense root competition in overstocked stands is an adaptation which favours survival during periods of environmental stress.

But the weakening effects of fire or the accumulation of slash resulting from thinning or harvesting operations during the *Sirex* flight season, and excessive damage and slash arising from forest operations during the flight season, can provide a supply of host material suitable for *Sirex* larval development. In addition, the occurrence of high-intensity rainfall over a short period of time can briefly terminate the period of aestivation, which, in the absence of any immediate compensatory mechanism, results in acute physiological stress to individual trees, and renders them attractive to attack, inoculation with both mucus and *Amylostereum* arthrospores, oviposition, and tree death. Such conditions are aggravated in unthinned stands. The process can be simulated experimentally by high girdling, herbicide poisoning, or the injection of the *Sirex* mucus into living trees.

In the presence of an abundance of suitable host material, a *Sirex* population will grow, and as numbers of horntails increase, any latent resistance can be overcome by the mucus. This renders a tree attractive to *Sirex* infestation within and between seasons. An infestation may remain undetected for some time, after which the momentum generated by numbers and the availability of hosts will result in an epidemic outbreak of tree deaths. The epidemic outbreak is limited only by the absence of suitable host material.

Given the above scenario, which applies in fact if not necessarily in detail, what strategy is most appropriate to develop and implement for *Sirex* control?

The plantation is a resource that can be located and exploited by *Sirex* females either arising from infested material or migrating from a previously infested area. Exploitation generates numbers of horntails which then exert pressure on the plantation estate. If this estate has many units, e.g., several unthinned stands, then ultimately the numbers of insects produced will increasingly exert greater pressure via the mucus effect and overcome more and more trees. The outbreak will end only when the supply of susceptible trees is exhausted.

But if the plantations are properly pruned and thinned, the availability of suitable resource for exploitation by *Sirex* will be lacking, and the reproductive and inoculation potential of the horntail will be restricted. Trap trees can affect localized and known units of infestation that can either be destroyed or utilized for production of parasitoids and nematodes. These agencies, in turn, will add to the general environmental resistance to increases of *S. noctilio*, and collectively to the containment of pest numbers to sub-economic levels.

An operational strategy should address the following points:

1. Ensure tree health through good site selection and preparation, use of proven seedling stock, and attending to pruning and thinning schedules so as to attain a height/diameter ratio consistent with optimum tree growth and form. (Attention to these qualities is of fundamental importance to any strategy, for they maximise the potential resistance of individual trees, which, in turn, acts to retard *Sirex* increase.)

2. Plantation areas should be systematically monitored for their health, particularly after periods of strong winds, rains, and other catastrophic events.

3. Frequent estimates of tree growth (e.g., diameter increments) should be made, to relate short-term changes with respect to environmental variables, particularly rainfall and levels of available soil water. (Such an activity would provide invaluable information on intra- and inter-site differences, infestation/infection levels of pests and diseases, and overall stand performance. At the same time it would remove much of the conjecture as to the possible cause of outbreaks.)

4. Trap trees should be established even in the apparent absence of the pest. These trees should be carefully examined on a routine basis. (Much remains to be learned about the dosages of herbicides required for different tree sizes and the rate of tree morbidity, for these factors relate to the drying out of the tree, which in turn impacts on the suitability of the tree as a resource for *Sirex* and, in turn, for the parasitoids and nematodes.)

5. Parasitoids and nematodes should be established and sustained to supplement the resistance delivered by good silvicultural management.

6. Ideally, operations should be executed neither during the *Sirex* flight season nor in the period immediately preceding it (Spring-Summer). If operations must proceed at these times, then all slash must be buried, destroyed, or removed, and the areas must be closely monitored and sampled for possible invasion by *Sirex*.

References

Coutts, M. P. 1969. The mechanism of pathogenicity of *Sirex noctilio* on *Pinus radiata*. I. The effects of the symbiotic fungus *Amylostereum* sp. (Thelephoraceae). Australian Journal of Biological Science. 22: 915-924.

Coutts, M. P. 1969. The mechanism of pathogenicity of *Sirex noctilio* on *Pinus radiata*. II. Effects of *S. noctilio* mucus. Australian Journal of Biological Science. 22: 1153-1161.

Fong, L. K.; Crowden, R. K. 1973. Physiological effects of the mucus from the woodwasp *Sirex noctilio* on the foliage of *Pinus radiata* D.Don. Australian Journal of Biological Science. 26: 365-378.

Gaut, I P. C. 1969. Identity of the fungal symbiont of *Sirex noctilio* in Tasmania. Australian Journal of Biological Science. 22: 905-915.

Madden, J. L. 1971. Treatments which render the host tree, *Pinus radiata* D.Don attractive to the woodwasp, *Sirex noctilio* F. Bulletin of Entomological Research. 60 (3): 47-52.

Madden, J. L. 1975. An analyses of an outbreak of the woodwasp, *Sirex noctilio* F. (Hymenoptera, Siricidae), in *Pinus radiata*. Bulletin of Entomological Research. 65: 491-500.

Madden, J. L. 1977. Physiological reactions of *Pinus radiata* to attack by woodwasp, *Sirex noctilio* F. (Hymenoptera: Siricidae). Bulletin of Entomological Research. 67: 405-425.

Madden, J. L. 1988. *Sirex* in Australasia. In: Berryman A. A., ed. Dynamics of forest insect populations: patterns, causes and management strategies. New York: Plenum Publishing Corp. Chapter 20. 407-429.

Rawlings, G. B.; Wilson, Nancy M. 1988. *Sirex noctilio* as a beneficial and destructive insect to *Pinus radiata* in New Zealand. New Zealand Journal of Forestry. 6(1):1-11.

Rook, D. A.; Swanson, R. H.; Cranswick, A. M. 1976. Reaction of radiata pine to drought. In: Proceedings of the Soil and Water Symposium. New Zealand, DSIR: Palmerston North. 55-58.

Spradbery, J. P. 1973. A comparative study of the phytotoxic effects of siricid woodwasps on conifers. Annual of Applied Biology. 75: 309-320.

Overview of *Sirex* control and development of management strategies in Australia

John Madden

Sirex noctilio F. has caused economically significant losses of Monterey pine, (*Pinus radiata* D.Don) trees in New Zealand and Australia. It was discovered in plantations of loblolly pine (*P. taeda* L.), slash pine (*P. elliottii* Engelm.), and *P. radiata* in Uruguay in 1980 and, more recently, in Argentina and Brazil; it is a current threat to the pine forests of Chile. It was also detected in pine stands near Capetown, South Africa, in 1990.

A review of specific instances of economic loss of trees attributable to *Sirex* indicates that outbreaks are most often characterized by lack of attention to three basic operational events: adherence to thinning schedules, regular monitoring of the plantation estate, and, once its presence is detected, the early introduction and establishment of natural enemies, notably entomogenous nematodes and parasitoids.

Initial attack and tree mortality occur most often in unthinned and generally neglected stands. Initial detection is often delayed until the infestation has expanded to the extent that tree mortality, and its cause, are obvious. If the introduction and release of natural enemies is left too long, their capacity to increase and disperse in time to affect the infestation is limited. Consequently tree mortality may continue to increase until the supply of susceptible trees is exhausted; only then can the *Sirex* population be said to be under control.

Summary of attempts undertaken in Australasia to control *Sirex noctilio* F.

New Zealand

Outbreak. Although *Sirex noctilio* was detected in Canterbury in 1900, it was not until the late 1920s and, in particular, 1946 to1951, that its destructive potential was recognized, when 30 percent of a 120,000-hectare *P. radiata* estate was destroyed.

Response. Introduction of the parasitoids *Ibalia leucospoides* (Hochenwarth) and *Rhyssa persuasoria* (Linnaeus) occurred during 1928 through 1929, and in 1931, using the services of the then Imperial Institute of Entomology (later the Commonwealth Institute of Biological Control and now the International Institute of Entomology).

Outcomes: *Rhyssa persuasoria* sent as adults were directly released into the field and became established. In contrast *I. leucospoides*, dispatched as parasitized host larvae, were severely weakened during the sea transport from England, and few survived. Successful breeding and release of this species did not occur until 1950-1951. Initial releases were confined to the Canterbury Plains area, with subsequent introduction into forests in the Kaingaroa area during the 1940s. Their presence did not affect the outbreak which developed in both districts from attack on predominantly unthinned stands. The *Sirex* nematode was discovered in the early 1960s.

Australia: Pittwater, Tasmania, 1952

Outbreak: *Sirex noctilio* was detected in an 1,100-hectare *P. radiata* plantation, with mortalities within compartments ranging from 30 to 80 percent.

Response: Federal authorities attempted to eradicate the pest and quarantine the export of pine products from Tasmania. The Tasmanian Department of Agriculture imported and released *Ibalia leucospoides* and *Rhyssa persuasoria* from New Zealand.

Outcomes: The eradication attempt failed, as top branches were not destroyed and served to provide refuge for developing larvae. Salvage operations based on "felling from the top" (i.e., the exclusive removal of the more dominant trees) damaged understory trees and provided ideal host material for *Sirex* emergents. The local pine industry was handicapped for nine years by quarantine restrictions.

Australia: Mornington Peninsula, Victoria, 1961-1962

Outbreak: *S. noctilio* was discovered in *P. radiata* windbreaks.

Response: The Commonwealth government immediately formed the National *Sirex* Council and implemented a two-part strategy of "search and destroy" in Victoria and research in Tasmania. Research objectives were addressed by the Commonwealth Scientific and Industrial Research Organization (CSIRO), Division of Entomology, Forest Research Institute (now CSIRO Division of Forestry) and the Waite Agricultural research Institute of the University of Adelaide. General research projects areas were:

- CSIRO: Biological control and the biology and behavior of *Sirex* and its natural enemies
- FRI: Silviculture, tree breeding, and resistance
- Waite: Fungal taxonomy and chemical control

Outcomes: The "search and destroy" strategy was conducted in Victoria from 1962 to 1974. Initial activity was based on a high level of ignorance of the basic insect/host-tree problem. Indiscriminate felling and the destruction of non-host trees was followed by public indignation. *Sirex* occurrence continued to expand. The need for a biological control strategy was recognized in early 1972, when mass-breeding facilities for parasitoids and nematodes were established within the Keith Turnbull Research Laboratory at Frankston, Victoria. The demand for biocontrols intensified at the time of the Delatite outbreak of 1979, and the discovery of *Sirex* in South Australia in 1980 and New Wales in 1981.

By the mid 1970s a considerable number of key research findings had been achieved, including identifying the symbiotic fungus; discovering factors influencing host-tree attractiveness and susceptibility; describing the basic biologies, behaviors, and ecologies of *Sirex* and key parasitoids; and identifying the *Sirex* nematode. In application, the impact of the parasitoids and the nematode on field populations of *Sirex* had been assessed; parasitoids had been released; trap trees had been established in Victorian forests; and mass culture of nematodes had been achieved.

In 1977, the National *Sirex* Council was disbanded. The Pests and Diseases Committee of the Australian Forestry Council was formed in its place. Formal research terminated in 1978, with monitoring and local projects being conducted and funded solely by state agencies. For example, attempts to control the Delatite outbreak in Victoria in 1979 were directed toward increasing the effectiveness of biocontrol agents, and nematodes were introduced into plantations at Dartmoor, Western Districts, Victoria.

Australia: Mt. Gambier and districts in South Australia, 1980-1991

Outbreak: In 1980, *Sirex* was detected in major pine plantations at Mt. Gambier, South Australia, and parasitoids were introduced into the then small areas of infestation between 1980 and 1984.

Response: Infested trap trees were inoculated with nematodes in 1985. In 1986 *Sirex* was increasingly detected throughout the adjacent areas of southeast South Australia and southwest Victoria, and, in increasingly larger numbers, in unthinned plantations older than 10 years.

Outcomes: Despite the introduction of both parasitoids and nematodes, an estimated 1.8 million trees were killed each year in the "Green Triangle" in 1987 and 1988. By 1989, *Sirex* had spread to forests adjacent to the state capital, Adelaide. The cost of attempts to control *Sirex* ranged from A$1.3 million in 1987 to greater than A$100,000 in 1989. The financial loss in royalties alone during the peak two years of the outbreak was approximately A$5-10 million.

These damaging outcomes in South Australia were influenced by poor aerial monitoring efficiency, poor interpretation and qualification, and the lack of on-ground inspection and verification. In addition, the nematode's effectiveness had declined in mass culture because of a reduction in the quality of its fungal food substrate. In some instances, nematode parasitism had fallen from 90 plus to less than 40 percent. Consequent to these events, the Australian Forestry Council convened a National *Sirex* Coordination Committee to address the inadequacies of previous attempts to control *Sirex* by developing a national strategy that would be subject to annual review. The strategy was released for augmentation by the forest industry in winter, 1990. The essential elements of the strategy are paraphrased at the end of this document and are detailed in the following document: Haugen, D. A.; Bedding, R. A.; Underdown, M. G.; Neumann, F. G. 1990. National strategy for control of *Sirex* in Australia. Australian Forest Grower 13(2). 8 p.

In summary, most *Sirex* outbreaks in Australasia have occurred in 15-to-20-year-old, unthinned, and heavily overstocked (more than 16,000 to 17,000 stems per hectare) plantations, the result of delayed thinning schedules caused by either poor management or depressed markets for the resource. In addition, the lack of rigorous and sustained monitoring of forest health and its relationship to weather effects has led too often to delays in implementing concerted control attempts. In almost all instances the introduction of biological control agents did not occur until after significant economic loss of trees had occurred. The following outline summarizes the essential elements of a general *Sirex* management strategy with specific details as it applies to Australia, being found in Haugen et al. (1987)

Essential elements of a *Sirex* control strategy

Prior to detection of *Sirex*, forest health procedures should be in place, i.e., quarantine, appropriate thinning, monitoring, and training of operations personnel. If *Sirex* is known to be present in districts adjacent to forest areas, then trap trees should be established three to four weeks before the *Sirex* flight season is expected.

Following *Sirex* detection, these procedures must be adopted:

1. Map and monitor tree mortality.
2. Prioritize a thinning program.
3. Intensify trap-tree establishment.
4. Release any cultured or field-collected parasitoids in areas of known *Sirex* infestation.
5. Increase nematode production for subsequent field inoculation strategy involving both naturally attacked and trap trees.
6. Confirm parasitoid establishment, and determine effectiveness of existing biocontrols.

These procedures should be ongoing:

1. Monitor *Sirex* activity in plantations by means of surveys and trap trees.
2. Evaluate the status of parasitoids and nematodes.
3. Supplement existing levels of parasitism by the culture and release of biocontrol agents.
4. Review culturing procedures for both the *Sirex* fungus and the nematode; assess the performance of the latter at regular intervals.

References

Bedding, R. A.; Akhurst, R. J. 1974. Use of the nematode *Deladenus siricidicola* in the biological control of *Sirex noctilio* in Australia. Journal of the Australian Entomological Society. 13: 129-135.

Haugen, D. A. 1990. Control procedures for *Sirex noctilio* in the Green Triangle: review from detection to severe outbreak (1977-1987). Australian Forestry. 53 (1): 24-32.

Haugen, D. A. ; Underdown, M.G. 1990. *Sirex noctilio* control program in response to the 1987 Green Triangle Outbreak. Australian Forestry. 53 (1): 33-40.

Haugen, D. A.; Bedding, R. A.; Underdown, M. G.; Neumann, F. G. 1990. National strategy for control of *Sirex noctilio* in Australia. In: Borough, C., ed., Australian Forest Grower 13(2). 8 p. (Special liftout).

Neumann, F. G.; Morey, J. L.; McKimm, R. J. 1987. The *Sirex* wasp in Victoria. Bulletin N°. 29. Melbourne: Department of Conservation, Forests and Lands. 41 p.

Madden, J. L. 1975. An analysis of an outbreak of the woodwasp, *Sirex noctilio* F. (Hymenoptera: Siricidae), in *Pinus radiata*. Bulletin of Entomological Research. 65: 491-500.

Taylor, K. L. 1981. The *Sirex* woodwasp: ecology and control of an introduced forest insect. In: Kitching, R. L.; Jones, R. E., eds. The Ecology of pests: some Australian case histories. 231-248.

Zondag, R. Control of *Sirex noctilio* with *Deladenus siricidicola* Bedding. New Zealand Journal of Forest Science. 1: 5-14.

Practical aspects of *Sirex* control

John Madden

Attempts to control *Sirex noctilio* will be successful only if all forest managers pay full attention to the following key aspects: silviculture; monitoring of tree survival; and the introduction, release, and evaluation of biocontrol agents.

If plantation establishment is based on the use of healthy seedlings of the appropriate cultivars in medium-to-high quality, fertile sites, then good potential growth is ensured. However, the original plantation design should also include a programme for different cultural events, e.g., fertilizer regimes, weed control, and schedules for pruning and thinning. The decision to prune or thin must be based primarily on the goal of maximizing future growth and yield. It should not, if practical, be delayed or postponed solely on the basis of marketing convenience. Consequently, forest managers must endeavor to convince senior management of the potential risk of compounded financial loss if the silvicultural programme is not strictly adhered to and if overstocking continues.

Secondly, all operations personnel must be convinced of the importance, with respect to forest health, of early detection of *Sirex* and other pests and diseases. Early detection can only be achieved through a regularized and efficient monitoring system. For example, a plantation estate can be divided into a number of zones on the basis of accessibility, and individuals can be given responsibility for systematic inspection of and reporting about those zones. Conveniently sized inspection blocks containing a minimum number of at least 100 trees should be established at an intensity of four to five blocks per 100 hectares.

Following detection of *Sirex*, a network of five to ten "trap" trees can be established conveniently within each inspection block of trees throughout each estate or zone, to provide the potential foci for *Sirex* attack at known locations.

After *Sirex* attack has taken place, the infested trap trees and any other trees in the immediate vicinity can be exploited for propagation of the *Sirex* nematode, *Beddingia (=Deladenus) siricidicola*, and as specific sites for the release of parasitoids. Every detection should be followed by a concerted inspection of all trees within and between each site to obtain an appreciation of the incidence of attack and tree mortality.

It is imperative that both nematodes and parasitoids be introduced as soon as possible after the initial detection of *Sirex* , to immediately reinforce any existing natural control, such as increased vigour of trees following thinning, or the predatory effects of any indigenous avian or insect fauna. Early introduction of natural enemies is essential if the increase and dispersal of *Sirex* is to be suppressed and contained.

The following sections summarize the methodology of "trap" tree establishment and the evaluation of biological control.

Value of trap trees

The benefits of trap trees are:

- they allow the early detection of stand infestations
- they provide a known resource for the introduction of biocontrols
- they permit convenient evaluation
- they are readily located

Trap trees should be located in 10 to 20 unthinned or damaged stands using five to nine tree plots, four to five plots per 100 hectares. Location will vary with respect to specific objectives.

The methods for establishing trap trees are as follows. Trees 15 to 20 centimeters diameter at breast height (dbh) should be pruned of all branches up to a convenient height; a strip of bark-phloem two centimeters wide should be removed from below the remaining branches. Trees so treated become attractive to *Sirex* ten to twelve days after establishment. Through root grafting, these trees can remain attractive to the horntails for weeks.

Similarly, trees can be injected with herbicides such as Dicamba or Triclopyr at two cubic centimeters per ten centimeters of circumference. Ensure that drill holes are directed tangentially, to maximize uptake in the outer sapwood. These trees are best established six to eight weeks prior to *Sirex* emergence. As the tree is killed by this method, the period of potential attractiveness is less variable than that of the surgical girdling method.

Evaluation of *Sirex* biocontrols

The objective of *Sirex* biocontrol evaluation is to determine the distribution and abundance of biocontrols in different stands and localities.

Biocontrol evaluations should preferably be located in areas of known parasitoid and nematode release, in order to determine establishment success. Areas adjacent to and remote from known areas of release should be sampled to assess the dispersal dynamics of both parasitoid- and nematode-infected *Sirex* females.

The following methods should be followed to evaluate nematodes.

1. Remove wood blocks five centimeters by five centimeters by two centimeters, with and without oviposition lesions, with a chisel or axe. Place the blocks in individual airtight plastic containers and store them in a cool box. At the laboratory, remove the block from the container, peel off the bark, and stand the block in a Petri dish containing clean water, with cut surfaces immersed.
2. Soak the blocks for 24 to 48 hours; decant the water to ca. 10 to 15 cubic centimeters, and examine for nematodes, using a binocular microscope at 40 x.
3. Examine the posterior ventral surface of mature larvae beneath a microscope for minute melanized lesions caused by invading infectives.
4. Dissect emergent *Sirex* adults to examine the testes of males and the ovaries of females.

The following methods should be used to evaluate parasitoids.

1. Attach fly-wire screen cages (0.2cm mesh) to infested trees.
2. Hold infested billets in insectary cages after end-coating them with mastic to retain their original moisture levels.
3. Alternatively, hold shorter billets laid horizontally in metal drums of 200-liter capacity, covered with plastic mesh attached to the drum's rim with packaging tape. The mesh should be fitted with a central access slit in the form of a zipper or Velcro™ hook-and-loop cling strap.

Note: Ensure that the billets are not in direct contact with soil, that drums have sufficient incline to prevent accumulation of water, and that all containers are examined frequently for the presence of spiders and any other limiting factor.

References

Anonymous. 1991. Operation worksheets. National *Sirex* Coordination Committee. 20 p.

Haugen, D. A.; Bedding, R. A.; Underdown, M. G.; Neumann, F. G. 1990. National strategy for control of *Sirex noctilio* in Australia. In: Borough, C., ed. Australian Forest Grower, 13 (2). 8 p. (Special liftout).

Madden, J. L. 1971. Treatments which render the host tree *Pinus radiata* D. Don attractive to the woodwasp, *Sirex noctilio* F. Bulletin of Entomological Research. 60(3): 47-52.

Madden, J. L.; Irvine, C .J. 1971. The use of lure trees for the detection of *Sirex noctilio* in the field. Australian Forestry. 35 (33): 163-165.

