Natural biological control of the pine processionary moth
*Thaumetopoea pityocampa* (Den. & Schiff.) by the Argentine ant
*Linepithema humile* (Mayr) in Portugal

M. J. Way,1 M. R. Paiva2 and M. E. Cammell1

1Imperial College of Science, Technology and Medicine, Silwood Park, Ascot, Berks SL5 7PY, U.K. and 2Universidade Nova de Lisboa, FCT, P-2825 Monte de Caparica, Portugal

**Abstract**

1 Defoliation by larvae of the pine processionary moth, *Thaumetopoea pityocampa*, is negligible in stands of *Pinus pinaster* colonized by the Argentine ant *Linepithema humile* which preys fiercely on the young moth larvae. In contrast, such damage is widespread where pine plantations are colonized by native ants, predominantly *Tapinoma nigerrimum* and *Lasius niger*, which seemingly disregard the larvae.

2 Where *L. humile*- and native ant-occupied sectors adjoin, there is a 20–50 m overlap in the transition area between *L. humile*- and native ant-occupied pines. This was most evident in a >500 ha plantation where there was severe or very severe *T. pityocampa* attack in native ant sectors contrasting with none in adjoining *L. humile* sectors.

3 Predation by *L. humile* is no doubt enhanced by its existence as super-colonies over very large areas, by its foraging activity and recruitment on trees throughout the time when *T. pityocampa* and other prey are present, and by honeydew-producing Homoptera which help retain foraging *L. humile* workers in pine tree crowns.

4 The role of *L. humile* could be enhanced by cultivations that disturb the soil and restrain ground vegetation.

**Keywords** Biological control, *Linepithema humile*, *Pinus pinaster*, predation, Portugal, *Thaumetopoea pityocampa*.

**Introduction**

Several ant genera, notably *Oecophylla*, *Formica*, *Dolichoderus* and *Solenopsis* spp. are recognized as important biological control agents (Way & Khoo, 1992). In such circumstances their beneficial roles greatly outweigh any harm they may do by attending Homoptera for honeydew (Way, 1963; Way & Khoo, 1992). However, *Solenopsis* spp., and the Argentine ant *Linepithema humile* (Mayr) are nuisance and public health pests particularly in urban environments. Worldwide, *L. humile* has invaded regions with Mediterranean-type temperatures where it is almost invariably regarded as a serious nuisance and as a pest because it may interfere with, or prey on, beneficial natural enemies (Frazer & van den Bosch, 1972; Panis, 1974; Dreistadt et al., 1986; Haney et al., 1987). It has been recorded as predatory on some pests (Wong et al., 1984; Olkowski & Olkowski, 1989), and in Portugal is an egg predator on the eucalyptus borer *Phoracantha semipunctata* but ineffective as a biological control agent (Way et al., 1992). We now report the first evidence of the relationship between *L. humile* presence and damage by the pine processionary moth *Thaumetopoea pityocampa* (Den. & Schiff.) which can severely defoliate pine plantations throughout Portugal and parts of the Mediterranean region of Europe.

**Methods**

**Thaumetopoea pityocampa** damage

Surveys of *T. pityocampa* damage were made in pine plantations, mostly of *Pinus pinaster*, in the regions of Abrantes, Muge and Marinha Grande. The work was done in May when ants are active and when it is still easy to record the previous year’s late season defoliation and also the empty larval ‘nests’, constructed
Table 1  Relationships between ant species on baits at tree bases and T. pityocampa attack at 20 sites in P. pinaster plantations.

<table>
<thead>
<tr>
<th>Season of attack</th>
<th>No. of sites</th>
<th>Total no. ant species per set of sites</th>
<th>Dominant ant species</th>
<th>% tree baits with ants</th>
<th>Damaged trees</th>
<th>Damage by T. pityocampa</th>
<th>Severity of attack of damaged trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>3</td>
<td>1</td>
<td>L. humile</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>7</td>
<td>L. niger</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>Moderate to very severe</td>
</tr>
<tr>
<td>Late season</td>
<td>4</td>
<td>2</td>
<td>L. humile</td>
<td>100</td>
<td>3*</td>
<td>3</td>
<td>Slight</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>6</td>
<td>L. niger</td>
<td>0</td>
<td>100</td>
<td>6</td>
<td>Slight to moderate</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>6</td>
<td>T. nigerrimum or A. senilis</td>
<td>+L. humile</td>
<td>4</td>
<td>27</td>
<td>14</td>
</tr>
</tbody>
</table>

* One A. senilis on one bait.
† Three of the four sites were at the boundary between exclusively L. humile- and native ant-dominated areas.

in the previous October–December, most of which had remained firmly attached to the branches. Nests formed during earlier attacks in July–September were not so durable. The routine samplings in May were all based on assessments of defoliation by larvae on the previous year’s growth on lower branches as follows: no damage; slight damage – about 1–5% of twigs with some needles partly, but rarely completely, eaten; moderate damage – about 5–25% of twigs damaged with some needles completely eaten; severe – about 25–100% of twigs attacked with most needles destroyed apart from a few at the distal end of the youngest twigs available at the time of attack; very severe – all twigs stripped of available needles apart from a few distal stubs. In May, all trees bore new undamaged growth that developed after larval attack had ceased, although some defoliated branches of very severely damaged trees had been killed. Irrespective of the severity of damage, the tops of the crowns of some larger trees remained relatively undamaged.

