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Short Article

Biological control agents in the management of pine shoot moth: studies, findings and expectations*

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Introduction

The pine shoot moth, *Rhyacionia buoliana* (Denis & Schiffermüller) (Lep.: Tortricidae), is a pest of European origin first found in Chile in Ensenada (Region X) in the south of the country in 1985, but its distribution now covers the country's entire two million hectares of exotic pine (*Pinus radiata*) plantations. Larvae attack the apical shoots of trees mostly less than five years old. Although the tree responds by the formation of defects such as multileaders, bifurcations and curvatures, many of these are corrected after a few years' growth, and the trees that still have defects (30%) can be eliminated in the first thinning. Larvae usually infest shoots singly (at the end of summer and in early spring, with a period of winter dormancy) where they are protected inside the buds. After a short migratory period (mostly in early September) they enter a new, bigger shoot. Within both buds and shoots, larvae are further protected by dried resin produced by the tree. At higher population levels there are usually two or three larvae per shoot, and up to 20 have been found in the bigger apical shoots.

A project to study biocontrol agents of the pine shoot moth began in 1996 (Lanfranco *et al.*, 1997). This is conducted principally by scientists from the Universidad Austral de Chile and is funded and co-ordinated by the Forest National Sanitary Committee/Chilean National Forestry Service (CONAF) and forest companies grouped in the Forest Pests Control Company (CPF). To date work has focused on classical biological control by the introduction, mass rearing and release of the specific braconid parasitoid *Orgilus obscurator* (Nees), also of European origin. In 1996 a complex of indigenous generalist parasitoids was discovered, complementing the native predatory insects, birds and spiders and bacterial and fungal pathogens which attack this pest. Appropriate silvicultural management practices for pine shoot moth control, including removing infested shoots and pest-related decision-making in standard pruning and thinning regimes, have been described recently. Nevertheless, these proposals have not been incorporated into commercial pine forest management, which remains focused narrowly on production criteria, apart from corrective pruning to ameliorate earlier pine shoot moth damage. Chemical control also plays an important role in the control of this pest but whilst product efficacy is routinely evaluated after application, there have been no studies on pesticide interference with the introduced parasitoid which is active in the same operational period. Current pesticide application strategy bears little relation to high pest populations or risk indicators such as apical pest incidence, but appears to be part of blanket policies for protecting young plantations. Chemical control is supposed to reduce moth populations to a level where *Orgilus* can then be introduced for their control. However, pesticide application has been observed in numerous sites where the parasitoid has already been released.

Our study aimed to identify the complex of natural enemies of the pine shoot moth in Chile, through an inventory of the arthropod and bird fauna associated with young plantations of *P. radiata* and subsequent determination of species associated with *R. buoliana* and assessment of their impact on the pest. Such information is crucial for the development of integrated pest management programmes incorporating biological control as a core component. We carried out the work over two consecutive seasons in Regions VIII, IX and X in southern Chile (regional capital cities: Concepcion, Temuco and Puerto Montt, respectively) using 18 sampling sites selected according to tree age, site characteristics, previous pine shoot moth incidence, security and accessibility. Sampling took place from March 1996 to April 1997.

Methods

For collecting invertebrates we set up ten replicates each of pitfall traps and aerial traps of equal size on ten trees within an area of approximately 60 m². Trap catches were collected and analysed each month. For birds, we carried out visual sampling along an observation transect at each site with the exception of one, where birds were trapped using mist nets. The observation transects were of a fixed width (100 × 20 m) which allowed us to determine density, frequency and diversity of bird species along with behavioural information such as foraging, shelter and nesting. Photographic and video records were also collected. Field data were entered

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into Excel spreadsheets along with land-use and laboratory data in order to calculate totals by site and sampling method for subsequent analysis. Infested shoots were also censused during the study period and analysed with respect to plantation age and location. Pine shoot moth larvae from these were collected for assessing parasitoids present.

Field collected material was identified to family, and species were determined for important predatory and parasitic families. Stomach contents of birds collected were analysed, using the mandibles as the key for confirmation of pine shoot moth larvae in the diet. Infested shoots were opened and examined; host and parasitoid emergence were recorded for each sample and site, together with the number of shoots with feeding damage but containing no larvae. One hundred infested shoots per site were also collected each season, and larvae from them were dissected and examined for parasitism, using standard head capsule measurements for both parasitoid and pine shoot moth larval stages.