Neumann, F. G.; Harris, J. A.; Kassaby, F. Y.; Minko, G. 1982. An improved technique for early detection and control of the *Sirex* wasp in radiata pine plantations. Australian Forestry. 45:117-124.

Neumann, F. G.; Morey, J. L. 1984. Influence of natural enemies on the *Sirex* woodwasp in herbicide-treated trap trees of radiata pine in northeastern Victoria. Australian Forestry 47: 218-224.

Neumann, F. G.; Morey, J. L.; McKimm, R. J. 1987. The *Sirex* wasp in Victoria. Bulletin N°. 29. Melbourne: Department Conservation, Forests and Lands. 41 p.

Taylor, K. L. 1978. Evaluation of insect parasitoids of *Sirex noctilio* (Hymenoptera: Siricidae) in Tasmania. Oecologia. 32: 1-10.

Taylor, K. L. 1980. Studies with *Sirex noctilio* (Hymenoptera: Siricidae) and its parasites that illustrate the importance of evaluating biological control attempts. Oecologia Applications. 1(2): 181-187.

Indigenous Siricid spp. parasitoid communities and principal biological control agents of *Sirex noctilio* in Australasia: a review

Sean T. Murphy

Introduction

Sirex noctilio F. (Hymenoptera: Siricidae), which is native to southern Europe, North Africa, and southern parts of the Near East, first appeared as an exotic pest of pine plantations in Australasia in the early 1900s (Nutall 1989). Since then, its worldwide range has expanded. It invaded South America through Uruguay in 1980 and spread to Argentina (1985) and Brazil (1988) (Ciesla 1993); it has also invaded South Africa, entering via the Cape in 1994 (Tribe 1994).

Soon after *S. noctilio* invaded Australasia, New Zealand and Australia set up a classical biological control project. One of the main purposes of the project was to survey for and select host- or genus-specific parasitoids from the area of origin of the pest. In addition, surveys were undertaken on other, closely related pine-feeding horntails on other continents to establish the full range of potential agents available. Thus, the survey did not restrict itself to the "old association" hypothesis that closely evolved natural enemies are likely to be the best control agents.

In view of the seriousness of *S. noctilio* in Brazil, Uruguay, and now in South Africa, classical biological control programmes are being set up in these countries to curb the spread of *S. noctilio* and reduce the damage it causes. Here I will summarise the results of the surveys for natural enemies conducted for the Australasia project; the initial assessment of parasitoid species on *S. noctilio*; and those species found to be good biological control agents after release. Most of this information can be found in Taylor (1976).

Siricid parasitoid communities

In its native environment, *S. noctilio* is not considered a serious pest. Thus when this species first invaded Australasia at the turn of the century, little was known about the ecology of this species or of closely related species. Likewise, little was known about the natural enemy communities associated with these insects (Berryman 1986).

New Zealand was the first country to request parasitoids, and between 1928 and 1952, two species (*Rhyssa persuasoria persuasoria* (L.) (Ichneumonidae) and *Ibalia leucospoides leucospoides* (Hochenwarth) (Ibaliidae) were collected by the International Institute of Biological Control (IIBC, formerly CIBC, now CABI-Bioscience) from *S. noctilio* in the U.K. and shipped to the Forest Research Institute (FRI) in New Zealand (Nuttall 1989).

After the discovery in 1961 of *S. noctilio* in the state of Victoria, on the Australian mainland, a coordinated research programme was initiated in 1962 to search for and establish additional exotic natural enemies. Staff of the CSIRO Division of Entomology studied natural enemies of *S. noctilio* in the European region, Turkey, and North Africa. A *Sirex* Biological Control Unit was established at Silwood Park, Berkshire, U.K. for the study and quarantine of siricids and their natural enemies (Taylor 1976). CSIRO and IIBC collected siricids and their natural enemies in other parts of the world. Areas included: the Himalayan regions, India and Pakistan, the USA (California, Nevada, and the Southeast), Canada (New Brunswick) and Japan. One collection was made in Canada

(Vancouver) by Dr. B. P. Beirne (Taylor 1976). All siricids and their natural enemies were also sent to the CSIRO laboratory at Silwood Park for study and shipment to Australia. In order to receive parasitoids, a *Sirex* unit was established at Hobart airport, Tasmania, where the species received could be reared and distributed to the *Sirex*-infested areas of Australia; material for New Zealand was sent direct from Silwood Park, Tasmania, or from IIBC stations. The search for natural enemies in the northern hemisphere was completed in 1972.

As mentioned earlier, the major aim of the surveys in the northern hemisphere was to collect all insect natural enemy species (including different populations of some species) associated with siricids in conifers from a wide range of climates (Taylor 1976); particular attention was paid to Mediterranean-type climates (Kirk 1974).

The results of the surveys are given in Table 1 (right).

Table 1. Siricid parasitoid communities (modified from Taylor, 1976)

Country/region	Species
Southwestern U.S.A.	*Ibalia leucospoides ensiger* *Ibalia montana* *Ibalia ruficollis* *Ibalia rufipes rufipes* *Megarhyssa nortoni nortoni* *Rhyssa alaskensis* *Rhyssa hoferi* *Rhyssa persuasoria persuasoria* *Schlettererius cinctipes*
Southeastern U.S.A.	*Ibalia leucospoides ensiger* *Megischus sp.* *Pristaulacus ater* *Rhyssa howdenorum* *Rhyssa persuasoria persuasoria* *Rhyssa lineolata*
Eastern Canada	*Ibalia leucospoides ensiger* *Ibalia rufipes rufipes* *Megarhyssa nortoni quebecensis* *Rhyssa crevieri* *Rhyssa lineolata* *Rhyssa persuasoria persuasoria*
Western Canada	*Megarhyssa nortini nortoni*
Europe and Turkey	*Ibalia leucospoides leucospoides* *Ibalia rufipes drewseni* *Megarhyssa emarginatoria* *Odontocolon geniculatus* *Rhyssa amoena* *Rhyssa persuasoria persuasoria*
Morocco	*Ibalia leucospoides leucospoides* *Rhyssa persuasoria persuasoria*
India	*Rhyssa persuasoria himalayensis*
Japan	*Ibalia aprilina* *Ibalia leucospoides leucospoides* *Megarhyssa praecellens* *Rhyssa jozana* *Rhyssa persuasoria persuasoria*

Table 1 lists the species compositions of the communities in each of the regions. It is likely that the number of species listed for each country/region is a function of sampling intensity and the size of the region sampled. The most common and important species in all communities are the ibaliids (Hymenoptera: Ibaliidae), which attack the eggs and early larval instars, and the ectoparasitic ichneumonids, *Rhyssa* spp. and *Megarhyssa* spp. (Hymenoptera: Ichneumonidae), which attack the larger larvae. These two groups of parasitoids complement one another, because they attack their hosts at different times during their development. It should be noted that *Ibalia ensiger* Norton is considered a subspecies of *I. leucospoides* Hochenw. and *I. drewseni* Borries a subspecies of *I. rufipes* Cresson (Kerrich 1975). Finally, it is now known that *Megischus* sp. (Hymenoptera: Stephanidae) and *Pristaulacus ater* (Westwood) (Hymenoptera: Aulacidae) are probably not parasitic on siricids.

The siricid parasitoid communities in Europe, Turkey, and North Africa have been particularly well studied (Spradbery and Kirk 1978). The host siricids located with their individual parasitoid communities are shown in Table 2 (modified from Spradbery and Kirk 1978).

Table 2. Host records of parasitoids of siricids (modified from Spradbery and Kirk, 1978)

	Host Species							
Species	*Sirex noctilio*	*S. cyaneus*	*S. juvencus*	*Urocerus gigas*	*U. augur*	*U. sah*	*U. fantoma*	*Xeris spectrum*
R. persuasoria	+	+	+	+	+	+	+	+
R. amoena	0	+	+	+	+	0	0	+
M. emarginatoria	0	+	+	+	+	0	0	+
I.l. leucospoides	+	+	+	+	+	+	+	+
I.r. drewseni	+	+	+	+	+	0	0	+
O. geniculatum	+	+	+	+	+	0	0	

Most of these siricids attack species of *Pinus*, *Picea*, *Larix*, *Cedrus* and *Abies*. Table 2 shows that most of the parasitoids recorded are polyphagous, but not all are parasitic on *S. noctilio*. The phenology of parasitoid attack on their hosts is as follows. *Ibalia leucospoides* emerges in the summer and autumn to attack *Sirex* larvae hatching soon after oviposition. However, *Ibalia rufipes drewseni* emerges in late spring to attack larvae in trees where the hatching has been delayed (Spradbery 1970). All the other parasitoids attack later stages of the larvae. These species possess a long ovipositor which is inserted through the wood in order to reach the host.

The species within the parasitoid community on *S. noctilio* coexist by exploiting different host stages or by having a temporal distribution pattern of attack. All species are widely distributed throughout the region where their host occurs, and some species (e.g, *Rhyssa persuasoria persuasoria*) also have a more extensive range in view of their wide host range.

On the basis of the structure of the siricid parasitoid communities found in Europe and elsewhere, it was decided to try and establish host- or genus-specific early and late larval instar parasitoids.

Assessment of agents on *Sirex noctilio*

All assessments of parasitoids on *S. noctilio* from other siricid hosts were conducted at the *Sirex* units at Silwood Park, U.K. and Hobart, Tasmania (Taylor 1976) and/or at the Forest Research Institute in New Zealand. A total of 21 species (including species collected from *S. noctilio*) were imported for assessment and rearing. Details of shipments and the numbers received are reviewed by Taylor (1976) and Nuttall (1989). Preliminary work (e.g., Spradbery and Kirk 1978) showed that some parasitoid species are specific on host trees of genera other than *Pinus* and/or the other host siricids. Examples from Europe include *Megarhyssa emarginatoria* Thunberg and *Rhyssa amoena* Grav. Some other species of parasitoid were found to attack *S. noctilio* in the laboratory, but cultures failed because of poor sex ratio problems. Examples here include *Rhyssa lineolata* (Kirby) and *Rhyssa alaskensis* (Ashmead).

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As a result of these assessments on *S. noctilio*, ten principal species (with subspecies and geographic races) were reared in sufficient numbers for trial field releases (see Table 3).

Ibalia leucospoides (subspecies *leucosopoides* and *ensiger*) and *Megarhyssa nortoni* were the most rapid colonisers. *Rhyssa* was slow to colonise. *Schlettererius cinctipes* (Cresson) (Stephanidae) was rare in areas where the two ichneumonids were present. *Ibalia* species produce the highest levels of parasitism (15% to 29%) in the Australian mainland, followed by *Megarhyssa nortoni* (12% or less); *Rhyssa persuasoria* failed to establish on the mainland; however, in Tasmania, *Megarhyssa nortoni* and *Rhyssa persuasoria* were the most abundant parasitoids. In New Zealand, parasitism by *Ibalia l. leucospoides* and the rhyssines has been 70% or more. Taylor (1967) provides a key to distinguish these biological control agents in the field.

Table 3. Principal species of siricid parasitoids reared in sufficient numbers for field release (see Taylor, 1976, for further details)

Species	Stage attacked	Origin
Ibalia leucospoides leucospoides	Egg/ Young larvae	Europe
Ibalia l. ensiger	Egg/ Young larvae	USA
Ibalia rufipes rufipes	Egg/ Young larvae	USA
Ibalia r. drewseni	Egg/ Young larvae	Europe
Megarhyssa nortoni nortoni	Late larvae	USA
Megarhyssa praecellens	Late larvae	Japan
Rhyssa persuasoria persuasoria	Late larvae	Europe
Rhyssa p. himalayensis	Late larvae	India
Rhyssa alaskensis	Late larvae	USA
Rhyssa hoferi	Late larvae	USA
Rhyssa lineolata	Late larvae	Canada
Odontocolon geniculatus	Late larvae	Europe
Schlettererius cinctipes	Late larvae	USA

Major biological control agents

The ten parasitoid species selected as potential biological control agents were directly field released in Australia without further study; some of these species were also released in New Zealand. These releases have been extensively reviewed by Taylor (1976) and Nuttall (1989). Five of these species became established in the field in various parts of Australasia. These are: *Ibalia leucospoides leucospoides; Ibalia l. ensiger; Ibalia rufipes drewseni; Megarhyssa nortoni nortoni; Rhyssa persuasoria persuasoria; and Schlettererius cinctipes.*

References

Berryman, A. A. 1986. Forest insects: principles and practice of population management. New York: Plenum Press. 279 p.

Ciesla, W. M. 1993. Recent introductions of forest insects and their effects: a worldwide overview. In: Proceedings of the conferencia regional de vespa da madeira, *Sirex noctilio*, na América do Sul. Florianópolis, S.C.: 23-27 November 1992. Colombo, PR, Brazil: EMBRAPA. 9-22.

Kerrich, G.J. 1973. On the taxonomy of some forms of Ibalia Latreille (Hymenoptera: Cynipoidea) associated with conifers. Zoological Journal of the Linnean Society. 53: 65-79.

Kirk, A. A. 1974. Bioclimates of Australian *Pinus radiata* areas and *Sirex noctilio* localities in the northern hemisphere. Australian Forester. 37:126-131.

Nuttall, M. J. 1989. *Sirex noctilio* F., *Sirex* wood wasp (Hymenoptera: Siricidae). In: Cameron, P. J.; Hill, R. L.; Bain, J.; Thomas, W. P., eds. A review of biological control of invertebrate pests and weeds in New Zealand: 1874 to 1987. CAB International Institute of Biological Control. Technical Communication No. 10. Wallingford, UK: CAB International. 299-306.

Spradbery, J. P. 1970. The biology of *Ibalia drewseni* Borries (Hymenoptera: Ibaliidae), a parasite of siricid woodwasps. Proceedings of the Royal Entomological Society of London. 45:104-113.

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.

Taylor, K. L. 1967. The introduction, culture, liberation and recovery of parasites of *Sirex noctilio* in Tasmania: 1962-67. Technical Paper N°. 8. Australia: CSIRO, Division of Entomology. 19 p.

Taylor, K. L. 1976. The introduction and establishment of insect parasitoids to control *Sirex noctilio* in Australia. Entomophaga. 21: 429-440.

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

International cooperation regarding quarantine procedures

Amèrico Iorio Ciociola

With modern transportation, products can move from one to the other side of the world in a matter of hours. In the past, the migration of species that cause harm to other regions of the world and the importation of species useful for biological control were uncommon. Today, however, organizations that are efficient and technically competent to confront the challenges of the damage done by the importation of exotic pests are essential.

Cooperation programs harbor such great differences, resulting from personal interests, or other interests not relevant to the program itself, that they are like "tug-o-wars". In an effort to do their best, people get so involved in their specific activities that they are not able to see the overall direction that the cooperation program is taking. Hence the importance of having, in any cooperation program, actions that are transparent, rapid, and that take into account the interests of all involved parties. It is important to realize that cultural factors can often slow down or even prevent the favorable progress of cooperation programs in spite of the sincere involvement of the parties. When these factors are overcome, the resulting actions are more objective, carrying real benefits for all.

Cooperation begins with **the will to cooperate**. No action between two organizations will be successful if those involved do not want it to be. It is also necessary to remember that cooperation is much easier when the people involved actively participate in the various stages of the program, and do not merely carry out the mandates formed by some organization. Many programs are successful simply because of people who are motivated and very familiar with them.

Another factor that stimulates cooperation is the existence of a common problem which is difficult or impossible for one group to solve alone. There is currently great difficulty stopping the migration of potentially harmful species around the world. Recent examples include the introduction of *Sirex noctilio* F. in Brazil and the green acaro that affects cassava in Africa.

In order for action in cases of quarantine procedures to be effective, **a trained technical body** with an adequate number of people to accomplish the many tasks of the process is necessary. A key point in any traditional biological control program is the exchange of experiences among researchers from diverse areas.

However, the mere existence of well-qualified personnel does not assure the effectiveness of a quarantine program. **Quarantine laboratories** are a very important factor in the execution of any such program. In addition, it is necessary to have sufficient **financial resources** to allow the proposed program to be fully carried out. The lack of these factors has slowed down or even ended traditional biological control programs all over the world. Many times, however, programs have not been successful due to the lack of **organization** in the direction of the work.

Any governmental action inevitably involves **bureaucracy** intended to guarantee that proposed actions are implemented, whether they originate as laws, decrees, resolutions, or administrative decisions. But when bureacratic functions are not carried out efficiently, their objectives are not reached within the proposed time, causing great problems for program administration as a whole.

What are the **problems** that prevent more efficient cooperative action among countries? First, a factor that is beyond the control of quarantine technical experts is **lack of understanding of quarantine measures** among the general population. It is not rare that tourists bring seeds or vegetables in their luggage without knowing that they are introducing exotic species that present great danger to the country's agriculture. A permanent educational program about quarantines and their importance should be a part of every citizen's life, from primary school, beginning with posters, leaflets and other informative materials available at ports, airports, and border posts.

Another problem that afflicts those that work in the prevention of the entrance of exotic organisms into their countries is the lack of a sufficient number of **quarantine laboratories** to attend to the demands of different countries. In Brazil, the new quarantine laboratory Costa Lima in Jaguariuna, Sao Paulo, was inaugurated only recently, after more than ten years of careful planning and searching for resources for its implementation. Countries that do not have this type of facility often use those of neighboring countries, thus permitting a more extensive cooperation in common problems. However, the scarcity of **qualified personnel** may often compromise the success of these laboratories, which frequently lack an **adequate budget** to function. In this last case, a problem that is becoming common lately is the low pay received by technical experts, which decreases both their motivation as well as the number of university graduates that choose this exciting career.

Commercial interests often make quarantine actions more difficult, as they are interested in quickly resolving any problems regarding the introduction of exotic species, often without understanding the reason or being willing to wait the time necessary to complete the work to guarantee the safety of the introduced material.

Two other factors can make international cooperation in quarantine procedures difficult: **bureaucracy** and **suspicion**. An example of the first factor is that border patrols may demand much bureaucratic paperwork when material headed for quarantine laboratories is presented, and an example of the second is the suspicion that containers labeled as biological material that should not be opened outside of the laboratory in fact contain other types of material. Sometimes, full investigations are performed at airports aiming to guarantee the nature of the introduced material, much to the dislike of the quarantine official anxiously waiting to take it to the laboratory.

Even when quarantined materials are handled appropriately, often the results leave much to be desired. In some cases, the directly interested person does not use all of the imported material (as in the case of the tomato moth), takes time to bring the material to the laboratory and clear it (as in the case of the coffee caterpillar), or the relatively low cost of the process prevents greater care with the imported material. In other cases, there is a greater dynamism and use of the obtained material, as with the case of the fruitfly in Northeast Brazil.

As can be seen, cooperation is indispensable, principally when dealing with regional organisms. With MERCOSUL, for example, much has already been done in the area of plant protection. The creation of the Plant Protection Committee of the Southern Cone (Comitê Fitossanitário do Cone Sul, COSAVE) has resulted in a formidable force for harmonizing existing standards in the various member countries so as to permit a greater agility in the treatment of actions to preserve environmental quality and transport vegetable and animal material across borders. COSAVE unites organizations that deal with aspects of plant protection in the member countries. As such, Argentina is represented by the Argentine Institute of Plant Health and Quality (Instituto Argentino de Sanidad y Qualidad Vegetal); Brazil by the Secretary of the Agricultural Protection of the Ministry of Agriculture (Secretária de Defesa Agropecuaria do Ministerio da Agricultura); Chile by the Agricultural Service (Servício Agricola y Pecuario); Paraguay by the Department of Vegetative Protection (Departamento de Defensa Vegetal); and Uruguay by the Service of Agricultural Protection (Servício de Protección Agricola). Representatives of these organizations have been meeting regularly, often in the form of work groups in specific areas, in such a way as to build a set of norms and procedures that, while respecting the individuality of countries, harmonizes their procedures to the benefit of regional integration in the area of plant protection.

References

COSAVE. 1995. Relatório Anual de Atividades. Brasilia.

CNPq. 1993. Cooperação Internacional - Expedição Científica. 34 p.

Nardo, E.A.B. De; Capalabo, D.M.F.; Moraes, G.J. De; Oliveira, M.C.B., coords. 1995. Requisitos para a análise de risco de produtos contendo agentes microbianos de controle de organismos nocivos: uma propuesta para os orgãos federais registrantes. Jaguarina: EMBRAPA - CNPMA. 42 p.

Nardo, E.A.B. De; Capalbo, D.M.F.; Moraes, G.J. De; Oliveira, M.C.B., eds. 1995. Análise de risco e avaliação do impacto ambiental decorrente do uso de agentes de controle biológico. Workshop. Jaguariuna, SP, Brasil; 18-20 de outubro de 1994. EMBRAPA-CNPMA. 127 p.

Moraes, G.J. De; Sá, L.A.N. De; Tambasco, F.J. 1966. Legislação Brasileira sobre o intercâmbio de agentes de controle biológico. Jaguariuna: EMBRAPA - CNPMA. 16 p.

Sá, L.A.N., De.1994. Enfoque regional relativo á introdução de inimigos naturais no cone sul. In: Simpósio de Controle Biológico. 4: 61-64.

The release and evaluation of parasitoids in classical biological control projects: a brief review

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Introduction

Before the implementation phase of a classical biological control project can be initiated, where one or more exotic parasitoid species have been selected for trial release against a target pest, consideration must be given to the following steps.

1. Importation, further quarantine, and initial rearing.

2. The needs for rearing, the needs for release, and the numbers required.

3. The design of field releases (where, when, size, number of releases, and methods).

4. The design of the evaluation programme to measure the outcome of the introductions.

Here, I shall briefly consider the release, monitoring, and assessment of impact of exotic parasitoids (i.e., steps 3 and 4, above). The general principles of some of these topics have recently been reviewed by Van Driesche and Bellows (1996) and Jervis and Kidd (1996).

Release and establishment of exotic parasitoids

Where to make releases

Usually the area affected by a pest is very large, and thus managers make trial releases of parasitoids at several sites within the area. Releases could profitably be made in relation to different climatic, altitudinal, and density zones rather than in relation to paired plots to investigate these factors (see next section). Before trial releases of a parasitoid are undertaken, some attempt can be made to estimate the likely range to be colonised by the insects. This can be done by use of the computer programme CLIMEX (Sutherst and Maywald 1985).

The size and number of releases to make

In classical biological control there is no hard and fast rule as to the numbers required to afford a reasonable chance of establishment. Some species colonise readily, and the release of only a few individuals is all that is required. For example, the parasitoid *Megarhyssa nortoni* (Cresson) (Hymenoptera: Ichneumonidae), released in Tasmania in the 1960s for the control of *Sirex noctilio* F. (Hymenoptera: Siricidae), established after the release of only a few hundred females (Taylor 1976).

However, Beirne (unpublished), in his analysis of biological control projects in Canada, concluded that releases of less than 800 stand less chance of establishment than where larger numbers are released. There are also good theoretical reasons for not releasing less than 1,000 individuals; populations of less than this may go extinct because low densities, resulting from dispersal into a new environment, lead to failure to mate, which, in turn, leads to a male-biased sex ratio (Hopper and Roush 1993).

The number of releases will depend on the phenology of the host population in the field and the number of different climatic and altitudinal sites chosen to test the parasitoid (see above).

Timing and method of releases

Releases should be made where hosts are abundant and in the correct stage. Even in the tropics, pests tend to be seasonal. Releases should also be made in areas where the pest population is increasing, not decreasing. Releases are often made in the early morning, to avoid bright sunlight and hot midday temperatures. Releases may be made in the open field or in field cages. Cage releases can exclude native competitors.

The evaluation of parasitoid introductions

Measuring the dispersal capacity of parasitoids

Some parasitoid species have a good dispersal capacity and can cover a wide area reasonably soon after release. However, some other species are poor dispersers. Data collected on the dispersal rate of *Sirex* parasitoids after release indicates great variability within and between species (see Table 1).

Table 1. Dispersal capacity of siricid parasitoids released in Australasia (literature records)

Parasitoid	Country	Dispersal capacity
Ibalia l. leucospoides	New Zealand	6 km in 4 years 125 km in 9 years
Magarhyssa n. nortoni	New Zealand	65 km in 9 years 115 km in 5 years?
	Tasmania	19 km in approx. 12 years
Rhyssa p. persuasoria	New Zealand	<5 km in approx. 20 years
	Tasmania	7.2 km in approx. 12 years

It is critical that a survey scheme is established in order to measure the dispersal capacity of a newly released parasitoid. This can be achieved as follows.

1. Establish Permanent Sampling Plots (PSPs) or "transects" of trees throughout the area affected by the pest so that parasitoid distribution and spread can be monitored over time. The number of plots will depend on time and resources available.

2. Visit all plots on a regular basis; for example, over a number of *Sirex* generations.

3. At each plot, record the following:

   - total number of trees sampled
   - estimate of the size of the *Sirex* infestation and the proportion of trees infested in the PSP
   - presence/absence of the parasitoids

This survey will allow the monitoring of the rate of spread of the parasitoid over time.

Measuring the impact of parasitoids

Here we need to be able to understand the role of parasitism in limiting numbers of the pest, and some of the factors that limit impact. That is, we need some practical understanding of the spatial and temporal dynamics of parasitoid-host interactions. There are three major ways to evaluate the impact of an introduced parasitoid.

1. Compare pest densities before and after the introduction of the natural enemy.

2. Compare pest densities in control plots without the biocontrol agent with treatment plots in which the agent has been released.

3. Perform life-table analysis of the pest population after the introduction of the natural enemy.

From the experimental design point of view, method two is the best (Ludlow, pers. comm.). However, the success of this method depends on the dispersal capacity of the natural enemy. For many parasitoids, this can be quite considerable; thus method two may not be possible. Plots may have to be so far apart that climatic, edaphic, and other factors may obscure the true effects of parasitism. Greater emphasis should, therefore, be placed on methods one and three. Luck et al. (1988) include a review of method one.

All three methods require estimates of either pest densities, pest numbers, or both. The numbers of pests that die due to parasitism should also be estimated. General problems that can be encountered when measuring parasitism have been discussed by Van Driesche (1983) and Van Driesche et al. (1991). Madden (this workshop) outlines methods for measuring parasitism of *Sirex noctilio* that were developed in Australia.

Methods one and two above may produce a clear measure of the overall impact of an introduced parasitoid on the host population. However, the interpretation of measures of parasitism obtained during such studies and for method three can sometimes be difficult. To overcome this problem, a series of life tables, collected for a number of generations of the pest, can be analysed. Bellows et al. (1992) review the general methods for estimating parasitism and the methods available for constructing and analysing a series of life tables for a pest. A series of life tables was used by Taylor (1978) for analysing the impact of *Sirex* parasitoids in Tasmania. Refer to this paper for the methods employed.

References

Bellows, Jr., T. S.; Van Driesche, R. G.; Elkinton, J. S. 1992. Life-table construction and analysis in the evaluation of natural enemies. Annual Review of Entomology. 37: 587-614.

Driesche, R. G. van [Van Driesche, R.G.] 1983. Meaning of "percent parasitism" in studies of insect parasitoids. Environmental Entomology. 12: 1611-1621.

Driesche, R. G. van [Van Driesche, R.G.]; Bellows, Jr., T. S.; Elkinton, J. S.; Gould, J. R.; Ferro, D. N. 1991. The meaning of percentage parasitism revisited: Solutions to the problem of accurately estimating total losses from parasitism. Environmental Entomology. 20: 1-7.

Driesche, R. G. van [Van Driesche, R.G.]; Bellows, Jr., T. S. 1996. Biological control. New York: Chapman and Hall. 539 p.

Hopper, K. R.; Roush, R. T. 1993. Mate finding, dispersal, number released, and the success of biological control introductions. Ecological Entomology. 18: 321-331.

Jervis, M.; Kidd, N. 1996. Insect natural enemies: practical approaches to their study and evaluation. London: Chapman and Hall. 491p.

Luck, R. F.; Shepard, B. M.; Kenmore, P. E. 1988. Experimental methods for evaluating arthropod natural enemies. Annual Review of Entomology. 33: 362-391.

Sutherst, R. W.; Maywald, G. F. 1985. A computerised system for matching climates in ecology. Agriculture, Ecosystems and Environment. 13: 281-299.

Taylor, K. L. 1976. The introduction and establishment of insect parasitoids to control *Sirex noctilio* in Australia. Entomophaga. 21: 429-440.

Taylor, K. L. 1978. Evaluation of the insect parasitoids of *Sirex noctilio* (Hymenoptera: Siricidae) in Tasmania. Oecologia. 32: 1-10.

Sirex noctilio problem in Brazil: detection, evaluation, and control

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Abstract

Brazil has about five million hectares of forest plantations of which two million hectares consist of *Pinus* spp. Most of these stands were planted; they contain a small number of species at high density and receive inadequate forest management. In 1988 an outbreak of *Sirex noctilio* F. was recorded in Rio Grande do Sul state. It is present in 250,000 hectares of forest, and is also advancing on Santa Catarina and Paraná states. The use of biological control is the best measure to control *S. noctilio*. The most effective agent is *Beddingia (=Deladenus) siricidicola* (Bedding), a nematode that sterilizes the *Sirex* females. Another parasite, *Ibalia leucospoides*, bred by the Programa Nacional de Controle À Vespa-da-Madeira (PNCVM) was introduced in 1989. This programme for control of *Sirex noctilio* is broad in scope; it also includes both the early detection and monitoring of the spread through the use of trap trees and ground inspections and the adoption of preventative measures through adequate forest management. Plans for the future include the introduction of the parasitoid *Rhyssa persuasoria* (L.) and *Megarhyssa nortoni* (Cresson) to complement the nematode.

Introduction

Of about five million hectares of forest plantations in Brazil, two million are planted with *Pinus* spp. Most of these plantations were planted using a few species at high density and managed using inappropriate silvicultural practices. The southern region concentrates approximately one million hectares of plantations, mainly of loblolly pine, *Pinus taeda* L., and slash pine, *P. elliotii* Engelm. These conditions are ideal opportunities for pest and disease outbreaks. *Sirex noctilio* attacks were detected in Rio Grande do Sul state in 1988, awakening the Brazilian forestry sector to the need for control strategies to prevent and monitor the pest. *S. noctilio* can currently be found in 200,000 hectares throughout the states of Paraná and Santa Catarina. Although *S. noctilio* is a minor pest in its regions of origin (Europe, Asia, and North Africa) it has become the primary pest in pine plantations where it has been introduced, in countries such as New Zealand, Australia, Uruguay, Argentina, Brazil and, more recently, South Africa.

Biological control strategies are the most efficient for controlling *S. noctilio*, especially when the nematode *B. siricidicola*, which sterilizes up to 70% of the *Silex* females through parasitism, is used. *S. noctilio* has been kept under control by the application of forest management techniques associated with biological control.

As the pest became a serious problem to Brazilian forestry, the Fundo Nacionale de Controle á Vespa-da-Madeira (FUNCEMA) was created in 1989 by public and private organizations in order to support the National Program of Wood Wasp Control (PNCVM). This program includes research activities to create and adapt technologies for the control of *S. noctilio*. At first, the program gave priority to the introduction of *B. siricidicola*. The National Program of Wood Wasp Control still includes the following practices.

1. Monitoring for the early detection and dispersal of the pest, using trap trees which are intentionally stressed to attract the insects by application of the Dicamba herbicide.

2. Adopting prevention strategies to improve the phytosanitary conditions of forest stands using silvicultural practices, especially thinning, to minimize the attacks.

3. Adopting quarantine strategies to control and slow dispersal.

4. Introducing the parasites *Ibalia leucospoides*, *Rhyssa persuasoria* and *Megarhyssa nortoni* to increase the range of natural enemies. (*M. nortoni* and *R. persuasoria* were introduced in 1996 and 1997, respectively, by means of a project supported by CABI-Bioscience and the United States Department of Agriculture Forest Service. *Ibalia leucospoides* was accidentally introduced and detected in 1990 in Rio Grande do Sul state; it is currently present in nearly all forest stands attacked by *S. noctilio*).

5. Publicizing, using the media and the researchers involved, in a vast training program for technical personnel and forest producers, to provide technical information to professionals and to inform the public. Integration within the National Program of Wood Wasp Control has been an example of the research and development policy nationwide, as more than a hundred private enterprises in Southern Brazil are involved, together with public organizations. Besides using technology, these enterprises also offer technical assistance to small-forest planters so the control strategies can reach all plantations attacked by *S. noctilio*.

Biology and ecology of *Sirex noctilio*

Sirex noctilio belongs to the order Hymenoptera, sub-order Symphyta, family Siricidae, sub-family Siricinae. Siricids develop inside tree trunks of several species and are known as horntails. This group is associated with conifers and angiosperms of northern hemisphere origin.

S. noctilio is endemic to Eurasia and North Africa, with high density populations in the Mediterranean zone. It prefers species of the genus *Pinus*, also attacking fir (*Abies*), spruce (*Picea*), larch (*Larix*) and Douglas-fir (*Pseudotsuga*).

In its countries of origin, *S. noctilio* normally develops in trees damaged or dead due to biotic or abiotic factors, such as fire, wind, other insects, diseases, snowstorms or mechanical operations, although it can develop in healthy trees as well.

According to Smith (1988), it is also found in Germany, Australia (where it was introduced in 1951), Austria, Belgium, Cyprus, Denmark, Finland, France, Greece, Hungary, England, Mongolia, Norway, New Zealand (introduced in 1900), Poland, Romania, the former Czechoslovakia and parts of the former Soviet Union. It has more recently been introduced into Uruguay (1980), Argentina (1985), Brazil (1988), and South Africa (1994).

In Brazil, most of the adults emerge between November and April, with emergence peaks in November and December. The males emerge before the females, and there is a male/female ratio varying from 1.5:1 to 32:1.

After the initial flight period, females perforate tree trunks with their ovipositors and lay their eggs in the sapwood. They can perforate up to four galleries each time they lay eggs, and the average number of eggs in each oviposition process is 2.2. The largest females lay 300 to 500 eggs in approximately 10 days. During this process, the females introduce spores (artrospores) of the symbiotic fungus *Amylostereum areolatum* Fries (Boidin), along with a mucous secretion, which causes toxicity and the consequent death of plants.

The plantations most susceptible to *S. noctilio* attacks are generally 10 to 25 years old and under stress. Unthinned stands are more susceptible than thinned stands. The insect weakens trees by injecting the phytotoxic mucus and the spores of the symbiotic fungus *A. aureolatum* in the sapwood during oviposition. This pathogenic fungus, which is the source of nutrients for the pest larvae, dries up the wood and makes it rot. In addition, wood quality is affected by the larvae building galleries and by the entrance of secondary agents which help to damage it, limiting its use or ruining it for the market. Once the tree is dead, the wood degrades quickly; it must be used, at the most, within six months after the attack.

The attack symptoms begin to show right after the insect population peaks in the months of November and December, but become more visible from March on. The most visible external symptoms are the progressive yellowing of the crown, which afterwards becomes brownish-red; wilting of the foliage; loss of leaves; resin drops on the bark (due to the perforations made for oviposition); and holes drilled for the emergence of the adults. Internal symptoms are brown spots along the inner bark caused by the fungus *A. aureolatum* and galleries drilled by larvae, all of which affect wood quality.

Sirex noctilio completes its development in one or two years. Approximately 75% of the larvae emerge in the first year, and although some may emerge in the third year, these are not likely to survive. The larvae that complete their development within a year go through an average number of six instars, while those which take two years to develop usually go through eight. In a temperate climate in Tasmania up to twelve instars have been observed.

The detection of *S. noctilio* in Brazil

The first registry of an outbreak of *Sirex* in Brazil occurred in October 1988 in a *Pinus taeda* stand in Gramado, Rio Grande do Sul state. The insect was found at first in a five-hectare stand 13 years old, planted at a 2-meter by 2-meter spacing (2,500 trees per hectare) where the first thinning was being conducted. Some trees showing attack symptoms were cut, and siricid larvae were found inside the trunk. Galleries containing larvae and drilled holes were recently found in logs obtained from thinned trees piled inside the stand.

On the same occasion mortality of 240 trees per hectare was registered in another *P. taeda* plantation on the border between Canela and São Francisco de Paula, also in Rio Grande do Sul state. The stands, which had not undergone thinning, were about 17 years old, and the trees were spaced 2 x 2 meters. The average mortality of 9.6% was being attributed to soil exhaustion and excessive competition of plants for nutrients, since the stand had not been thinned. When some of the trees with yellowing or dry crowns were cut, *S. noctilio* larvae were found. One of the trees cut was quite dry and had old *Sirex* galleries, proving the occurrence of attacks in former years (Iede et al. 1988).

In December 1989 *S. noctilio* was found in Lages, Santa Catarina state, in *P. taeda* trap trees. Two interceptions were made in Paraná state in 1993 and 1994, avoiding the establishment of the insect. In July 1996, however, the pest managed to get established in *P. taeda* plantations in General Carneiro, Paraná state.

S. noctilio currently occurs in approximately 200,000 hectares of *Pinus* spp. plantations in about 60 cities of the three southern states of Brazil.

National program for *S. noctilio* control

The discovery of *S. noctilio* in *Pinus* stands in Brazil has caused critical concern in the Brazilian forestry sector because of the pest's damage potential. The infestation of *P. taeda* stands by *Sirex noctilio* in southern Brazil is serious and gradually increasing. The dissemination of the pest to other *Pinus* plantations in Brazil is inevitable, since it can spread 30 to 50 kilometers per year. Urgent and efficient strategies are needed to control, monitor, and delay its advance. The National Fund for Wood Wasp Control was created in June 1989 to manage the problem. It is a non-profit civil organization formed by private and public institutions whose main objective is to generate funds for the development of the Programa Nacional de Controle á Vespa-da-Madeira (PNCVM). This program has undertaken the following activities.

Monitoring for the early detection of *Sirex noctilio*

The program originally intended to have all the *Pinus* plantations in the country mapped from satellite images. All the plantations in Rio Grande do Sul, Paraná, and Santa Catarina states were to be allocated in detailed maps with data on the number and location of the groups of trap trees installed, the spots where *Sirex* was found, and the places where nematodes and parasites were released. Aerial and terrestrial searches were also planned.

Aerial monitoring

Aerial monitoring with visual observations in surveys for early detection of the pest and estimates of attacked areas were planned. However, this procedure has not been evaluated because of its lack of precision, since the smaller trees normally preferred by the insect are not visible from the air.

Terrestrial monitoring

The trees initially attacked by *S. noctilio* tend to present smaller diameters or be somehow damaged, although attacks to dominant trees do occasionally happen.

The use of trap trees stressed by herbicide injection is the most appropriate and efficient technique for the early detection of the pest, as well as for monitoring dispersion. Detecting *S. noctilio* during its early stages of development and colonization helps to define locations for releasing biological control agents and allows thinning practices to be carried out before the pest reaches high levels of damage. Maintaining a trap tree system may greatly increase the efficiency of biological control of *S. noctilio*.

The choice of a detection method, as well as the intensity with which it should be applied, must be based on a risk analysis of the introduction and dispersal of the pest in each region. The Centro Nacional de Pesquisa de Florestas-EMBRAPA recommends that trap trees, preferably between diameters at breast height (DBH) of 10 and 20 centimeters, be installed in groups of five, and that the distance among the groups vary according to where the pest is established:

- in areas where *Sirex* is present, as well as in areas up to 10 kilometers away from the infestation focus, install groups of five trap trees every 500 meters
- at distances between 11 and 50 kilometers from the focus, the groups should be spaced 1000 meters apart
- more than 50 kilometers from the infestation focus, especially near borders, the groups should be spaced 10 kilometers apart
- in areas more than 200 kilometers from the infestation focus, forest vigilance is the most appropriate technique

The groups of trap trees should be installed in easily accessible areas and cover the entire stand.

Other recommendations are as follows.

1. The installation of trap trees in Brazil must be done from August to October, two months before the population peaks of *S. noctilio* adults, which generally occur between November and December.
2. The groups of trap trees should be revisited in January and May to check on insect attack.
3. The process of installing trap trees must be carried out every year, since there is a progressive reduction in trees attracting *S. noctilio* from one year to the next.
4. Trees with DBH under 30 centimeters should receive a dose of one to two milliliters of the herbicide Dicamba at 20%, or Tordon at 10%, every 10 centimeters in the circumference, while trees with DBH greater than 30 centimeters should receive the same dose every 8 centimeters in the circumference.

As soon as *S. noctilio* is detected in a region, the number of groups of trap trees should be increased and installed in susceptible plantations, close to saw mills, along the main wood transportation routes, and on the borders of the area of natural dispersion of the pest. After detection, trap trees must be annually installed to receive the inoculation of *B. siricidicola*. Once the biological control agents are established in the region and the population of *S. noctilio* declines, groups of trap trees must be planted for monitoring the presence of the pest and its natural enemies.

Prevention strategies

It is currently estimated that most of the plantations still show low levels of mortality; only a small portion of the total forest is under high attack levels. If, however, monitoring, prevention, and control strategies are not carried out, this condition will worsen.

Trees resistant to *S. noctilio* are those which remain free of injuries and continue growing vigorously in good sites and well-managed blocks. The level of mortality of the trees is significantly related to the DBH of the trunk. Trees with low DBH show higher levels of mortality than thicker ones inside the same stand.

Management practices tend, therefore, to impose limits on long rotations and, more important, to draw attention to the composition, structure, age, and vigor of the forest, in order to avoid serious insect attacks. According to Davis (1966), more effective pest control may be obtained through silvicultural practices in the long run, creating a reasonable forest-insect resistance. Complete control will never be attained this way, but the loss caused by insects may be reduced.

Thinning is one of the most important silvicultural practices, conducted in order to accelerate or modify the course of competition. The position of the crown is an important criteria in deciding which trees to cut and which to favor. Vigorous trees that outgrow their neighbors dominate the canopy. These trees usually have a greater chance of surviving future competition than do less vigorous ones which take lower positions in the forest.

Most of the thinning practices reduce loss due to damaging agents not only because thinning works as a prevention strategy, but also because it increases the vigor and resistance of the trees. Thinning can only enhance the susceptibility of trees to insect attack under special circumstances, as when it is carried out during the flight period of the pest.

Biological control

Successful experiences in which the pest was introduced have demonstrated that biological control, along with prevention strategies, is the most efficient and economical method for controlling *Sirex*, especially since it is an exotic insect introduced to the advantage of not having natural enemies.

In order to test a similar system in Brazil, the nematode *Beddingia (=Deladenus) siricidicola* and the parasites *Ibalia leucospoides*, *Rhyssa persuasoria* and *Megarhyssa nortoni*, were introduced to control *S. noctilio*, to make the ecosystem of the pest more stable.

Nematodes. The most effective biological control agent of the *S. noctilio* is the nematode *B. siricidicola*, which sterilizes adult *S. noctilio* females. Cultures of these agents were developed in Australia and sent to Brazil in 1989 and 1990. The first inoculations were made at the end of August 1989 and between February and August in the following years.

This nematode has two life cycles: a free-life one, during which it feeds on *Amylostereum areolatum*, the symbiotic fungus associated with *S. noctilio*, and a parasite-life one, inside *S. noctilio* larvae, pupae, and adults. As its free-life cycle is based on the fungus *A. areolatum*, it is easily bred in laboratory conditions and then released in the field by application into trees attacked by *S. noctilio*, where it can achieve parasitism levels close to 100%.

The inoculation of *B. siricidicola* in trees is done with a special hammer used to make holes in the trunk spaced 30 centimeters apart. The nematodes, sent to the field in 20 milliliter doses (each one containing approximately one million nematodes measuring five to 25 millimeters in length), are mixed in a gelatinous solution at 10% and introduced by a syringe into the holes made with the hammer.

After the inoculation, the nematodes penetrate the wood in search of the fungus they feed on, and reproduce, originating young nematodes in free-life cycle. When they find *Sirex* larvae, however, they develop into infectious adult forms and penetrate the larvae, leaving a scar in the integument. They double their size inside the larvae, and when the host pupates, they move to the reproductive organs and penetrate the ovaries, sterilizing the female *Sirex noctilio*. The infected adult females emerge from the trees and lay their eggs, but these eggs are not fertile and may contain between 100 and 200 nematodes each.