Results and Discussion

Pine shoot moth density was greatest in the northern-most of the regions, Region VIII, which currently suffers the highest pest incidence, but parasitism by *Orgilus* was generally low or absent. Within this region, highest parasitism rates of 29% were recorded at Menir, with an average of 232 host larvae per tree. The pine shoot moth densities of the generation in summer 1997 were the highest we have ever recorded in Chile. However, in Region IX, pest density was low and sometimes undetectable by our sampling regime, and *Orgilus* was recorded at all sample sites in this region. At La Zanja, where host densities of 50 larvae per tree were recorded, parasitism was over 50%. Pine shoot moth density was lowest in the southernmost region, Region X, where parasitism levels reached more than 60%.

Insects were collected from 21 orders, 12 of which were important in all three regions. Some (Coleoptera / Diptera / Lepidoptera / Hymenoptera) were commonly collected in both types of trap, while others were better represented in soil-surface sampling (Archaeognatha / Orthoptera / Blattaria / Dermaptera / Coleoptera), and others in aerial traps (Psocoptera / Diptera / Lepidoptera / Hymenoptera). Family level analysis is still underway but by far the most numerous insects are Dipt: Mycetophilidae, which sometimes make up over 99% of samples. In total, we collected 176,385 (34%) arthropods in pitfall traps and 337,998 (66%) in aerial traps. Preliminary analysis reveals a tendency for greater species richness in older plantations but before total canopy closure, presumably owing to greater environmental heterogeneity.

We have found a complex of native species complementary in action to the introduced control agent *Orgilus*. Laboratory studies revealed parasitism by species in the hymenopteran families Braconidae, Ichneumonidae, Torymidae and Chalcididae and by tachinid flies. Most of these parasitoids are widely distributed throughout Chile, yet their combined parasitism varied between only 3% and 8%; it was highest in Region X which has the oldest incidence of the pine shoot moth.

Native predators which feed on pine shoot moth include birds, spiders and insects. These are mainly generalist predators and it would take long periods of fieldwork to verify whether pine shoot moth is a major item in their diet. Our laboratory studies showed that almost any predatory spider or insect will eat pine shoot moth in confinement but this is unlikely to hold true under field conditions. The predator complex may be more active consumers of the pest in the two short periods when the larvae are exposed (egg hatch and migration) and far less significant when the predator would have to find and break open the shoots to consume prey, although this does occur with a few birds, insects and spiders.

We recorded 79 spider species in 31 families associated with pine plantations. Some of these are active hunters such as Thomisidae and Salticidae species which have been observed inside infested shoots, and on some occasions using the pest's pupal chamber to protect their egg masses. Species of Theridiidae, Anyphaenidae and Clubionidae web and silk spinners are also numerous. It was not possible to determine predation rate for these spiders with either the sampling methods or laboratory studies we used, but the spider complex can be considered as a significant part of the natural control of pine shoot moth.

The results of a study conducted at a site in Region X indicated that the commonest species of bird captured was the finch *Carduelis barbata* (Fringillidae), at 38% of total individuals captured, and this species was found to consume significant numbers of pine shoot moth larvae. The highest consumption rates of 21-54 larvae per bird were recorded in October.

Insects which prey on pine shoot moth are generally well known, but it is interesting to note that while they form an important complex at some sampling sites, their low abundance to date has not led to their inclusion as effective biocontrol agents which are capable of regulating pine shoot moth populations, despite their widespread distribution.

Pine shoot moth densities increase from south to north in the country. *Orgilus* was introduced first in the southernmost-region, Region X. It is far more common here than further north and has become a key mortality factor for the host pest. This has not occurred in Regions VIII or IX, probably because the parasitoid introduction is more recent in these regions. Native natural enemies also play a more important role in Region X, where control estimates for their entire complex reach 15%. Notable adaptations to this exotic pest have been observed in indigenous species of predatory bird and spider. Pine shoot moth control in Chile should therefore combine both classical biological control and the conservation of native natural enemy complexes. Appropriate measures to maximize biological control include, amongst others, reduction in the use of pesticides; conservation of native forest areas around pine stands; supplementary food sources for natural enemies to achieve full reproductive potential; suitable timing and mode of silvicultural practices; and augmentation of key natural enemies in the ecosystem.

Reference

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