The average level of parasitism obtained in Australia with the nematode was 70%. Although the level of parasitism verified for the nematode in the attacked areas in Rio Grande do Sul and Santa Catarina in Brazil has been quite variable, it was found to be as high as 70 or 80% in a 12,000-hectare *Pinus taeda* plantation in Encruzilhada do Sul, Rio Grande do Sul.

Parasites. *Ibalia leucospoides* was detected in Brazil for the first time in December 1990 in *Pinus* plantations attacked by *S. noctilio* around the city of São Francisco de Paula, Rio Grande do Sul (Carvalho, 1991). It is nowadays possibly established in nearly all cities in Rio Grande do Sul and Santa Catarina where *S. noctilio* occurs, and in Paraná state, where the pest is more recent. Evaluations indicate a level of parasitism up to 39%, with an average close to 25%.

Eggs and larvae of first and second instar suffer parasitism. This parasite is attracted to the oviposition holes of the host when the fungus *A. areolatum* begins to spread (Madden, 1968; Spradbery, 1974).

The parasites *Rhyssa persuasoria* and *Megarhyssa nortoni* have long ovipositors and therefore attack larvae in more advanced stages of development. The parasite introduces the ovipositor into the wood in search of the host larvae. The parasite first paralyzes the *S. noctilio* larvae with its sting, and then lays its eggs on the body of the host. After the eggs hatch, the parasite larvae feed on the host, and after consuming it, are transformed into pupae.

In this group of species, most of the members of each generation undergo a diapause in the larval state once they are completely fed. They pupate in the following spring and emerge when the host larvae move towards the tree bark to pupate. Those which do not undergo diapause pupate immediately, to emerge in the beginning of summer.

According to Taylor (1967), *I. leucospoides* may spread quickly over long distances—up to 80 kilometers—and when it reaches new areas it reproduces intensively. It has also been observed that *I. leucospoides* is more efficient in dry places.

Taylor (1967) observed that *Rhyssa* spp. and *Megarhyssa* spp. can spread over all areas infested by *Sirex*, between seven and 18 kilometers from the release point.

The complex of parasites (*Ibalia* + *Rhyssinae*) can eliminate up to 70% of the population of *Sirex noctilio* in certain places (Nuttal 1989). It doesn't usually, however, exceed 40% of the population, an insufficient percentage to keep *S. noctilio* attacks from reaching high levels. Nevertheless it is important to maintain the ecosystem/pest equilibrium.

Quarantine strategies

Sirex noctilio can spread naturally between 30 and 50 kilometers per year. However, the transportation of wood from attacked areas to plantations where it hasn't yet been detected increases the possibilities of its dispersal. That is probably how *S. noctilio* was introduced in Brazil, coming from Uruguay. For that reason, monitoring affected areas and prohibiting transportation of wood from attacked areas to non-attacked ones are strategies which can help avoid the dispersal of the pest.

General recommendations

Sirex noctilio is essentially a secondary, opportunistic pest. The prevention of economically important damage in *Pinus* spp. plantations is a management problem which may be mitigated by monitoring forest stands and by using appropriate silvicultural practices. Healing procedures include phytosanitary thinning and the use of biological control agents.

References

Bedding, R. 1972. Biology of *Deladenus siricidicola* (Neotylenchidae) an entomophagous-mycethophagous nematode parasitic on woodwasps. Nematologica. 18:482-493.

Bedding, R. A. 1989. Relatório e recomendações sobre o ataque de *Sirex* no Brasil. Curitiba: EMBRAPA-CNPF. 8p.

Bedding, R. A.; Akhurst, R. J. 1989. Use of *Deladenus siricidicola* in the biological control of *Sirex noctilio* in Australia. Journal of Australian Entomological Society. 13: 129-135.

Caravalho, A. G. 1991. Parasitismo de Ibalia sp. (Hymenoptera: Ibaliidae) em *Sirex noctilio* Fabricius, 1973 (Hymenoptera: Siricidae) em São Francisco de Paula, RS. Boletim de Pesquisa Florestal. Curitiba: EMBRAPA/ CNPF.

Chrystal, A. G. 1930. Studies on the *Sirex* parasites: the biology and post-embryonic development of *Ibalia leucospoides* Hochenw. (Hymenoptera: Cynipoidea). Oxford Forestry Memories. 11: 1-63.

Coutts, M. P. 1968. Rapid physiological change in *Pinus radiata* following attack by *Sirex noctilio* and its associated fungus *Amylostereum* spp. Australian Journal of Science. 30 (7): 274-276.

Coutts, M. P. 1969. The mechanism of pathogenicity of *Sirex noctilio* on *Pinus radiata* I. Effects of the symbiotic fungus *Amylostereum* (Thelophoraceae). Australian Journal of Biological Science. 22: 915-924,

Davis, K. M. 1966. Forest management: regulation and valuation. 2 ed. New York: Mcgraw-Hill. 516 p.

Furniss, R. L.; Carolin, V. W. 1977. Western forest insects. Washington: USDA Forest Service. 654 p.

Gilbert, J. M.; Miller, L. W. 1952. An outbreak of *Sirex noctilio* (F.) in Tasmania. Australian Forestry. 16: 63-69.

Gilmour, J. M. 1965. The life cycle of the fungal symbiotic of *Sirex noctilio*. New Zealand Journal of Forestry. 10 (1): 80-89.

Hanson, H. S. 1939. Ecological notes on the *Sirex* woodwasps and their parasites. Bulletin of Entomological Research. 30 (1): 27-65.

Haugen, D. A. 1990. Control procedures for *Sirex noctilio* in the green triangle: review from detection to severe outbreak (1977-1987). Australian Forestry. 53 (1): 24-32.

Haugen, D. A.; Underdown, M. G. 1990. *Sirex noctilio* control program in response to the 1987 green triangle outbreak. Australian Forestry. 53 (1): 33-40.

Iede, E. T. 1988. Estratégia de ação para a busca e controle de *Sirex noctilio* em *Pinus*. Curitiba: EMBRAPA-CNPF. 5 p.

Iede, E. T.; Penteado, S. R. C.; Bisol, J. C. 1988. Primeiro registro de ataque de *Sirex noctilio* em *Pinus taeda* no Brasil. Circular Técnica 20. Curitiba: EMBRAPA-CNPF. 12 p.

Iede, E. T.; Bedding, R. A.; Penteado, S. R. C.; Machado, D. C. 1989. Programa Nacional de Controle da vespa-da-madeira-PNCVM. Curitiba: EMBRAPA-CNPF. 10p.

Kile, G. A.; Turnball, C. R. A. 1974. Drying in the sapwood of radiata pine after inoculation with *Amylostereum areolatum* and *Sirex* mucus. Australian Forestry Research. 6 (4): 35-40.

Madden, J. L. 1974. Oviposition behavior of the woodwasp, *Sirex noctilio* F. Australian Journal of Zoology. 22: 341-51.

Madden, J. L. 1975. An analysis of an outbreak of the woodwasp, *Sirex noctilio* F. (Hymenoptera: Siricidae), in *Pinus radiata*. Bulletin of Entomological Research. 65: 491-500.

Madden, J. L. 1988. *Sirex* in Australia. In: Berryman, A.A. Dynamics of Forest Insect Populations. Australia: Plenum Pub. Corp. 407-427.

Miller, D.; Clark, A. F. 1935. *Sirex noctilio* F. and its parasite in New Zealand. Bulletin of Entomological Reseach. 26: 149-154.

Morgan, D. F. 1968. Bionomics of Siricidae. Annual Review of Entomology. 13: 239-256.

Morgan, F. D.; Stewart, N. C. 1966. The biology of the woodwasp *Sirex noctilio* (F) in New Zealand. Transactions of the Royal Society of New Zealand. 7 (14): 195-204.

Neumann, F. G. 1979. Insect pest management in Australian radiata pine plantations. Australian Forestry. 42: 30-38.

Neumann, F. G.; Morey, J. L.; McKimm, R. J. 1987. The *Sirex* wasp in Victoria. Lands and Forest Division Bulletin. 29: 1-41.

Nuttall, M. J. 1980. *Deladenus siricidicola* Bedding (Nematoda: Neotylenchidae): Nematode parasite of *Sirex*. Forests and Timber Insects in New Zealand. 48: 1-8.

Rawlings, G. B. 1953. Insect epidemics on forest trees in New Zealand. New Zealand Journal of Forestry. 6 (5): 405-412.

Rawlings, G. B.; Wilson, N. M. 1949. *Sirex noctilio* as a beneficial and destructive insect to *Pinus radiata*. New Zealand Journal of Forestry. 6: 1-11.

Rebuffo, S. 1990. La "Avispa de la Madera" *Sirex noctilio* F. en el Uruguay. Montevideo: Dir.For. 17p.

Smith, D. R. 1978. Hymenopterorum Catalogus-Suborder Symphita (Xyelidae, Pararchexyelidae, Parapamphiliidae, Xyelydidae, Karatavitidae, Gigasiridae, Sepulcidae, Pseudosiricidae, Anaxyelidae, Siricidae, Xiphydriidae, Paroryssidae, Xyelotomidae, Blasticotomidae, Pergidae). Holland: W. Junk. 59-63.

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.

Taylor, K. L. 1967. The introduction, culture, liberation and recovery of parasites of *Sirex noctilio* in Tasmania, 1962-67. CSIRO Paper 8. Melbourne: CSIRO. 19 p.

Taylor, K. L. 1976. The introduction and establishment of insect parasitoids to control *Sirex noctilio* in Australia. Entomophaga. 21: 429-440.

Taylor, K. L. 1981.The *Sirex* woodwasp: ecology and control of an introduced forest insect. In: The Ecology of pests: some Australian case histories. Australia: CISRO. 12: 231-248.

Zondag, R. 1959. Progress Report on the Establishment in New Zealand of *Ibalia leucospoides* a parasite of *Sirex noctilio*. New Zealand Forestry Research Notes. 20: 1-9.

Zondag, R. 1969. A nematode infection of *Sirex noctilio* F. in New Zealand. New Zealand Journal of Science. 12: 732-747.

Sampling methods for evaluating *Sirex noctilio* attack levels in *Pinus taeda* stands and for monitoring the efficiency of its natural enemies

Susete do Rocio Chiarello Penteado; Edilson Batista de Oliveira; Edson Tadeu Iede

Abstract

Brazil has about five million hectares of forest plantations, of which two million are planted with *Pinus* spp. South Brazil and São Paulo state have 1.2 million hectares of pine plantations, mainly planted with loblolly pine (*Pinus taeda* L.) and slash pine (*Pinus elliottii* Engelm.). These forests provide the raw material for Brazil's pulp and paper, particleboard, ply and veneer, sawing, and resin industries.

Due to lack of proper forest management, large areas of pine forests are in bad phytosanitary condition; these forests are vulnerable to pests and diseases. *Sirex noctilio* (Hymenoptera: Siricidae) registers the largest amount of damage in these forests. A native of Europe, Asia, and Northern Africa, *S. noctilio* was detected in Brazil in February 1988. By 1997, *S. noctilio* could be found in 250,000 hectares in Rio Grande do Sul, Santa Catarina, and Paraná states.

The nematode *Beddingia (=Deladenus) siricidicola* (Bedding) (Nematoda: Neotylenchidae) and the parasitode *Ibalia leucospoides* (Hymenoptera: Ibaliidae) are used to control *Sirex*. *B. siricidicola* acts in the reproductive system of female *S. noctilio* to make them sterile. *I. leucospoides* attacks eggs and first and second instar larvae.

This paper aims at defining sampling methods for the evaluation of damage caused *S. noctilio* and for monitoring the efficiency of its natural enemies.

Methodology

All field trials were carried out in *P. taeda* stands located at Encruzilhada do Sul, RS, and Lages, SC. In each place, five *P. taeda* trees under attack by *S. noctilio* were inoculated with *B. siricidicola*. Subsequently, the trees were divided into billets, which were stored in meshed cages in the laboratory.

Distribution of insects along the stems of *Pinus taeda*

All emerging adults of *S. noctilio* and *I. leucospoides* were collected and counted to determine the distribution of insects along the stems of *P. taeda*. *S. noctilio* adults were dissected and analyzed under a stereomicroscope to determine the presence of nematodes in their reproductive systems.

A regression analysis was used to determine the insects' distribution along the stem. The relative height of each billet was calculated by measuring the distance from the mean point of the billet to the base of the tree and dividing by the total height of the tree.

Polynomial models up to the fourth degree were used in the regression analysis, with the number of insects as dependent variable, and relative height, $\frac{hi}{H}$ as independent variable, where:

h_i = height of tree on point i

H = total height of tree

In addition, polynomial models up to the fourth degree using $\frac{hi}{H}$ as independent variable and $\frac{di}{BHD}$ as dependent variable were used to describe the variation diameters along the stem (dos) (di = diameter of stem, hi = height, and BHD = Breast Height Diameter). This analysis aimed at studying the occurrence of insects also in relation to stem taper.

An analysis of the percentage of residue was made based on Neter and Wasserman (1974) to determine the variation between the number of insects in each billet and the position of the billet in the stem.

Size of sample of *Pinus taeda*

The sample size for populational evaluation of *S. noctilio* and of parasitism with *B siricidicola* and *I. leucospoides* was determined by a variance analysis using a mixed model of hierarchical model, with three stages, as in Snedecor and Cochran (1978) , and Lima (1979):

$$y_{ijk} = \mu + a_i + p_{ij} + t_{ijk}$$

where:

- y_{ijk} = observation in billet k, at position j, of tree i
- μ = populational mean
- a_i = effect of tree i (i = 1,2,3,4,5)
- p_{ij} = effect of position j (j = upper, middle, and lower) of tree i
- t_{ijk} = effect of billet k (k = 1,2,3,...,7) at position j of tree i

A double entry table of variation coefficients was built with the proposed model, considering that the number of trees varied from one to five (rows of the table) and billets varied from one to seven (columns of the table), with a fixed position of stem previously determined in the study of insects' distribution along the stem.

Sequential sampling to define *Sirex noctilio* attack level in *Pinus taeda* stands

Because of its cost effectiveness and precision, sequential sampling was chosen to define the *Sirex noctilio* attack level in *P. taeda* stands.

Theoretical approaches were based on Penteado et al. (1993) and Penteado (1995).

Results

Distribution of insects along the stems of *Pinus taeda*

The model which best described the distribution of insects in relation to tree height was:

$$\text{No. of insects} = a\left(\frac{hi}{H}\right) + b\left(\frac{hi}{H}\right)^2$$

The results indicated that although the largest amount of wood is in the first 30 % of the stem, this area presented a smaller incidence of insects. From this point to the top of the tree, the distribution of insects is regular and proportional to the wood volume of each section. The low occurrence of *I. leucospoides* led to a not-so-marked curve, but the trend is similar to that seen for *S. noctilio* (see Figures 1 and 2).

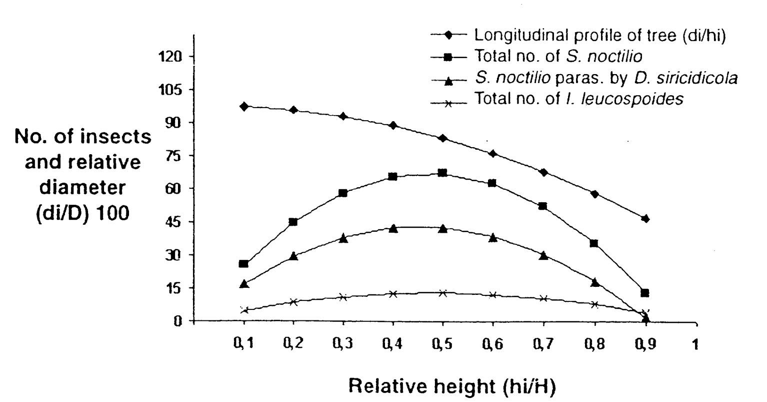

Figure 1. Relation between the total numbers of *Sirex noctilio* and *Ibalia leucospoides* and stem taper in *Pinus taeda* trees at Encruzilhada do Sul, RS.

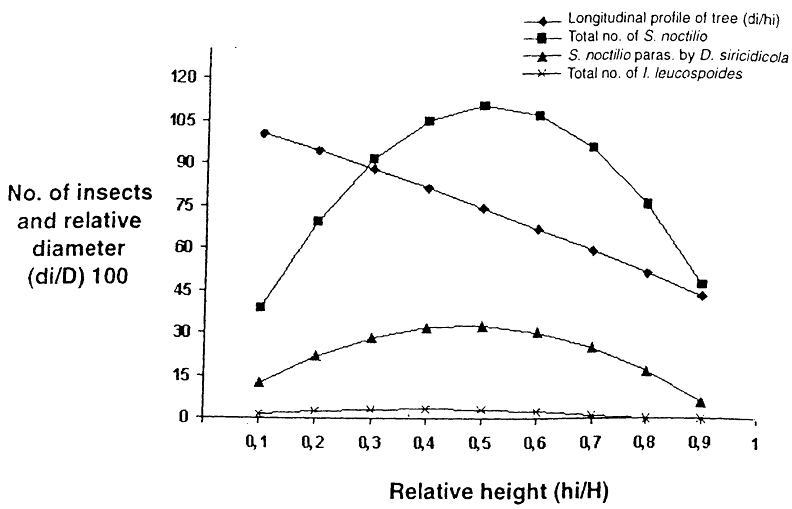

Figure 2 - Relation between the total numbers of *Sirex noctilio* and *Ibalia leucospoides* and stem taper in *Pinus taeda* trees at Lages, SC.

The non-preference of insects for the initial 30% of the stem may be related to its high humidity content. Humidity content analysis (Table 1) showed that humidity is higher in the first third of the stem, with 86.4 % in Encruzilhada do Sul, and 96.2% in Lages. Bark thickness could also act as a physical barrier to egg laying, both for *S. noctilio* and for *I. leucospoides*.

Table 1. Breast height diameter (BHD), height and humidity (dry weight basis) of *Pinus taeda* trees selected for *Deladenus siricidicola* inoculation at Encruzilhada do Sul, RS, and Lages, SC. 1993-1994

Place	BHD (cm)	Height (m)	Humidity Content (%)			Average
			Lower third	Middle third	Upper third	
Encruzilhada do Sul-RS						
Tree 1	19.00	12.30	119.86	29.78	22.68	57.44
Tree 2	18.70	9.70	64.15	29.77	23.17	39.03
Tree 3	16.30	9.70	72.28	29.30	23.14	41.57
Tree 4	20.40	11.30	80.07	31.61	23.64	45.11
Tree 5	16.00	10.80	95.64	29.37	23.02	49.34
Average	18.08	10.76	86.40	29.97	23.31	46.50
Lages-SC						
Tree 1	22.10	16.00	126.35	35.23	31.02	64.20
Tree 2	19.70	14.80	59.73	38.80	29.32	42.62
Tree 3	12.90	12.00	49.57	38.69	28.79	39.02
Tree 4	27.60	15.30	146.80	50.40	33.11	76.77
Tree 5	16.40	15.50	98.69	35.11	34.93	56.24
Average	19.74	14.72	96.23	39.65	31.43	55.77

The residues analyses (Figures 3 and 4) indicated that the samples had a high dispersion at the first third of the tree in relation to the curve of the regression equation.

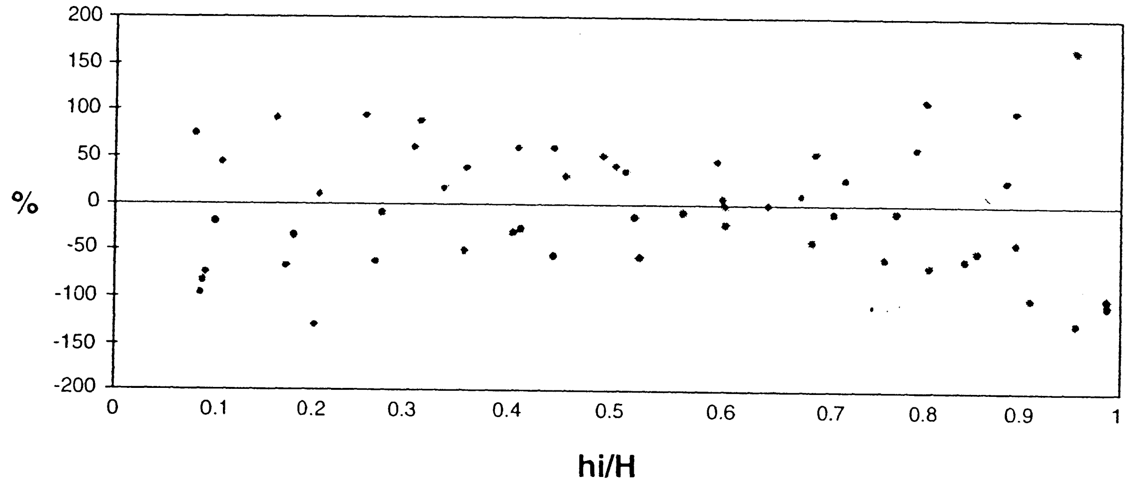

Figure 3. Residue of total number of *Sirex noctilio* and *Ibalia leucospoides* in relation to *Pinus taeda* tree height. Encruzilhada do Sul, RS. 1993-1994.

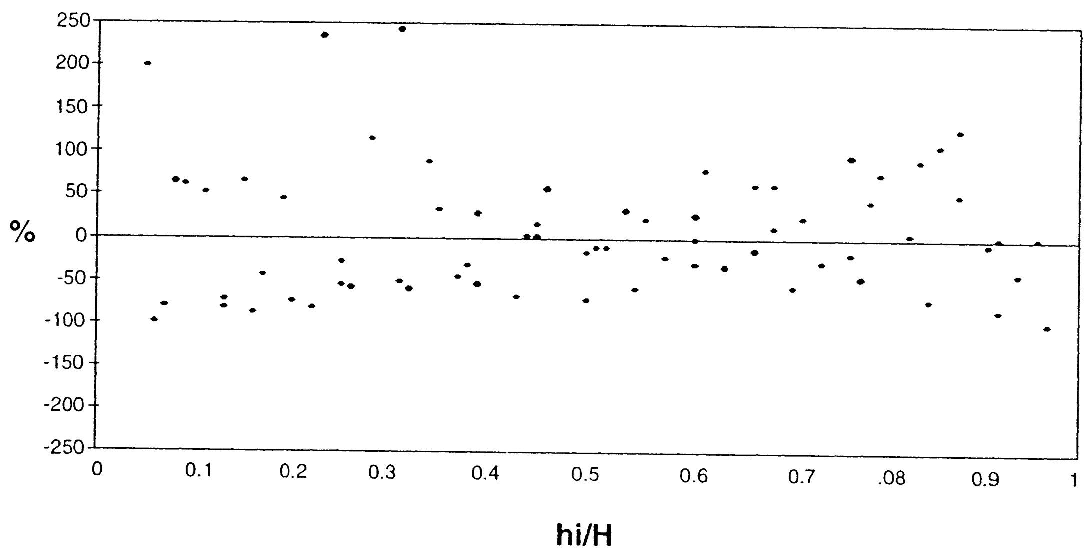

Figure 4. Residue of total number of *Sirex noctilio* and *Ibalia leucospoides* in relation to *Pinus taeda* tree height. Lages, SC. 1993-1994.

A large dispersion was also noted above 80% of tree height. The stem section between these two heights showed a smaller number of errors. The larger variability noted at the base and at the top of the stem is related the occurrence of fewer insects in these regions. Therefore, sampling should be made in the portion between 30% and 80% of the relative height of the tree.

Size of sample of *Pinus taeda*

The first step of sampling is the determination of the desired precision. Table 2 presents the number of billets and trees that should be sampled to achieve a certain precision represented by a coefficient of variation.

Table 2. Coefficient of variation for total number of *Sirex noctilio* and *Ibalia leucospoides* as a function of the number of trees and the number of billets per tree of *Pinus taeda*

Number of Trees	Number of Billets						
	1	2	3	4	5	6	7
	Coefficient of Variation %						
1	43.17	35.85	33.04	31.55	30.62	29.98	29.52
2	30.53	25.35	23.36	22.31	21.65	21.20	20.87
3	24.94	20.71	19.09	18.23	17.69	17.33	17.06
4	21.59	17.92	16.52	15.77	15.31	14.99	14.76
5	19.34	16.06	14.81	14.15	13.73	13.45	13.24

Use of the Coefficient of Variation Table (CV Table)

Operational ease and available room for sample storage should be considered when using the CV table. These two aspects will define the number of trees and billets that will be sampled.

The sampling of three trees and three billets gives a CV of about 19% (see Table 2) which can be considered appropriate to field conditions, i.e., the sample will have nine billets (three per tree). The number of billets can be reduced by increasing the number of trees. If five trees are sampled, only one billet for each tree is necessary. The final sample will have only five billets (almost half the previous sample size) with the same CV.

The researcher can decide sample size in the field based on requirements and convenience; e.g., if natural parasitism of *B. siricidicola* is to be evaluated, and the felling of trees is required, a smaller number of trees and a larger number of billets may be the most operational choice. On the other hand, if parasitism of inoculated trees is to be evaluated, and trees have already been felled, there is no need to take more trees or billets. In both cases the factor limiting the number of billets in the final sample will be the amount of storage space and kind of transport available.

Sequential sampling to define *Sirex noctilio* attack level in *Pinus taeda* stands

The method employed in this sampling procedure is based on the sequencial sampling technique, where samples do not have a fixed size. Size of samples is determined at the time that intermediate results are obtained.

Table 3 (right) shows how to determine whether the number of samples collected is large enough. Use of the table allows economy of time and resources without loss of precision.

Use of the sequential sampling table

1. Start by sampling 68 trees.
2. Record the number of attacked trees.
3. If 34 or more trees have been attacked, the sample is complete.
4. If fewer than 34 trees have been attacked, sample another six trees.
5. If 36 or more trees have been attacked, the sample is complete.
6. If fewer than 36 trees have been attacked, sample another six trees.
7. The process continues until the number in column two is equal to or greater than the corresponding number in column three, or until 272 trees have been sampled.

Number of sampled trees	Number of attacked trees	
	Trees attacked in the sample	Minimum to stop sampling
68		34
74		36
80		37
87		38
94		39
102		41
111		42
121		44
132		45
145		46
159		48
175		49
194		50
215		52
241		53
272		54
272		49
272		44
272		38
272		27
272		22
272		16
272		11
272		5
272		1

Table 3 -Definition of sample size for the evaluation of percentage of trees attacked by *Sirex noctilio* in *Pinus taeda* stands by the use of sequential sampling.

The percentage of trees attacked by *S. noctilio* is given by:

$$\% \text{ attack} = 100 \left(\frac{\text{no. of trees attacked}}{\text{no. of trees sampled}}\right)$$

Conclusions

- the first third of the stem is the least preferred by *S. noctilio* and its natural enemies

- samples to evaluate *S. noctilio* population and parasitism levels of *D. siricidicola* and *I. leucospoides* should be collected in the segment between 30% and 80% of stem length, i.e., in the medium third and in the lower half of the upper third of the stem

- the CV table is a valuable tool in planning the monitoring of the activities of *S. noctilio* and its enemies; precision of results, storage of samples, and operational costs should be considered

- sequential sampling is a viable alternative for the evaluation of *S. noctilio* attack level in *P. taeda* stands; it is fast, cost-effective, and reliable

Recommendations

1. Although CV tables can help to define the number of trees and billets that should be collected, choice of trees is very important. It is recommended that only billets with resin drops be collected. This guarantees a reasonable number of insects in the billet.

2. Variations among stands and within stands due to soil, age, and management can interfere with the precision of results; if necessary, sampling should be done for each different condition.

3. Sequential sampling requires homogeneous areas. If variations occur in the same stand, the stand should be stratified and evaluations made within each stratum.

References

Iede, E. T.; Penteado, S. R. C.; Bisol, J. C. 1988b. Primeiro registro de ataque de *Sirex noctilio* em *Pinus taeda* no Brasil. (EMBRAPA-CNPF Circular Técnica 20) Colombo: EMPRABA-CNPF. 12 p.

Lima, P. C. 1979. Método de amostragem para a avaliação do índice de infecção da ferrugem do cafeeiro (*Hemileia vastatrix* Berk. E Br.). Piracicaba: Tese (Mestrado em Estatística e Experimentação Agrícola)-Escola Superior de Agricultura "Luiz de Queiróz". 65 p.

Mendenhall, W. 1985. Probabilidade e estatística. Rio de Janeiro: Campus. 489 p.

Neter, J.; Wasserman, W. 1974. Applied linear statistical models. Richard D. Irwin, Inc. 842 p.

Penteado, S. R. C.; Oliveira, E. B.; Iede, E. T. 1993. Amostragem sequencial para determinação de níveis de ataque de *Sirex noctilio* (Hymenoptera: Siricidae) em povoamentos de *Pinus* spp. In: Conferência regional da vespa-da-madeira, *Sirex noctilio*, na América do Sul; 1992; Florianópolis. Anais. Colombo: EMBRAPA/FAO/USDA/FUNCEMA: 175-181.

Penteado, S. R. C. 1995. Métodos de amostragem para avaliação populacional de *Sirex noctilio* F. (Hymenoptera: Siricidae) e de seus inimigos naturais, em *Pinus taeda* L. e aspectos do controle biológico. Curitiba: Tese (Mestrado em Ciências Biológicas)-Setor de Ciências Biológicas, Universidade Federal do Paraná. 131 p.

Snedecor, G. W.; Cochran, W. G. 1978. Métodos Estadisticos. Compania Editorial Continental, S.A. México. 703 p.

Biological aspects of *Sirex noctilio* F. (Hymenoptera, Siricidae) and its parasitoid *Ibalia leucospoides* (Hymenoptera: Ibaliidae)

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Abstract

These observations are based on examination of infested logs collected from the field in March 1995 and maintained in non-controlled environmental conditions. The short cycle occurrence of *Sirex noctilio* and its parasitoid *Ibalia leucospoides* in 1995 was from April 8 to June 1. These same logs produced a long cycle generation that appeared from October 14 to February 4. The average body length of a short-cycle *S. noctilio* adult was 13.84 centimeters for females and 10.71 centimeters for males. *I. leucospoides* adults in the same cycle were 10.06 centimeters and 9.35 centimeters for females and males respectively. Parasitism rate was 4.85%. Long-cycle *S. noctilio* adults measured an average of 26.35 centimeters for females and 22.53 centimeters for males. Females and males of *I. leucospoides* measured 12.05 centimeters and 10.15 centimeters, respectively. Parasitism rate in this cycle was 23.45 percent. It was verified that 8°C was the most recommended temperature for *I. leucospoides* storage, with a survival rate of 100% for up to 35 days, longevity being extended by non-controlled environmental conditions for an average of 15 to 30 days. It was also verified that feeding did not affect *I. leucospoides* longevity, and that in any tested diet the temperature of 12°C produced the highest longevity rate (80.2 days).

Introduction

Sirex noctilio F. originated in Europe, Asia, and North Africa (Morgan 1968). It was reported in southern Brazil in the municipalities of Gramado and Canela, RS in 1988 (Iede et al. 1988, Pedrosa-Macedo 1988). Since then it has become a serious menace to the Brazilian national forestry sector, having already reached the states of Santa Catarina and Paraná.

Due to the importance of the insect, private companies and public institutions created the National Fund for Wood Wasp Control (FUNCEMA). FUNCEMA's main objective was to finance the National Program for Wood Wasp Control (PNCVM) (Iede et al. 1989).

As *S. noctilio* is an exotic species, biological control was emphasized, particularly the use of the *Beddingia (=Deladenus) siricidicola* (Bedding) nematode. The PNCVM also foresaw the introduction of *Ibalia leucospoides* (Hochenwarth), *Rhyssa persuasoria* (L.), and *Megarhyssa nortoni* (Cresson), as they are the species with best possibilities of adapting to Brazilian conditions (Iede et al. 1989). In 1990, after the accidental introduction of *I. leucospoides* was verified, new possibilities of advance in *Sirex* control appeared.

This study investigated *Sirex noctilio* and *I. leucospoides* adult population fluctuation in two emergence periods (annual cycle and short cycle), as well as temperature and feeding influences on *I. leucospoides* longevity.

Literature review

Even before the 1952 *Sirex* report in southern Tasmania, it had been recognized as a serious menace to Australian *Pinus* plantations, as it had already caused considerable damage to *P. radiata* D. Don in New Zealand. In 1961, *S. noctilio* was detected on the Australian continent, where a biological control program was developed. Its objective was to collect parasitoids from the regions where *Sirex* originated in order to rear them in the laboratory and then release them (Taylor 1976).

One of the parasitoid groups used for siricid control is the Ibaliidae, which attack eggs and/or larvae in a first or second instar (because they possess a short ovipositor). They are attracted to *Sirex* oviposition holes only when the symbiotic fungus starts to grow, which occurs at the same time as host egg eclosion (Madden 1968; Spradbery 1974). The larval period presents four instars, three of them occurring inside the host larvae, and the fourth in wood galleries (Nutall 1980). Males, small adults between 5 and 16 milimeters, emerge a few days before females (Nutall 1980). According to Taylor (1967), *I. leucospoides* disperses over long distances, reproducing intensively in new areas.

Ibalia species are the only Siricid larval endo-parasitoids found in European, Asian, and North American forest regions (Weld 1952).

According to Weld (1952), Rebuffo (1990), Carvalho (1993) and Klasmer (1996), *I. leucospoides* presently occurs in the following countries: France, England, Germany, Austria, Russia, New Zealand and Australia (including Tasmania), Uruguay, Argentina, and Brazil.

According to Weld (1952), *Sirex juvencus*, *S. noctilio*, *S. cyaneus*, *Urocerus gigas*, and possibly *Xeris spectrum*, are all *I. leucospoides* hosts.

The utilization of parasitoids in *S. noctilio* biological control started in New Zealand in 1928, with the successful introduction of *Rhyssa persuasoria*, collected in Europe (Chrystal 1930; Hanson 1939). In the same period, *I. leucospoides* was introduced in England, but its establishment was verified only in 1957, after a second introduction in 1950 (Zondag 1959). According to Taylor, (1976; 1981), *I. leucospoides* was introduced in Tasmania between 1959 and 1960, through collecting in New Zealand.

In South America, *I. leucospoides* was first reported in Uruguay, in 1984, where it attacked an average 24% of the *S. noctilio* population (Rebuffo 1988); according to Klasmer (1996), in 1993 and 1994 the attack rate reached 20% in Argentina. In Brazil, the parasitoid was detected in 1990, where it controlled up to 29% of the pest (Carvalho 1992). In none of these places was there an intentional release of *I. leucospoides* (Iede, pers. comm.).

In Brazil this parasitoid occurs in nearly all areas where its host is present. In some cases, they were brought up in laboratory and later released in fields by reforestation companies, with the objective of introducing the parasitoid in areas where it was not yet present or in the attempt to increase parasitism rates (Penteado 1995).

In many trees, symbiotic fungus growth happens in three to five weeks. But in some cases, due to high wood humidity, fungus development is retarded, and *Sirex* egg eclosion can take more than 12 months (Spradbery 1974, quoted by Taylor 1976).

Carvalho (1992), verified that the duration of the *I. leucospoides* short cycle in Brazil, from the egg to the emergence of the adult, was from 90 to 95 days. On the other hand, Chrystal (1930), verified in England, in temperate weather, that the duration of this period was not less than three years.

According to Taylor (1966), *I. leucospoides* is one of the most efficient *S. noctilio* parasitoids, because of its high reproductive capacity, independent of whether food is available.

For mass production of *I. leucospoides* the use of small *Pinus taeda* logs one meter in length and 15 to 20 centimeters in diameter, in which *S. noctilio* eggs have been laid, is recommended. These small logs should be offered to *I. leucospoides* couples, previously mated in glass flasks, preferably in a controlled cabinet with temperature of 25°C and 70% humidity. EMBRAPA Florestas recommends that, as *I. leucospoides* males emergence a few days before females, they should be stored at a temperature between 4 and 6°C, for up to four weeks, as couples are gradually formed.

Carvalho (1992) discovered that at room temperature, when *I. leucospoides* was fed honey and water, its longevity increased an average of 15 days for males and 25.1 days for females. Longevity of non-fed insects was 15.2 days for males and 15.9 days for females. Taylor (1967), offering honey and raisins to *I. leucospoides* and *I. ensiger* adults, verified that they rarely fed themselves. Egg laying was not affected by the absence of food or water.

Methodology

Ibalia leucospoides specimens used in this study were obtained from small (80-centimeter) *Pinus taeda* logs attacked by *Sirex noctilio*, collected in March 1995, at São José do Cerrito, SC. To record the emergence of adults, the small logs were put in 200-liter barrels and covered with a net. These barrels were maintained in the EMBRAPA Florestas entomology laboratory in non-controlled environmental conditions (average temperature 20°C and 68+ 10% humidity).

The influence of temperature on the storage period was determined by individualizing ten adults in bakelite flasks of five centimeters in height and four centimeters in diameter. The temperatures of 0°C, 4°C, 8°C, and 12°C were tested, at storage periods of 5, 10, 15, 20, 25, 30, and 35 days. BOD incubators that provided a variation of up to +1°C were used.

The influence of food on *I. leucospoides* longevity was observed by offering hydrolyzed protein at 5 percent, honey at 20 percent, and water alone, to recently emerged adults, at the temperatures of 12°C, 25°C, and room temperature.

Results and discussion

Population fluctuation of *Sirex noctilio* and *Ibalia leucospoides*

The emergence period of short-cycle *Ibalia leucospoides* and *Sirex noctilio* occurred from April 8 to June 1. Long-cycle individuals were obtained from the same logs. These emerged from October 14 to February 4. Iede et al. (1993), Carvalho (1992), and Carvalho et al. (1993) found a shortened emergence period for the two species, from November to May. This difference can be attributed to the annual average temperature, the attacked-log collection date, as well as log diameter and storage conditions.

Average body size of short-cycle *S. noctilio* adults was 10.71 centimeters for males and 13.84 centimeters for females. The sex ratio was 1:5.5. In this same cycle, *I. leucospoides* were an average of 9.35 centimeters (males) and 10.36 centimeters (females) in body length. The sex ratio was 1:8.5. In this period, the rate of parasitism was 4.85%.

Long-cycle *S. noctilio* adults were 22.53 centimeters in length (males) and 26.35 centimeters (females). As for *I. leucospoides*, males measured 10.15 centimeters and females 12.05 centimeters. The rate of parasitism in this cycle was 23.45%, close to the rates found by Carvalho (1992) and Penteado (1995).

Less than 10 percent of the individuals obtained in the two cycles emerged in the first cycle; as these were of very small size, this cycle is not recommended for parasitoid mass production. For the same reasons, the production of short-cycle parasitoids for direct field release is not recommended (see Tables 1 and 2, below, and 3, next page).

Collection Dates	Emergence Periods	*Sirex noctilio*			*Ibalia leucospoides*		
		male	female	ratio of sexes	male	female	ratio of sexes
March 1995	April - July 1995	349	63	1:5.5	12	8	1:1.5
March 1995	Oct. 1995 - Feb. 1996	4,384	516	1:8.5	757	392	1:1.9

Table 1. Number of adults and ratio of females to males of *Sirex noctilio* and *Ibalia leucospoides*, from logs of *Pinus taeda* collected in March 1995. São José do Cerrito SC. 1996.

Sample Collection Dates	Emergence Periods	Percentage of Parasitism
March 1995	April to June 1995	4.85
March 1995	Oct. 1995 - Feb. 1996	23.45

Table 2. Percentage of parasitism of *Sirex noctilio* by *Ibalia leucospoides*, from logs of *Pinus taeda*, collected in March 1995. São José do Cerrito SC. 1996.

Sample Collection Dates	Emergence Periods	*Sirex noctilio*				*Ibalia leucospoides*			
		male		female		male		female	
		Length (cm)	D.P.	Length (cm)	D.P.	Length (cm)	D.P.	Length (cm)	D.P.
March 1995	April-July 1995	10.95	1.71	13.83	1.72	9.35	0.94	10.36	1.14
March 1995	Oct. 1995-Feb. 1996	23.60	4.43	26.35	5.11	10.15	1.08	12.05	1.38

Table 3: Average *Sirex noctilio* and *Ibalia leucospoides* adult body length, from *Pinus taeda* logs, collected in March 1995 at São José do Cerrito SC. 1996.

Temperature and storage period influence on *Ibalia leucospoides* longevity

As the temperature of 8°C maintained 10% survival of *I. leucospoides*, for up to 35 days, it was considered the mostly indicated for storage. It added an average of 15.3 days to life expectancy compared to non-controlled conditions of temperature and humidity.

Comparing the influence of temperatures (12° C, 25° C, and room temperature), it was verified that at 12° C, average longevity was 80.2 days, significantly superior to the other temperatures. On the other hand, The type of diet did not influence *I. leucospoides* longevity, which is in agreement with Taylor (1976) but not with data found by Carvalho et al. (1992), who found an increase of 10.1 days in longevity of females when fed with a honey solution at 20%.

References

Carvalho, A. G. 1992. Bioecologia de *Sirex noctilio* Fabricius, 1793 (Hymenoptera: Siricidae) em povoamentos de *Pinus taeda* L. Curitiba: Tese (Doutorado em Ciências Florestais)-Setor de Ciências Agrárias, Universidade Federal do Paraná. 127 p.

Carvalho, A, G. 1993. Aspectos biológicos de *Ibalia leucospoides* (Hochenwarth), Hymenoptera: Ibaliidae). In: Conferência regional da vespa-da-madeira, *Sirex noctilio*, na América do Sul. (Florianópolis: 1992). Anais. Colombo: EMBRAPA/FAO/USA/ FUNCEMA. 11-120.

Chrystal, R. N. 1928. Studies of *Sirex* parasites. The Empire Forestry Journal. 2 (7): 145-154.

EMBRAPA-CNPF. Metodologia para criação massal de *Ibalia leucospoides*. Folder. Colombo, PR: EMBRAPA-CNPF.

Hanson, H. S. 1939. Ecological notes on the *Sirex* woodwasps and their parasites. Bulletin of Entomological Research. 30 (1): 27-65

Iede, E. T.; Penteado, S. R. C.; Bisol, J. C. 1988. Ocorrência de ataque de sirícídeos (Hymenoptera: Sirícidae) em *Pinus taeda* L. no estado do Rio Grande do Sul. In: Congresso Florestal do Paraná, 2. Anais. Curitiba: Instituto Florestal do Paraná 2 p.

Klasmer, P. 1996. Estudios sobre *Ibalia leucospoides* (Hymenoptera: Ibaliidae) para el control biológico de *Sirex noctilio* (Hymenoptera: Siricidae) en la reigion Andino-Patagonica, Argentina. V Simpósio de Controle Biológico. Resumos. 353 p.

Madden, J. L. 1968. Behavioral responses of parasites to the symbiotic fungus associated with *Sirex noctilio* F. Nature (London). 218 (13): 189-190.

Pedrosa-Macedo. J. H.; Siqueira, J. D. P.; Marques, E. N. 1988. Vespa-da-madeira em *Pinus taeda*. In: Congresso Florestal do Paraná, 2. Encontro paranaense de engenheiros forestais. 3. Anais dos resumos. Curitiba: Instituto Florestal do Paraná. 14 p.

Penteado, S. R. C. 1996. Métodos de amostragem para avaliação populacional de *Sirex noctilio* F. (Hymenoptera: Siricidae) e de seus inimigos naturais, em *Pinus taeda* L. e aspectos do controle biológico. Curitiba: Tese (Mestrado em Ciências Biológicas)-

Setor de Ciências Biológicas, Universidade Federal do Paraná. 131 p.

Rebuffo, S. 1988. La ävispa de la madera *Sirex noctilio* F. en el Uruguay. [Serie Protection Forestal I(1)] Montevideo: Ministério e Ganaderia, Agricultura y Pesca, Dirección Forestal. 14 p.

Spradbury, J. P. 1974. The responses of Ibalia species (Hymenoptera, Ibaliidae) to the fungal symbiont of Siricidae woodwasp host. Journal of Entomology. 48 (2): 217-22.

Taylor, K. L. 1976. The introduction and establishment of insect parasitoids to control *Sirex noctilio* in Australia. Entomophaga, Paris. 21 (4): 429-440.

Taylor, K. L. 1981. The *Sirex* woodwasp: ecology and control of an introduced forest insect. In: Kitching, R, L.; Jones, R. E., eds. The ecology of pests: some Australian case histories. Melbourne: CSIRO.

Taylor, K. L. 1967. The Introduction, culture, liberation and recovery of parasites of *Sirex noctilio* in Tasmania. Technical Paper N° 8. Australia: CSIRO, Divison of Entomology.

Weld, L. H. 1952. Cynipoidea (Hym.): 1905-1950. Michigan: Privately Printed 150 p.

Forest management for the prevention and control of *Sirex noctilio* in *Pinus taeda*

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Abstract

Prevention and control of *Sirex noctilio* F. (Hymenoptera: Siricidae) in Brazil is being accomplished by means of integrated management that involves monitoring for early detection by using trap trees, employing silvicultural practices, and rearing and releasing natural enemies, such as the nematode *Beddingia (=Deladenus) siricidicola* (Bedding). A commonly used method in plantations with an attack level greater than 50% is the immediate clearcut. Thinning, with the removal of attacked trees, could leave the stand understocked, making its continuation to more advanced ages uneconomic. In this paper, the effects of different attack percentages of *S. noctilio* on loblolly pine (*Pinus taeda* L.) growth and production are evaluated in technical and economical terms. The data used were obtained by the simulation of growth and production of forests aged from 12 to 16 years and with attack rates ranging from 0 to 70%. The study compared, for each level of attack, the economic advantages of the immediate clearcut with those of the extension of forest rotation age for up to 20 to 30 years. For the extension of the rotation age, the application of established integrated control was considered. The study indicated that if attacked forests are maintained to an age of more than 20 years and integrated pest management is used, higher economic advantages will be realized than if the forest is clearcut on the occasion of the attack, even if the attack rate is over 50%.

Introduction

The total reforested area in Brazil is approximately five million hectares; out of these, about two million are of *Pinus* spp. About 1.2 million hectares are in the southern region and in São Paulo state; these are made up mainly of loblolly pine (*Pinus taeda* L.) and slash pine (*Pinus elliottii* Engelm). The main purpose of reforestation is to supply raw materials for the pulp, paper, particle board, resin processing, and wood panel industries.

Planting forests in a system of monoculture, combined with inadequate silvicultural practices, have resulted in extensive reforested areas that lack good phytosanitary conditions, making them susceptible to pest attacks. *Sirex noctilio* F. (Hymenoptera: Siricidae), reported for the first time in Brazil in February 1988, quickly adapted itself to these conditions, reaching, in 1996, about 200 thousand hectares of *Pinus* spp. populations in Rio Grande do Sul, Santa Catarina, and Paraná.

Because of its preference for attacking weakened trees, silvicultural control through thinning during critical periods is the most adequate measure for preventing or minimizing damage caused by *S. noctilio*. A strategy commonly used in plantations with attack rates over 50% is the immediate clearcut, as the use of biological control methods cannot be effective in such conditions. Also, damage caused by *S. noctilio* causes the death of attacked trees, and drastic thinning could make the stand understocked, affecting final production of wood.

This paper aims to study the effects of different *S. noctilio* attack rates on the growth and production of *P. taeda* and to evaluate, in technical and economic terms, the recuperation of *P. taeda* populations by means of silvicultural practices and biological control.

Literature review

Trees most susceptible to *Sirex noctilio* attack

According to Chrystal (1928), the genus *Sirex* cannot be considered a primary pest, because other factors initially contribute to making the tree attractive to, and presenting favorable conditions for, *Sirex* development.

Madden (1975) observed that trees initially preferred by *S. noctilio* have smaller diameters and are suppressed, although attacks of dominant trees have also been reported.

Neumann et al. (1987) verified that plantations most susceptible to *S. noctilio* attack are over 12 years of age and are under stress. According to Mendes (1992), the growth curve of *P. taeda* causes its greatest development after the age of 12 years. Consequently, if a *P. taeda* stand attacked during this phase is clearcut, about 60% of the expected wood will be lost, and the wood obtained will have a high production cost.

Trees resistant to *S. noctilio* attack are those that have suffered no physical damage and that have grown in adequate conditions (Neumann et al. 1987).

Means of *Sirex noctilio* prevention and control

According to Neumann et al. (1987), *S. noctilio* attack is a problem originated mainly by the use of inadequate silvicultural practices. They recommend the following means of prevention and control:

- thin during the right periods, to reduce competition among trees and allow the removal of dominated, forked, deformed, and damaged trees
- do not thin and prune during periods immediately before the emergence of adult insects
- avoid planting of *Pinus* spp. on steep land, which makes silvicultural management difficult, in order to minimize lesions to trees during silvicultural practices

Ure (1949) quoted by Sutton (1984) developed a silvicultural regime for planting *Pinus radiata* D. Don in New Zealand, recommending frequent low-intensity thinning to maintain the strength of plants and reduce competition. The principles of this thinning regime formed the basis of silvilcultural practices used since then in New Zealand.

Taylor (1981), states that *S. noctilio* attack can be minimized if plantations are located on good quality sites with management adequate to maintain the strength of plants; this reduces the mortality rate in initial attack phases.

Neumann et al. (1987) verified, in a 17-year-old, non-thinned *P. radiata* stand, that trees with a diameter of less than 23 centimeters had higher mortality rates and that those with a diameter greater than 26 centimeters were less likely to be attacked. Trees with diameter greater than 35 centimeters remained healthy; forked trees were significantly more susceptible to attack.

According to Neumann et al. (1987), trees resistant to *S. noctilio* attack are those that have not suffered any physical damage and that have grown under adequate conditions.

Methodology

Attack percentages and characteristics of stands studied

Percentages of attacked trees were studied in the proportion of 0, 10, 20, 30, 40, 50, 60 and 70%, in two *Pinus taeda* stands, both with a site rate (determined by the projection of the dominant height at 15 years of age) of 21.0 meters. The first stand had 1,850 trees per hectare, a basal area of 52 m^2/ha and was 12 years old. The second had 1,700 trees/ha, basal area of 60 m^2/ha, and was 16 years old. Monitoring and biological control with nematode operations (in the proportion of 20% of the attacked trees in the stand) were considered.

Wood growth, production, and classification data

P. taeda growth and production data, as well as wood classification for multiple uses, were obtained by simulation, using Sispinus Version 2.1. This software generates, from information and measurements from a young-aged *P. taeda* stand, tables with growth and production prognosis at any age and production prognosis tables by diameter classes, from harvested and thinned trees, for multiple industrial uses (Oliveira 1995).

Adopted management regimes

For the first stand, the planned management regime consisted of two thinnings, the first at 12 years (systematic thinning with the removal of one line of trees in every four, followed by the selective removal of attacked trees and of those with smaller diameters, until the proportion of 925 trees/ha was reached); and the second at 16 years (selective removal of attacked trees and of trees with smaller diameters, leaving 450 trees/ha).

For the second stand a thinning was done at 16 years (systematic thinning with the removal of one line of trees in every three, followed by the selective removal of attacked trees and of those with smaller diameters, until the proportion of 900 trees/ha was reached), and the second at 19 years (removal of attacked trees and of those with smaller diameters, leaving 450 trees/ha).

In both cases, thinning could exceed the planned intensity by the removal of attacked trees.

The ages studied for the final harvest were from 20 to 30 years, with two-year intervals.

It was stipulated that two-thirds of the attacked trees belonged to the smaller diameter classes and that the others were randomly distributed among the rest of the stand. In this manner, after the application of systematic thinning of whole lines of trees, the thinning of the remaining trees, the application of nematodes in 20% of attacked trees, and the removal of the remaining trees was also considered according to the proportion of two-thirds to one-third.

Log dimensions for different industrial uses and prices, referring to the Curitiba-PR market as of August 1996, are specified in Table 1.

Table 1. Log dimension and price per M³ according to industrial use of wood

Use	Small diameter (cm)	Length (m)	Price US$/m³
Veneer	25.0	2.4	24.56
Saw wood	15.0	2.4	16.87
Pulp wood	8.0	1.2	10.64
Fire wood	--	--	6.00

Production costs are presented in Table 2.

Table 2. Production cost of *Pinus* spp. in Curitiba-PR (as of August 1995)

A. Forest establishment	US$ 600/ha
B. Harvesting	
1. Felling	US$ 0,98/m³
2. Debranching	US$ 0,18/m³
3. Hauling	US$ 1,00/m³
4. Bucking	US$ 0,16/m³
5. Loading	US$ 0,71/m³
6. Transport	US$ 2,30/m³
7. Unloading	US$ 0,67/m³
C. Administrative costs	US$ 20/ha/ano
D. Forest maintenance	
1st year	US$ 150/ha
4th year	US$ 50/ha
9th year	US$ 40/ha
E. Monitoring and control of *S. noctilio*	US$ 30/ha/5 anos

Evaluation of economic profit

Planin software (Oliveira 1997) was used for evaluation of economic profits. This program has as its base the Annual Equivalent Value (AEV) method, in which the Present Liquid Value of financial profit at a minimal appeal rate is transformed into an equivalent uniform annual series.

Results and discussion

Systematic thinning of whole lines with selective thinning of the remaining trees is constant among *Pinus* producers, mainly to facilitate the cutting and removal of trees. This practice was maintained in all the simulations studied; however, if the producer chooses to use selective thinning only, removing attacked and smaller-diameter trees, he can obtain higher wood production rates, especially in stands with attack percentages such that expected thinning will not remove all attacke trees.

The results obtained in the two studied stand: are shown next.

12-year-old attacked stand

For *S. noctilio* occurrence percentages of up to 30%, systematic thinning, followed by selectiv thinning, was enough to remove all attacked trees at the age of 12. However, from the rate 40% onwards, the removal of all attacked trees made the remaining number of trees per hectare less than the expected rate of 925.

Production prognosis for final harvest ages from 20 to 30 years, according to different attack rates, are presented in Table 3.

Table 3. Growth and wood production values m³/ha of *Pinus taeda* for example # 1, without *Sirex noctilio* attacks.

Age (years)	Dominant height (m)	N/Ha	Average diameter (cm)	Average height (m)	Basal area (m^3)	Total volume (m^3)	IMA (m^3)	ICA (m^3)
12	17.7	1,850	19.0	15.2	52.4	372.0	31.0	31.0
Thinning by the removal of one line in every 4, followed by thinning by the removal of 463 trees								
		925	21.0	15.9	32.0	233.4	Removed=	138.6
14	20.0	918	22.8	17.8	37.7	313.8	32.0	38.2
16	22.1	907	24.6	19.6	43.0	395.0	33.1	40.6
Thinning by the removal of 457 trees								
		450	27.4	20.6	26.5	254.1	Removed=	140.9
18	23.7	449	28.9	22.4	29.4	308.0	32.6	26.9
20	25.6	447	30.7	24.1	33.2	375.7	32.8	33.8
22	27.4	444	32.4	25.6	36.5	440.4	32.7	32.1
24	29.1	441	33.8	27.2	39.5	505.1	32.7	32.3
26	30.6	436	35.1	28.6	42.1	567.7	32.6	31.3
28	32.2	431	36.2	30.0	44.4	626.9	32.4	29.6
30	33.6	425	37.3	31.3	46.4	685.5	31.2	29.3

Economical analysis of these productions is presented in Table 4, indicating that rotation at 24 years of age presents the highest economic benefit for any rate of *S. noctilio* occurrence.

Table 4. Wood production (m^3/ha) of *Pinus taeda* for example # 1, by industrial use classes, for *Sirex noctilio*, attack rates from 0 to 70 %.

No attack	Total m^3	Veneer m^3	Sawlogs m^3	Pulp m^3	Energy m^3
Final harvest at 12 years	372.0	12.1	210.5	125.0	24.4
1st Thinning (12 years)	138.6	3.3	64.4	57.3	13.5
2nd Thinning (16 years)	140.9	10.0	87.5	37.4	6.0
Final harvest at 20 years	375.7	202.6	136.9	30.6	5.5
Final harvest at 22 years	440.4	265.2	142.6	27.3	5.3
Final harvest at 24 years	505.1	328.4	139.3	31.8	5.6
Final harvest at 26 years	567.7	398.7	142.6	26.0	4.8
Final harvest at 28 years	626.9	453.5	135.5	28.7	4.8
Final harvest at 30 years	685.5	519.3	132.7	20.6	4.9

Attack in 10 % of trees	Total m^3	Veneer m^3	Sawlogs m^3	Pulp m^3	Energy m^3
1st Thinning (12 years)	138.6	3.3	64.4	38.7	32.1
2nd Thinning (16 years)	140.9	10.0	87.5	37.4	6.0
Final harvest at 20 years	375.7	202.6	136.9	30.6	5.5
Final harvest at 22 years	440.4	265.2	142.6	27.3	5.3
Final harvest at 24 years	505.1	328.4	139.3	31.8	5.6
Final harvest at 26 years	567.7	398.7	142.6	26.0	4.8
Final harvest at 28 years	626.9	453.5	135.5	28.7	4.8
Final harvest at 30 years	685.5	519.3	132.7	20.6	4.9

Attack in 20 % of trees	Total m^3	Veneer m^3	Sawlogs m^3	Pulp m^3	Energy m^3
1st Thinning (12 years)	150.2	3.7	73.0	36.7	36.8
2nd Thinning (16 years)	131.9	8.1	76.3	42.3	5.2
Final harvest at 20 years	366.6	194.0	136.7	31.1	4.7
Final harvest at 22 years	430.4	255.2	139.9	30.6	4.8
Final harvest at 24 years	494.7	318.2	139.4	32.0	5.1
Final harvest at 26 years	556.0	386.7	136.2	28.6	4.6
Final harvest at 28 years	615.2	441.9	137.9	30.4	5.0
Final harvest at 30 years	671.6	505.5	130.6	30.6	4.9

Attack in 30 % of trees	Total m^3	Veneer m^3	Sawlogs m^3	Pulp m^3	Energy m^3
1st Thinning (12 years)	189.6	2.6	42.9	25.3	118.8
2nd Thinning (16 years)	95.2	3.3	48.2	37.1	6.7
Final harvest at 20 years	353.0	183.7	135.3	28.9	5.1
Final harvest at 22 years	416.1	243.5	138.5	28.6	5.6
Final harvest at 24 years	477.8	305.8	137.3	28.9	5.8
Final harvest at 26 years	538.7	372.4	132.2	28.8	5.3
Final harvest at 28 years	598.4	424.1	139.9	29.3	5.1
Final harvest at 30 years	654.5	491.8	130.6	27.0	5.2

Continuation of Table 4:

Attack in 40 % of trees	Total m^3	Veneer m^3	Sawlogs m^3	Pulp m^3	Energy m^3
1st Thinning (12 years)	208.4	1.9	31.6	18.8	156.1
2nd Thinning (16 years)	73.1	2.4	34.6	30.7	5.4
Final harvest at 20 years	349.6	181.6	134.6	27.6	5.9
Final harvest at 22 years	411.4	238.7	138.6	28.7	5.5
Final harvest at 24 years	472.0	300.0	137.3	29.5	5.1
Final harvest at 26 years	532.5	357.1	140.6	29.5	5.3
Final harvest at 28 years	591.3	422.5	135.4	28.4	5.1
Final harvest at 30 years	647.8	481.8	131.4	29.2	5.3

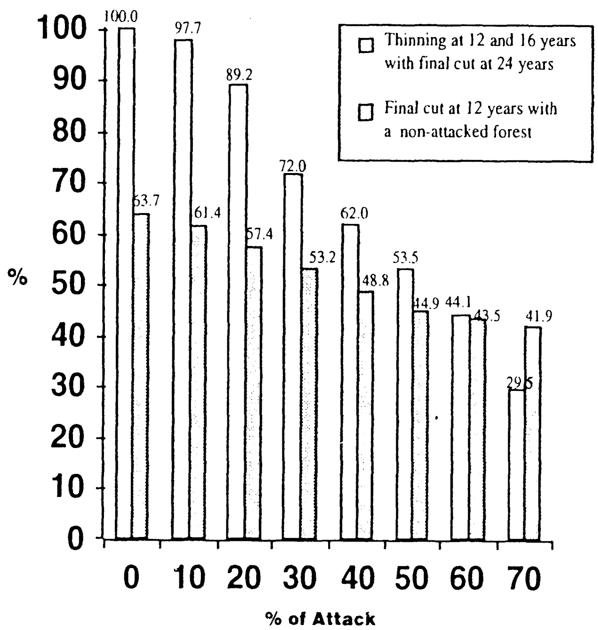
Attack in 50 % of trees	Total m^3	Veneer m^3	Sawlogs m^3	Pulp m^3	Energy m^3
1st Thinning (12 years)	227.6	1.3	21.5	12.7	192.1
2nd Thinning (16 years)	51.4	1.5	23.2	22.7	3.9
Final harvest at 20 years	345.6	179.0	129.8	30.5	5.4
Final harvest at 22 years	406.3	235.8	136.0	28.9	5.6
Final harvest at 24 years	466.9	296.9	136.9	28.3	5.3
Final harvest at 26 years	527.3	353.9	139.8	28.3	5.4
Final harvest at 28 years	585.0	418.5	132.7	28.4	5.4
Final harvest at 30 years	641.3	477.8	130.3	27.6	5.7

Attack in 60 % of trees	Total m^3	Veneer m^3	Sawlogs m^3	Pulp m^3	Energy m^3
1st Thinning (12 years)	265.3	1.3	21.4	12.7	166.1
2nd Thinning (16 years)	13.7	0.2	4.1	8.0	1.4
Final harvest at 20 years	331.6	168.3	127.1	30.6	5.5
Final harvest at 22 years	391.9	223.7	131.8	30.8	5.6
Final harvest at 24 years	451.9	290.6	126.3	29.8	5.3
Final harvest at 26 years	510.2	340.2	134.1	30.5	5.4
Final harvest at 28 years	568.1	405.4	128.1	28.9	5.7
Final harvest at 30 years	623.6	457.6	132.3	28.1	5.7

Attack in 70 % of trees	Total m^3	Veneer m^3	Sawlogs m^3	Pulp m^3	Energy m^3
1st Thinning (12 years)	293.5	1.0	16.0	2.8	273.7
2nd Thinning (16 years)	0	0	0	0	0
Final harvest at 20 years	290.4	145.0	112.6	28.0	4.8
Final harvest at 22 years	346.1	199.5	113.5	28.1	4.9
Final harvest at 24 years	402.9	258.2	114.2	25.2	5.3
Final harvest at 26 years	457.4	314.2	110.6	27.7	4.8
Final harvest at 28 years	511.6	367.6	112.2	27.0	4.8
Final harvest at 30 years	566.6	422.2	112.2	27.0	5.1

In Figure 1, profit percentages of 12-year-old attacked stands are presented, related to the best profit management regime (no attack, 2 thinnings, final harvest at 24 years), in a 24-year-planning horizon.

Figure 1. Profit percentages in 12-year old stands attacked by *Sirex noticilio*, in relation to the management regime of best profit (no attack, 2 thinnings, final harvest at 24 years), in a planning horizon of 24 years.



As can be observed, for different levels of *S. noctilio* attacks, the final harvest of the stand followed by the plantation of a new forest is recommended only for attack rates of more than 60%, where the decrease of profit becomes equivalent.

16-year-old attacked stand

Rotation at 24 years, for any *S. noctilio* attack rate, was the most profitable amongst the 20-to-30-year rotation, as previous studies done by simulation for the prior example (attack at 12 years). Production prognosis for the stand with attack at 16 years, considering the immediate final harvest at age 24, are presented in Tables 5 and 6.

Table 5. *Pinus taeda* wood production (m^3/ha) by industrial use class for example #2, with *Sirex noctilio* attack rates ranging from 0 to 70 %, with final harvest at 24 years.

S. noctilio attack rate (%)	Age (years)	Total m^3	Veneer m^3	Sawmill m^3	Cellulose m^3	Energy m^3
0	16	203.0	25.4	102.2	64.4	11.0
	19	129.4	7.5	75.6	40.8	5.5
	24	426.7	237.7	156.2	27.4	5.4
10	16	203.0	22.8	93.7	49.8	36.7
	19	129.4	7.5	75.6	40.8	5.5
	24	426.7	237.7	156.2	27.4	5.4
20	16	203.0	20.3	47.4	35.2	100.1
	19	129.4	7.5	75.6	40.8	5.5
	24	426.7	237.7	156.2	27.4	5.4
30	16	204.4	17.7	39.4	21.5	125.8
	19	129.4	7.5	75.6	40.8	5.5
	24	426.7	237.7	156.2	27.4	5.4
40	16	228.3	15.6	39.4	20.3	153.0
	19	102.3	7.9	60.7	30.0	3.7
	24	437.4	249.7	155.0	27.3	5.4
50	16	293.0	25.2	71.1	16.9	179.8
	19	53.5	2.5	29.6	18.8	2.6
	24	422.4	238.1	145.4	33.1	5.8
60	16	321.0	23.3	74.9	15.6	207.2
	19	16.8	0.5	10.1	5.6	0.6
	24	429.3	245.1	146.4	32.2	5.6

Table 6. *Pinus taeda* wood production values (m^3/ha) by industrial usage class, for example # 2, considering final harvest at 16 years.

S. noctilio attack rate %	Total	Veneer m^3	Sawlogs m^3	Pulp m^3	Energy m^3
0	537.8	77.1	292.1	145.8	22.8
10	537.8	74.5	283.6	131.2	48.4
20	537.8	72.0	237.3	116.6	111.9
30	537.8	69.4	228.9	102.1	137.5
40	537.8	66.8	220.4	87.5	163.1
50	537.8	64.3	211.9	72.9	188.7
60	537.8	61.7	203.4	58.3	214.4
70	537.8	59.1	195.0	43.7	240.0

...) by industrial
...o attack rates
at 24 years.

Cellulose m³	Energy m³
64.4	11.0
40.8	5.5
27.4	5.4
49.8	36.7
40.8	5.5
27.4	5.4
35.2	100.1
40.8	5.5
27.4	5.4
21.5	125.8
40.8	5.5
27.4	5.4
20.3	153.0
30.0	3.7
27.3	5.4
16.9	179.8
18.8	2.6
33.1	5.8
15.6	207.2
5.6	0.6
32.2	5.6

...ues
...nple # 2,

Energy m³
22.8
48.4
111.9
137.5
163.1
188.7
214.4
240.0

The Equivalent Annual Values (EAVs) for stands with attack rates from 0 to 70%, submitted to thinning at 16 and 19 years, removal of attacked trees, treatment with nematodes, and final harvest at 24 years, and with final harvest at 16 years (assuming also, in this last case, eight more years of forest profit with no attacks) are shown in Tables 7 and 8.

Table 7. Equivalent annual values for example # 1, considering final harvest from 20 to 30 years.

S. noctilio attack (%)	Final harvest age							Final harvest - 12 years plus replanting*
	12	20	22	24	26	28	30	
0	68.2	144.9	149.5	149.5	149.5	141.9	136.6	95.2
10	63.1	141.1	146.0	146.0	146.0	138.7	133.5	91.8
20	54.2	127.0	132.0	133.0	132.8	127.7	122.4	85.8
30	44.8	98.5	105.0	106.7	107.6	103.8	100.2	79.6
40	35.0	83.2	89.9	92.7	92.3	90.8	86.5	73.0
50	26.1	68.3	75.9	80.0	80.0	78.5	75.0	67.1
60	23.0	51.8	60.0	66.0	65.7	65.4	61.8	65.0
70	19.5	27.7	37.5	44.1	46.2	45.9	44.3	62.7

*After the stand cutting, made at age 12, replanting took place, in which there will be no *S. noctilio* attack, being cut at age 24, allowing best economic profit.

Table 8. Equivalent annual values for example # 2, considering final harvest at ages 16 and 24.

S. noctilio attack (%)	Final harvest age		Final harvest-16 years Plus replanting*
	16	30	
0	106.5	128.2	110.7
10	98.4	121.7	102.4
20	74.3	103.3	84.8
30	66.3	96.1	78.4
40	58.2	93.4	71.8
50	50.1	90.6	65.3
60	42.0	85.2	58.8
70	33.9	76.3	52.3

*After the stand cutting, made at age 16, replanting took place, in which there will be no S. noctilio attack, being cut at age 24, allowing best economic profit.

Profit percentages in each situation, related to the best profit management regime (no attack, 2 thinnings, final harvest at 24 years) in a 24-year planning horizon are presented in Figure 2 (right).

In terms of profit, for all attack rates, forests managed and cut at 24 years equal or surpass forests cut at 16 years. Taking as an example the attack rate of 50%, the immediate cut of the stand would cause loss of about 49.1% of the economic profit; continuing the stand with adequate management would reduce this loss to 29.3%.

Final considerations

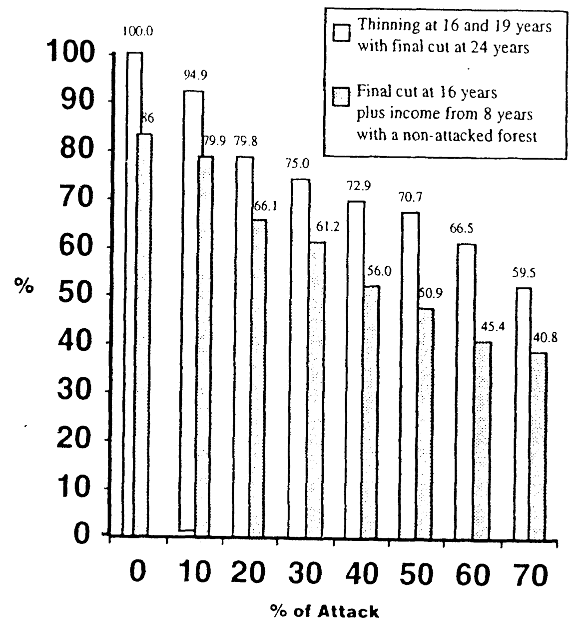
The Sispinus and Planin software made possible the quantification of production and economic profit rates of forests with different *S. noctilio* attack rates, submitted to different management regimes. Nevertheless, some additional considerations should be noted:

- the system does not allow for differences associated with geographical distribution of attacked trees
- there is the possibility of "acamamento" of remaining trees, after specially intense thinning
- there might be problems with roads and other difficulties associated with exploration and thinning
- aspects such as commitments made to the consumer market or the supplying of raw material to factories may dictate the cutting of stands that are not of ideal age

Thus, the decision to clearcut or to thin and manage cannot always be based on economic criteria alone. In all situations, good sense should prevail in the final decision.

An analysis of profit sensibility should be done, changing the various cost centers and prices, looking for a strategic vision that would make losses due to *S. noctilio* the lowest possible.

Figure 2. Profit percentage rates of 16 year old stands attacked by *Sirex noctilio*, in relation to the highest profit management regime (no attack, 2 thinnings, final harvest at 24 years), in a planning horizon of 24 years.



References

Centro Nacional de Pesquisa de Florestas, EMBRAPA. 1992. Inoculação de nematóides. Colombo, PR: EMBRAPA, CNPF. Folder.

Chrystal, R. N. 1928. Studies of *Sirex* parasites. The Empire Forestry Journal. 2 (7): 145-154.

Madden, J. L. 1975. An analysis of an outbreak of the woodwasp, *Sirex noctilio* F. (Hymenoptera: Siricidae), in *Pinus radiata*. Bulletin of Entomological Research. 65: 491-500

Neumann, F.G.; Morey, J. L.; McKimm, R. J. 1987. The *Sirex* wasp in Victoria. Bulletin 29. Victoria: Department of Conservation. Forest and Lands. 41 p.

Oliveira, E. B. 1995. Um sistema computadorizado de prognose de crescimento e produção de *Pinus taeda* L. com critérios quantitativos para a avaliação técnica e econômica de regimes de manejo.

Curitiba: Universidade Federal do Paraná. Tese Doutorado. 134 p.

Sutton, W. R. J. 1984. New Zealand experience with *radiata* pine. Vancouver: The H. R. MacMillan Lectureship in Forestry. N°. 23. 24 p.

Taylor, K. L. 1981. The *Sirex* woodwasp: Ecology and control of an introduced forest insect. In: Kitching, R. L.; Jones, R. E., eds. The ecology of pests: some Australian case histories. Melbourne: CSIRO. 231-248.

Organization of information on *Sirex noctilio*: a simple, practical, and inexpensive solution

Erich Schaitza

Advances in communications and computer science are making the retrieval of bibliographic information simpler. Data bases are being distributed in CD-ROM format or are readily accessible on the Internet. Document delivery systems and virtual libraries provide access to papers almost in real time.

Nevertheless, papers published by Latin American researchers do not flow to these data bases and information systems; sometimes they are not even registered in the data bases of their own institutes. Therefore, these papers are neither read nor quoted by other researchers.

A number of factors contribute to this situation. With few exceptions, the circulation of local journals is very restricted; their editors do not send copies to the Agricultural Research Information System (AGRIS) institutes or the Commonwealth Agricultural Bureau International (CABI). Some AGRIS institutes are not very active in the forestry area. There are many non-indexed publications. Libraries tend to be passive, waiting for people to borrow books. Articles published in Portuguese or Spanish are not read by English-speaking scientists. Latin American information systems are poorly equipped to keep the pace with their European and North American counterparts.

An example of this situation is research on *Sirex noctilio*, a pest attacking *Pinus* spp. The Entomology Laboratory of EMBRAPA-Forestry alone has published 42 papers on the subject over the last five years, including theses, papers, and technical notes. But a search of AGRIS yielded no entries on *Sirex* when all countries in South America were searched. Only 15 entries on *Sirex* were found in CABI's TREECD.

There is clearly, for *Sirex* researchers, a need to organize information systems that will be able to disseminate both bibliographic references and full papers effectively throughout Latin America.

This can be done either by strengthening libraries and institutional information systems or by creating small networks geared towards the organization and dissemination of information on a focal subject. A *Sirex* network could concentrate on all institutes and researchers working with any aspect of *Sirex*.

A suggestion for a cooperative project aiming at the creation of a *Sirex noctilio* information center in Latin America

Currently, Internet technology facilitates both cooperative work between groups whose members work far apart, and the linking and harmonization of independent work. Electronic mail allows for the exchange of messages and files. Web pages can handle thousands of pages of information and link distributed data bases which do not need to be on the same platform, have comparable structure, or exchange data. Image technology facilitates the transfer of technical papers to ready-to-distribute electronic media.

With these tools, the organization of a network of experts on *Sirex* should be reasonably easy, and should bring few additional costs to the institutes involved. The hard work will be bringing experts together and convincing them that they will benefit from sharing information.

A *Sirex* information network can start with a simple web page which will serve as a link between various research institutes and scientists. If a given institute does not have an Internet server, it can use other servers to store its information at very little cost. Each institute would be responsible for offering information about its research results on *Sirex*, for keeping its data bases updated, and for maintaining lists of publications which can be retrieved or borrowed from its library.

A Web page with a form for requesting papers and information about *Sirex* and also a short questionnaire about who and why the information is requested would have a twofold purpose:

- It would allow access to institutional information

- It would keep institutes aware of who their clients are and what they need

If papers requested are not in electronic format, or when restrictions due to authoring rights apply, information could be sent by mail. All documents of an institute could be scanned and either sent by e-mail or left in an area for file transfer. These documents can be offered in several different formats, such as word processor (.DOC), Adobe portable document (.PDF), text or HTML files.

This is an easy-to-develop project, but a moderator will be required, and an institute must lead and coordinate the process. Otherwise, all institutes will continue to keep their work to themselves and no links will be developed.

Another point which should be discussed by scientists working with *Sirex* in different countries is the possibility of standardizing a minimum set of data in each research area. With that, institutes would be able to add and exchange data and develop models for pest behavior, dispersion, reaction to pest management measures, and the like, based on regional data bases.

Latin American and Caribbean Information Systems Network and IUFRO SPDC

The International Union of Forest Research Organizations (IUFRO) is a nongovernmental organization created over 100 years ago whose members are research institutes, universities, private companies, and individuals all over the world.

Members pay an annual fee, and most of the work is volunteer. There are working groups which discuss forest research in many different areas. Probably, a large part of all forest researchers have already participated in some kind of event promoted by IUFRO or have published documents with IUFRO's support.

One of these working groups is the Working Unit 6.03.04 (Latin American and Caribbean Information Systems Network - RIFALC) which aims at promoting the organization and dissemination of information on forestry information in the region. The RIFALC is coordinated by Maria Teresa Motta Tello of CONIF, Colômbia, and, as it has been discussing ways to disseminate information in the region, it certainly can support projects like the one mentioned above, either by looking for funds or by simply facilitating IUFRO information services.

RIFALC's WWW page (http://iufro.boku.ac/at/iufro/iufronet/d6/hp6034.htm) can be found through the IUFRO home page. Lists of events and activities in the region, bibliography and links to other pages of IUFRO and information services all over the world are also found there.

The IUFRO home page (http://iufro.boku.ac.at) describes IUFRO's objectives and is a gateway to a broad scope of information on forestry, including links to virtual libraries, full texts of proceedings, and a directory of research institutes. Besides, it has a very powerful search tool which allows for searches by keywords in all its pages (IUFRO Search).

In 1997, the IUFRO page was accessed daily by almost 2,000 people just in its Austrian server. As it has five other mirrors (Costa Rica, South Africa, Minnesota, Chile, and Finland), many more people have browsed through its pages.

Another possibility of support offered by IUFRO is the Special Program for Developing Countries (SPDC). SPDC sponsors the organization of events, technical trips, international training and planning of regional projects. SPDC has partially supported this training on Integrated Pest Management of *Sirex* and can help in the search of funds for a cooperative information network on *Sirex* in Latin America.

Sirex noctilio F. : present status in Uruguay

Juan Francisco Porcile Maderni

In Uruguay pine covers about 16% of man-made forests, representing approximately 50,000 hectares.

The older and largest stands are located in the southern part of the country, on sandy soils on the coast of the Atlantic ocean and Rio de la Plata. The main planted tree in this area is maritime pine (*Pinus pinaster* Ait.) followed by other species like Monterey pine (*P. radita* D. Don), Aleppó pine (*P. halepensis* Mill.), loblolly pine (*P. taeda* L.), and slash pine (*P. elliottii* Engelm.).

From the early 1970s until the present, a significant area was also planted in the northern part of the country: Rivera, Paysandú, Río Negro, and recently, Durazno. During the period from 1984 to 1993, more than 11,000 hectares of pine were planted in northern Uruguay.

The first *Sirex noctilio* F. infestation was detected in 1980. At first, *Sirex* appeared in isolated dead trees; gradually it started to cause severe damage in pine stands in the northwest area of the country.

Some of these pine stands showed up to 70% of trees damaged. The most injured species was *Pinus taeda* L.; other more resinous species, like *P. elliottii*, appeared to be more resistant to the attack of this siricid. Average attack percentages are shown in Tables 1 and 2.

Table 1. Percentage of *Sirex*-attacked trees in different spacings for *Pinus* spp. in Uruguay

Average attack (%) in different spacings		
Species	3.0 x 3.0 m	2.5 x 2.5 m
Pinus taeda	40.4 %	25.7 %
P. patula	-	26.0 %
P. pinaster	25.0 %	-
P. radiata	38.5 %	11.0 %
P. elliottii	24.0 %	18.0 %
P. echinata	-	14.0 %
P. palustris	-	8.0 %
P. halepensis	2.5 %	-

*20-year-old stand. Evaluation done in 1985 (Porcile, pers. com.)

Table 2. Percentage of *Sirex*-attacked trees in *Pinus elliotti* stands in Uruguay

Average attack (%) in *Pinus elliotti**		
Spacing	Trees/ha	Average attack (%)
2.0 x 2.0 m	2,500	11.0
2.0 x 2.5 m	2,000	8.3
2.5 x 2.5 m	1,600	7.5
3.0 x 3.0 m	1,111	1.8

*20-year-old stand. Evaluation done in 1985 (Porcile, pers. com.)

The infestation was linked to accidental introduction in sawtimber imported from overseas as well as in packing materials.

Later on, the pest spread all over the country, and it is now present in all pine-growing areas.

Chronology

From 1980 to 1985:

- *Sirex noctilio* was detected
- specimens of the insect were sent abroad to confirm its identification
- the parasite *Ibalia leucospoides* (Hochenwarth) was found in the Entomology laboratory of Forest Service in Toledo, Uruguay
- an F. A. O. advisory, assisting the Forest Service, outlined an initial approach to the control of the pest
- *S. noctilio* was included in the national list of plant pests

From 1986 to present:

- a private forest owner introduced the nematode *Beddingia (=Deladenus) siricidicola* (Bedding) under technical assistance provided by Faculty of Agronomy
- the Forest Service created a Department of Forest Pest and Disease Prevention; monitoring pine pests, including *Sirex*, was one of their commitments
- the Plant Protection Committee for the Southern Cone established a Working Group on Forest Protection to develop a program to organize control measures against *Sirex* in the Region

Surveys carried out in different pine-growing areas of Uruguay showed a direct relationship between the percentage of attacked trees and stand density (number of trees per hectare). Furthermore, weakness resulting from other factors, including attacks by other insects, low-quality, poor soils, or lack of management, makes stands more vulnerable to *Sirex* attack. Proper forest management and the action of natural enemies such as the Ibalia parasitic wasp contributed to the maintenance of a low pest population level.

Preventive strategies aimed at detecting new outbreaks of the insect are necessary now and in the future. The last reported phytosanitary inspection, carried out in 1995 by Forest Service Management and Protection Division, showed that *Sirex* is still present in the northeast of Uruguay. In this area,the control measures are mainly based on forest management practices.

In the southern region, the population of this insect appears to have increased recently. The land-owning scheme and the nature of uneven-aged and high-density stands is contributing to the difficulty of control.

Activities for *Sirex noctilio* detection in Chile

Miguel Angel Poisson

Forest resources are very important to Chile, especially Monterey pine, (*Pinus radiata* D. Don) plantations which are the basis for the sustainable development of the Forestry Sector. This fact is demonstrated by Chile's 1994 exports of forest products, amounting to US $1.52 billion, or 13% of all the country's exports (INFOR, 1995).

This multi-million dollar resource is under threat of potential damage by various forest pests, the most important of them *Sirex noctilio*, a class A1 quarantine pest in Chile. This insect has negatively impacted pine plantations in all countries where it has become established, with direct losses of tens of millions dollars and indirect losses (loss of market, control costs, and the like) that could be even larger.

Monterey pine plantations occupy 1,375,886 hectares of Chilean forests (INFOR, 1995) and are distributed from Region V to X, forming an almost continuous mass of forests. A large proportion of this forest area is in the age class most susceptible to attack by *S. noctilio*, as shown in Figure 1.

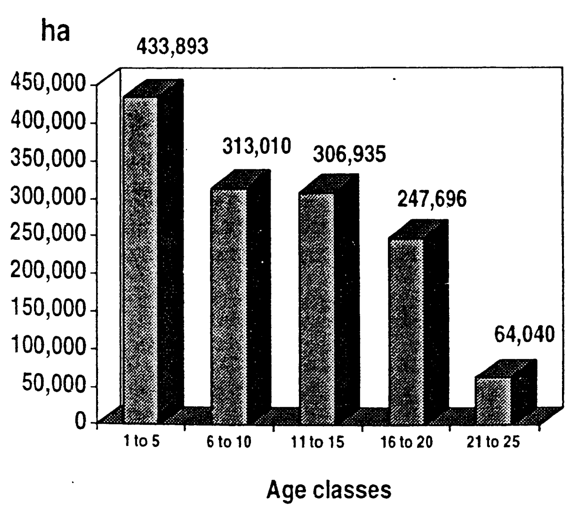


Figure 1 - Distribution of *Pinus radiata* area according to age classes in Chile (1994).

Due to the risk of *S. noctilio*, the Servicio Agricola y Ganadero (SAG) established a cooperative program six years ago with the main private forest companies of the country. This program aims to detect the presence of *S. noctilio* throughout Chile. In the 1995-1996 season, 200 groups of trap trees were installed in six regions of Chile (Regions V-X). No *S. noctilio* were detected in any of the trap tree groups cut in September and October. The 1996-1997 season began in the last week of October, 1996, and trap trees groups were installed during early November in a manner similar to that used the previous season. Groups were installed according to risk areas, which were defined by possible paths of introduction into the country.

Natural dispersion path

Because *S. noctilio* have been found in Bariloche, Argentina, Region X, which borders Argentina, was considered a region with potential for natural dispersion of *Sirex*. Trap-tree groups were installed at a frequency of one group for each 5,000 hectares of forest. In neighboring areas within a 50-kilometer distance of the Puesco border (Region IX), trap-tree groups were installed at a density of one to each 2,500 hectares of forest (due to the detection of *Ibalia leucospoides* (Hochenwarth) there in 1994).

Incidental introduction path

Ports and international centers

Ports and international centers are potential points of introduction of *S. noctilio,* because woody containers are a potential dispersion vehicle. In zones with ports and international centers, trap-tree groups were installed as shown in Table 1:

Dispersion distance in kilometers			
Risk level	0-10	10-20	20-50
High	1/500	1/1,000	1/5,000
Medium	1/1,000	1/5,000	1/10,000
Low	1/5,000	1/10,000	--

Table 1. Density of trap tree groups (N/ha) according to risk level and distance of dispersion from port or center

Areas of arrival or movement of imported goods in woody containers

In areas where imported goods packed in wooden containers arrive or move in commerce, monitoring is more difficult, because of the random characteristics of the movement of goods. This group contains all sites where the arrival of wooden containers was registered, especially those where container origin was from high-risk areas, i.e., areas where the *S. noctilio* occurs. Trap-tree groups were installed in all places registered as important arrival centers of packaging wood, such as industrial plants under construction or in operation, non-port container yards, and the like. The density of trap-tree groups for these areas are shown in Table 2:

	Dispersion distance in kilometers	
	0-15 km	15-30 km
Density of groups	1/500 ha	1/5,000 ha
Distance between groups	2.2 km	7.0 km

Table 2. Density of trap tree groups and distance of groups in areas of container arrival centers according to distance of dispersion

Groups of trap trees have a minimum of five trees; in some forest companies, groups may be as large as 10 trees. Trap trees are 10 to 20 centimeters breast height diameter; they are either intermediate or suppressed individuals and are distributed along roads. Trees on the borders of stands and forked trees are avoided.

Trap trees will be cut from August to October (the end of the 1996-1997 season), and information will be presented to Australian experts who will follow these actions throughout the year.

Current situation in Chile of insects associated with *Pinus radiata* D. Don: developing a strategy to prevent the introduction of *Sirex noctilio* F.

Angélica M. Aguilar

Introduction

Forestry is important to the Chilean economy, providing about $2.37 million in foreign exchange and representing about 15% of the country's exports. The principal products for exportation include cellulose, wood chips, sawtimber, and logs, as well as many secondary products (Instituto Forestal [INFOR] 1996). The principal buyers are Japan, South Korea, Belgium, and the United States (Corporación Nacional Forestal [CONAF] 1996).

The forestry sector's growth began in 1974, with the promulgation of a law granting subsidies to reforestation projects. Since then, there has been a significant increase in new areas of forest plantations, which today cover about 1.8 million hectares, of which 76 percent are planted with *Pinus radiata* D. Don, 17 percent with *Eucalyptus*, and seven percent with other species (INFOR 1996).

On the world level, *P. radiata* is one of the species most utilized in forest plantations, especially in the Southern Hemisphere, where it is important to the forest industries of Chile, South Africa, New Zealand, and Australia (Ohmart 1980, Corporación Chilena de la Madera 1995, Tribe 1995). It is undeniable from an ecological point of view that the intensive cultivation of an exotic species implies an unstable system, contributing to the possibility that the resource will be susceptible to pest attacks, given the absence of natural enemies and the great number of potential hosts. Such an event would lead to significant economic losses. For this reason, the principal insects currently found in plantations of *P. radiata* in Chile and the potential introduction of other agents are important topics of investigation. Much emphasis is placed on preventive actions that have been developed in Chile to prevent or slow down the introduction of *Sirex noctilio* (Hymenoptera: Siricidae), as this insect is quarantined in Chile as it is in many other countries with which Chile has commercial ties.

Principal insects associated with *P. radiata*

In general, available literature indicates that the greatest problems with insects in *P. radiata* have occurred in the Southern Hemisphere, where this resource has been introduced extensively as an exotic species. Billings et al. (1971) state that although most of the insects associated with *P. radiata* in Chile do not constitute a serious problem, several insects, such as *Rhyacionia buoliana* (Lepidoptera: Tortricidae), which attack pine buds, and *Sirex noctilio*, a horntail that bores into the tree's bark, are important.

In 1975 the National Forestry Corporation, a state-owned company, became aware of potential risks to forestry resources, and, in association with the Austral University of Chile, created the National Plan for Plant Protection. In 1977, activities to protect forestry resources were included among the activities of the project PNUD/CONAF/FAO regarding "Forestry Development and Research". For several years, these projects confronted diverse issues of plant protection in natural forests as well as in plantations (Cameron and Peredo 1974; Dafauce 1974; Osorio et al. 1977).

In 1982, the first cooperative agreements between CONAF and forestry companies were established to study the principal problems present in *P. radiata*. Also in this decade, the bark beetles *Hylurgus ligniperda*, *Hylastes ater*, and *Orthotomicus erosus* (Coleoptera: Scolytidae) were discovered in Chile (Ciesla and Parra 1988; Ciesla 1988). These insects play a secondary role in pine plantations and are considered potentially harmful for countries such as Chile which sell wood as logs (USDA Forest Service 1993). It is likely that their original introduction occurred by means of wooden shipping containers.

The detection in 1985 of *R. buoliana* marked an important change in the health of *P. radiata*; the association of this pest with the principal Chilean forestry resource resulted in the creation at the end of the decade of the National Committee on Plant Protection, led by CONAF in conjunction with private and state companies and universities (Ramírez and De Ferari 1991). This committee has as a principal objective the eradification of pests and other forest health problems. In an experience unique at the world level, the Chilean forestry sector chose to use biological control for *R. buoliana* through the introduction of the parasite *Orgilus obscurator* (Hymenoptera: Braconidae). In the ten years that have passed since the detection of *R. buoliana*, much research has been completed in relation to this insect, which is well distributed throughout the country and in some areas is considered a great economic liability.

Regarding insects native to Chile that have caused harm to *P. radiata*, isolated pest attacks have been observed under certain environmental conditions. Several defoliators, most important among them *Ormiscodes* spp. (Lepidoptera: Saturniidae), *Bacuncullus phyllopus* (Phasmatodea: Pseudophasmatidae), *Tanatopsyche chilensis* (Lepidoptera: Psychidae), *Antandrus viridis* (Orthoptera: Acriididae), and *Coniungoptera nothofagi* (Orthoptera: Tettigonidae) contribute to damage to *P. radiata* (Villa and Ojeda 1981; Baldini and Villa 1992; Lewis 1996).

Potentially harmful insects in Chile

The majority of the insects that are able to become established in new areas are species that are transported in wood or other products, implying the need to establish strict quarantine measures. It is most likely these are the circumstances which have surrounded the accidental introduction of pests like wood or trunk borers, which are considered the most destructive in *P. radiata*.

S. noctilio is considered to be the most significant of potentially harmful forest insects in Chile (Béeche et al. 1993). In South America, it is present in Argentina, Brazil, and Uruguay. In this context, following the National Committee of Forest Health, a subcommittee on *S. noctilio* was created in 1989 to implement a strategy for action that included a bibliographic reference collection, training, education, and early detection. Seven years have passed since the study of this potentially harmful agent began; accomplishments are summarized below.

1. **Collection of bibliographic references** at the world level, resulting in two publications on the subject (Aguilar and Lanfranco 1988 ; Lanfranco and Aguilar 1990).

2. **Training** at the national and local level dealing with aspects of detection and recognition of the harmful effects.

3. **Education** through posters and brochures by CONAF and the Agriculture and Cattle Service (SAG).

4. **Visits to other countries**. Chilean professionals employed by the state, private companies, and universities visited countries now facing the *Sirex* problem, establishing contacts with other experts in the area. In 1990, a special investigation of *S. noctilio* was carried out in Bariloche, Argentina, where an infestation was discovered at that time in saw timber which had come from Northern Argentina (Aguilar et al. 1990).

5. **Early detection**. In Chile, more than 600,000 hectares of plantations 11 to 25 years old are considered susceptible to *S. noctilio*. Since 1990, a program for early detection has been developed at the national level which involves quarantine measures. This program has been led by SAG and supported by private forestry companies. Its activities encompass three main areas: the establishment of check points at the national level, installation of trap trees for monitoring, and the development of an international agreement of cooperation with Argentina oriented primarily toward detection and control of *S. noctilio* (Klasmer and Fritz 1995). In addition, since August 1994, the SAG has implemented a law that regulates the entrance of wood containers into the country.

Comments

A retrospective analysis shows that through time, various insects have been associated with plantations of *P. radiata*, seemingly in direct relation to the increase in the total area of plantations. The largest impact has been caused by those insects that have been introduced, as in the case of *R. buoliana*. As a result of this problem, a national strategy of integrated pest management is currently being developed which involves the entire forestry sector. Several defoliators native to Chile are in the process of adapting to the pine resources and can cause sporadic infestations. Although not be permanent and present only under certain environmental conditions, these infestations stress the resource and carry potentially large ecological and economic impacts.

Many insects might potentially be introduced into Chile. As in other countries that possess large areas of pine forest plantations, the insects that bore into tree bark and wood are the most common of these. Given the types of products that Chile exports and the requirements of the countries that buy them, *S. noctilio* is the most likely potential danger. Thus it is necessary to develop a national strategy that prevents or slows down the introduction of this insect. Two aspects of this endeavor, forest management and quarantine, are very important if Chile is to avoid the introduction and development of new pest infestations.

Forest management

At the national level, it is necessary to strengthen the intensive forest management of plantations of *P. radiata*, in order to permit an increase in growth at the level of individual tree, stand, and plantation. When establishing plantations, aspects such as site selection, planting density, and quality of seedlings should be considered carefully.

Quarantine

Another important aspect is the development of a protocol for quarantine. The various commercial agreements that Chile has recently made imply that, without doubt, the establishment of a system of international cooperation regarding quarantine procedures is fundamental to build awareness about the subject at the national level. As is evident, sufficient human and financial resources should be allocated to this effort. With these efforts, it is certain that the plantations of *P. radiata* will become less susceptible to pest infestations and other forest health problems.

References

Aguilar, A.; Lanfranco, D. 1988. Aspectos biológicos y sintomatológicos de *Sirex noctilio* Fabricius (Hymenoptera: Siricidae): una revisión. Bosque 9(2): 87-91.

Aguilar, A.; Lanfranco, D.; Puentes, O. 1990. Prospección para la detección de *Sirex noctilio* (Hymenoptera: Siricidae) en Bariloche, Rapública Argentina. Informe de Convenio N° 180. Serie Técnica. Universidad Austral de Chile, Facultad de Ciencias Forestales. 13 p.

Baldini, A.; Villa, A. 1992. Bicho del cesto: *Thanatopsyche chilensis* (Lepidoptera: Psychidae). Folleto de Divulgación N° 19. Corporación Nacional Forestal. Protección Fitosanitaria Forestal. s/p.

Béeche, M.; Cerda, L.; Herrera, S.; Lermanda, M.; Moreno, C.; Vergara, C. 1993. Manual de Reconocimiento de Plagas Forestales

Cuarentenarias. Santiago, Chile: Ministerio de Agricultura, Servicio Agrícola y Ganadero. 169 p.

Billings, R. F.; Holsten, E. H.; Eglitis, A. 1971. Insects associated with *Pinus radiata* in Chile. Turrialba 22: 105-109.

Cameron, S.; Peredo, H. 1974. Proposición de un Plan Nacional de Prospección Sanitaria Forestal. In: VIII Jornadas Forestales. Valdivia, Chile. 6 p.

Ciesla, W.; Parra, P. 1988. *Orthotomicus erosus* Wollaston (Coleoptera: Scolytidae). Folleto de Divulgación N° 16. Chile: Corporación Nacional Forestal, Protección Fitosanitaria Forestal. s/p.

Ciesla, W. 1988. Pine bark beetles: a new pest management challenge for Chilean foresters. Journal of Forestry. 86(12): 21-31.

Chile. Institutio Forestal. 1996. Estadísticas forestales. Estadístico N° 45. Boletín. 117 p.

Chile. Corporation Nacional Forestal. 1996. Se consolida el dinamismo. Revista Chile Forestal N° 235. 42-43.

Corporacion Chilena de la Madera. 1995. Las plantaciones en el Hemisferio Sur. Revista Corma N° 247. 20-21.

Dafauce, C. 1974. Fortalecimiento del Programa Forestal Nacional de Chile. Plagas Forestales en Chile. FO: SF/CHI 26. Informe Técnico N° 3. s/p.

Klasmer, P.; Fritz, G. 1995. Acciones de detección y control de *Sirex noctilio* en la Región Cordillerana Andino Patagónica Argentina (Hymenoptera: Siricidae, Sericinae). Informe de la Temporada 1993-1994. 12 p.

Lanfranco, D.; Aguilar, A. 1990. Opciones de control biológico para *Sirex noctilio*: una revisión (Hymenoptera: Siricidae). Bosque 11(2): 9-12.

Lanfranco, D. 1994. Pest problems of intensive forestry: the shoot moth invasion of *radiata* pine in Chile. In: Alfaro, R; Kiss, G; Fraser, G., eds.The white pine weevil: biology, damage and management. Proceedings of a Symposium held January 19-21, Richmond, British Columbia, Canada. 301-311.

Lewis, P. 1996. Ortópteros defoliadores de *Pinus radiata* D. Don: nuevos registros. In: XVIII Congreso Nacional de Entomología. Temuco: 20-22 de Noviembre. Sociedad Chilena de Entomología/Universidad de la Frontera. 11 p.

Ohmart, C.P. 1980. Insect pests of *Pinus radiata* plantations: present and possible future problems. Australian Forestry. 43(4): 226-232.

Osorio, M., Cerda, L., Donoso, M., Peredo, H.; Gara, R. 1977. Programa para la Protección de los Bosques Nacionales. Contribución al Proyecto CONAF/PNUD/FAO. CHI/76/003. Valdivia, Chile: Universidad Austral de Chile, Facultad de Ingeniería Forestal. 23 p.

Ramirez, O.; De Ferari, L. 1991. Comité Nacional de Sanidad Forestal: memoria anual 1990. Santiago, Chile: CONAF/Empresas Forestales. 24 p.

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

United States Department of Agriculture, Forest Service. 1993. Pest risk assessment of the importation of *Pinus radiata*, *Nothofagus dombeyi*, and *Laurelia philippiana* logs from Chile. Miscellaneous Publication N° 1517. Washington, DC: USDA Forest Service. 248 p.

Villa, A.; Ojeda, P. 1981. La cuncuna espinuda, un insecto nativo defoliador de pino insigne (Ormiscodes sp. Leptidoptera: Saturniidae). Programa de Control de Plagas y Enfermedades Forestales. CONAF. Folleto de Divulgación N° 5. s/p.

Current status of research on *Sirex noctilio* F. in the Andean-Patagonian region in Argentina

P. Klasmer, G. Fritz, J. Corley, and E. Botto

Presence of *Sirex noctilio* F. in Argentina

Sirex noctilio F. is a forest pest of recent appearance in Argentina. It was detected for the first time in 1985, in the province of Río Negro, in the eastern part of the country (Ezpinoza et al. 1986). From there it spread to other provinces: Corrientes y Missiones (NE); Buenos Aires (E); Jujuy (N) and Córdoba (Centro).

Introduction in Patagonian Argentina

The presence of *S. noctilio* in Pategonian Argentina was detected in 1990, in a private forest company close to the city of San Carlos de Bariloche (71° W - 41° S), Río Negro province (Aguilar et al. 1990). It is thought that its accidental entrance into the region was made through infected wood from Buenos Aires. In January 1993, it was discovered in a mixed conifer plantation. From then on several Argentinean public institutions initiated a program to combat the pest. Instituto Nacional de Tecnologia Agropecuária-National Institute of Agriculture and Livestock Technology (INTA), Servicio Forestal Andino de Río Negro-Rio Negro Andean Forestry Service (SFA), Instituto Argentino de Sanidad y Calidad Vegetal-Argentinean Institute of Plant Health and Quality (IASCAV), and, recently, Consejo Nacional de Investigationes Científicas y Técnicas-National Council for Scientific and Technical Research (CONICET) are involved in this effort.

Program objectives

Pest control

The initial strategy against *S. noctilio* was its eradication, as its presence was concentrated in an area close to the private forest company. In this manner, control was made by the elimination (cut and incineration) of trees that presented symptoms of having being attacked by *S. noctilio*. Controladora de Plagas Forestales (Forest Pest Control-Chile) (CPF) financing, and Servicio Agrícola y Ganadero-Chile (SAG) technical support were used for the development of these tasks for two seasons.

Pest Monitoring

The early detection of *S. noctilio* was attempted in all susceptible pine plantation areas in the zone. To make this possible, several trap trees were installed by using herbicide (e.g., dicamba) applying two mililiter doses for a ten-centimeter perimeter in the base of the trees, with six trees per plot. These plots allow the monitoring of the pest and the disposition of its natural enemies.

Bio-ecological studies

The population dynamics of *S. noctilio* was evaluated on larvae and adult insects collected from bait trees, as well as from trees which were naturally infested. The material was put in cages laid in the same plantation. Density, sex ratio, adult emergence period, size, and mortality factors were estimated. These studies made possible the verification of *S. noctilio* population phenology and the detection of the presence of *Ibalia leucospoides* (Hochenwarth), its only natural enemy observed until now (Klasmer & Fritz 1994). The evaluation of the possible impact of *I. leucospoides* on the pest was also verified.

Information distribution

The importance of *S. noctilio,* its biological aspects, and action measures to be considered will be divulged to forest product producers and the general public by means of meetings, publications, and radio and television broadcasting. An informative brochure was published with the contribution of SAG and economic support of CFP from Chile.

Current situation

Three years after the beginning of research, the following information has been obtained:

- The activity period of *S. noctilio* starts at the end of December and goes on until May
- Between 1993 and 1996, the pest spread about 20 kilometers, from the concentrated area of its initial infestation, in the direction of the prevailing winds (west to east)
- The emergence of adults causes a population peak in March
- The density of adults varied from eight to $124/m^2$ of trunk surface area
- The sex ratio slightly favored females (1:1.2)
- *S. noctilio* life cycles varied from one to three years
- *Ibalia leucospoides* (Hochenwarth) was the only natural enemy of *S. noctilio* found; an excellent synchronicity between *S. noctilio* and *I. leucospoides* life cycles was observed
- Parasitism rates of *S. noctilio* by *I. leucospoides* varied between 20 and 40 percent, depending on the season
- These parasitism percentages are considered important because of the low population levels of *S. noctilio*

Based on these results a biological control strategy that contains the following aspects will be developed:

- Increase parasitic activity of *I. leucospoides,* through its periodic seasonal production and release
- Introduce new *S. noctilio* natural enemies *Beddingia [=Deladenus] siricidicola, Megarhyssa nortoni* [Cresson],and *Rhyssa persuasoria*(L.)
- Evaluate *Urocerus gigas* potential as an alternative host to *I. leucospoides*
- Search for basic information to elaborate life tables and permit the development of predictive models of *S. noctilio* populational dynamics

Biological control of *Sirex noctilio* in South Africa

Geof Tribe

The Kamona strain of the parasitic nematode *Beddingia* (= *Deladenus*) *siricidicola* (Bedding) was inoculated into 250 Monterey pine (*Pinus radiata* D. Don) trees infested with *S. noctilio* F. larvae in the southwestern Cape Province in 1995. Only 3.3% of trees had been killed by *Sirex*. Prior to the emergence of *Sirex* from these logs, sections were removed to the research station where they were individually caged. The percentage of parasitism by *B. siricidicola* over their entire range averaged 23 percent. This low parasitism rate was due to reduced dispersion of the nematode within the logs after inoculation, but the rate is expected to improve considerably when spread naturally by *S. noctilio* itself. Importations of *Ibalia leucospoides* (Hochenwarth) and *Megarhyssa nortoni* (Cresson) have been proposed to augment the present control exerted by *B. siricidicola*.

The distribution of *Sirex noctilio* in South Africa

Waldo Hinze

Introduction

In South Africa *Sirex noctilio* F. is limited to an area within a radius of 90 kilometers from the Cape Peninsula. This area is mainly planted to Monterey pine (*Pinus radiata* D. Don) and, on the poorer sites, to maritime pine (*P. pinaster* Ait).

The Forestry Regions are concentrated in the higher rainfall areas in the east between latitudes 23 degrees South and 34 degrees South. Only 30 percent of the country has a rainfall exceeding 1,000 milimeters per annum. The Western Cape has its rain in winter, the Southern Cape over the whole year, and the eastern part of the country in summer.

The total afforested area can be summarised as follows:

Softwoods (*Pinus*)	757 833 ha
Hardwoods (*Eucalyptus*)	670 797 ha
Total	1,428 630 ha

Expected spread of infestation of *Sirex* in South Africa

Natural movement

At a rate of 30 kilometers per annum, *Sirex* should be confined to the Cape for a number of years. There are a number of gaps along the Eastern Cape coast which are not planted to *Pinus*.

Movement through transportation of timber

The greater danger is that *Sirex* will spread through transportation of timber by road, rail, or ship. *Sirex* may be introduced to the northern part of the country by the transportation of logs from the south over 2,000 kilometers. *Sirex* may be introduced from outside the country through the Richards Bay or Maputu harbours. *Sirex* can also be introduced to countries who buy timber from South Africa. Timber is presently being exported to Turkey, Korea, the Phillippines, and Japan.

Conclusion

The biological control of *Sirex* in the Western Cape is vital for the other South African Forestry Regions and countries further north. When the pest eventually reaches the Eastern and Northern Forestry Regions, the industry should be prepared and ready to deal with the problem. Work on the biological control of *Sirex* is therefore of utmost importance.

List of acronyms

AGRIS-Agricultural Research Information System; a program of the United Nations FAO.

BHD-breast height diameter, also DBH, diameter at breast height

BIOCAT-a database of published information on all introductions to date of insect natural enemies against arthropod pests. Created and maintained by CABI-Bioscience, formerly International Institute for Biological Control (IIBC).

CABI-Centre for Agriculture and Bioscience International

CLIMEX-a computer program for modeling climate

CNPF-Centro Nacional de Pesquisa de Florestas (Brasil)(National Center on Forest Pests)

CONAF-Corporación Nacional Forestal (Chile) (National Forestry Corporation)

CONICET-Consejo Nacional de Investigationes Científicas y Técnicas (National Council for Scientific and Technical Research)

CONIF-Corporacion Nacional de Investigacion Florestal de Colombia

COSAVE-Comitê Fitossanitário do Cone Sul (Comité de Sanidad Vegatal del Cono Sur, Plant Protection Committee of the Southern Cone)

CPF-Controladora de Plagas Florestales de Chile

CSIRO-Commonwealth Scientific and Industrial Research Organization

DAP-Dados de diâmetro à altura do peito (diameter at breast height)

DSIR-Department of Scientific and Industrial Research (New Zealand) In 1992, restructured as various insitutes, including Industrial Research Lab (IRL)

EMBRAPA-Empresa Brasileira de Pesquisa Agropecuaria (Brasil) (Brazilian Agricultural Corporation)

EPAGRI-Empresa de Pesquisa Agropecuária de Santa Catarina (Stana Catarina State Research Company)

FAO-Food and Agriculture Organization (United Nations)

FRI- Forest Research Institute (New Zealand) (now CSIRO Division of Forestry)

FUNCEMA-Fundo Nacional de Controle à Vespa-da-Madeira (Brasil) (National Fund for Wood Wasp Control)

IASCAV-Instituto Argentino de Sanidad y Calidad Vegetal (Argentinian Institute of Plant Health and Quality)

IBAMA- (Brasil) National Resources Institute

IIBC-International Institute for Biological Control (formerly CIBC), now CABI Bioscience

INFOR-Instituto Forestal (Chile)

INTA-Instituto Nacional de Technologia Agropecuária (Argentina) (National Institute of Agriculture and Livestock Technology)

IUFRO-International Union of Forest Research Organizations (União Internacional das Organizaçõe de Pesquisa Florestal)

MERCOSUL; MERCOSUR-Southern cone treaty similar to NAFTA

MOU-Memorandum of Understanding

Planin-Computer modeling program fro evaluating economic profits

PNCVM-Programma Nacional de controle a vespa-da-madeira (Brasil) (National Program for Woodwasp Control)

PNUD- Programa das Nações Unidas para o Desenvolvimento (United Nations Program for Development)

PAP-parcelas de amostras permanentes

PSP-permanent sampling plot

RIFALC-Rede de Informação Florestal para a América Latin e Caribe (Latin American and Caribbea Information Systems Network)

SAFCOL-a South African commercial company

SAG-Servicio Agricola y Ganadero (Chile) (Chilean Agriculture and Livestock Service)

SFA-Servicio Florestal Andino de Río Negro (Rio Negro/Andean Forestry Service)

Sispinus-a computer modeling program; generates tables showing timber growth and production fo multiple industrial uses

SPDC-Special Program for Developing Countries (Programa Especial de Apoio a Países em Desenvolvimento)(United Nations)