Ant surveys

The presence and abundance of different ant species in sampled sites were determined using sugar baits at the base of each tree (Cammell et al., 1996; Paiva et al., 1998). Initially, baits were placed within areas mostly occupied either by L. humile or by native ants, and involved up to 30 trees at each of 20 sites. Bait transects were also made across boundaries between L. humile- and native ant-dominated areas. The activity of ants in trails on tree trunks was noted. After 1 h the numbers of each ant species at each bait were counted and compared with the damage by T. pityocampa seen on the trees.

Results

Where L. humile was the sole ant species at baits, there were usually well-defined trails up the tree trunks, and only one set of sampled pines showed evidence of slight T. pityocampa attack (Table 1). Elsewhere there were up to eight native species at a particular site, usually with one very common species, namely Pheidole pallidula (Nylander) or Tapinoma nigerrimum (Nylander) or Lasius niger L., exclusively occupying most of the baits at the tree bases. These species sometimes formed trails up the tree trunk which were usually much less pronounced than those of L. humile, and their presence did not prevent T. pityocampa damage (Tables 1–3). The most striking contrasts were in the >500 ha Leiria pine stand between Marinha Grande and S. Pedro de Moel. Here, undamaged L. humile-dominated trees contrasted with trees severely damaged by T. pityocampa in adjoining areas occupied only by native ants (Table 1, summer). Outside this region, the 1997 attacks, unlike those in 1996, were mostly slight. The worst damage in 1997 was at Muge, where the sampled areas were all at edges of boundaries between L. humile- and native ant-occupied parts of a plantation; hence some overlap of ant species (Table 1, late season).

Current work shows that branches with nests containing young T. pityocampa larvae, transferred to pine trees foraged by L. humile, were fiercely attacked and the larvae killed and removed. In contrast, similarly transferred larvae were disregarded by native dominant ants (E. B. Moura, M. R. Paiva and M. E. Cammell, unpublished).

The boundaries between parts of a plantation occupied by L. humile and native ants are usually well defined (Way et al., 1997), so detailed counts were made in May 1998 along transects across such boundaries, one where there had been light (Table 2), and three where there had been severe attacks by T. pityocampa (Table 3). At Abrantes (Table 2) there was a sharp transition from exclusive L. humile- to native ant-occupied trees, with T. nigerrimum dominant among five recorded ant species, of which Plagiolepis schmitzii Forel and Crematogaster auberti Emery were also common. The ant changeover coincided with a change from an L. humile sector with no T. pityocampa damage to a native ant sector where most trees were damaged and bore larval nests. Counts were also made along three transects in a large plantation heavily attacked in summer at Leiria. The combined results (Table 3) show insignificant damage in sectors occupied by L. humile but severe and very severe damage in the adjoining native ant-occupied sectors where L. niger was the commonest ant. However, in the 20–50 m wide transition areas, 46% of trees were exclusively occupied by small populations of L. humile (35 per occupied baits compared with 342 within the L. humile sectors). Of the remaining 54% of baits, 67% were
unoccupied. This scarcity of native ants at baits in a transition area confirms earlier work in oak plantations (Way et al., 1997). One transect, examined in detail (Fig. 1), showed that *L. humile* numbers decreased from nearly 800 per bait 60 m within the *L. humile* sector to 18 at the adjoining part of the transition area and only one per bait where it adjoined the native ant sector. In the transition area, the slight and moderate damage to some trees adjoining the *L. humile* sector changed to 100% severely or very severely damaged by *T. pityocampa* adjoining the native ant sector where 65% of baits were occupied exclusively by *L. niger*, and of the remainder 13% were unoccupied. *Pheidole pallidula*, a recognized dominant in some habitats (Cammell et al., 1996; Paiva et al., 1998), was scarce within the native ant sector but, corresponding with this sector, it exclusively occupied all baits placed at 10 m intervals along an adjoining road verge. However, at the transition point a single unoccupied bait marked the change to exclusive occupation of the verge baits by *L. humile* (Fig. 1). The obvious presence of either *P. pallidula* or *L. humile* along a verge can therefore be a good indicator of the nature of the ant community within a plantation.

Topography, soil conditions and understorey vegetation can affect the distribution of *L. humile* (Way et al., 1997). Soil types, however, appeared identical across the transects – sandy loam at Abrantes and sand elsewhere. All the transects were on slightly sloping land, however, with only about 2–3 m difference along lengths of 150–200 m. *Linepithema humile* occurred at the higher level at the Abrantes site (Table 2), and native ants at the other sites, although with negligible altitude differences across the transitions. Whilst no effect of such differences can be envisaged as affecting the ants (Way et al., 1997) or the damage, this was confirmed in a level plantation near Marinha Grande, where in 1997 an ≈ 3 ha patch of native ant-occupied *P. pinaster* with many *T. pityocampa* nests and slight to moderate damage was completely surrounded by a large area of undamaged *L. humile*-occupied trees.

### Discussion

The results confirm the absence, except at boundaries, of damage by *T. pityocampa* within *P. pinaster* plantations occupied by *L. humile*. It is surprising that this striking relationship associated with fierce predation by *L. humile* has not previously been recognized. The workers can be powerful predators, as is evident from the well known ability of introduced *L. humile* to kill and displace native ants, as in Portugal (Cammell et al., 1996; Way et al., 1997), and also to prey on brood in wasps nests in spite of defending wasp workers (Gambino, 1990).

Known natural enemies such as some birds and Tettigoniidae (e.g. Ledesma, 1971; Gonzalez-Cano, 1981) seem unlikely to have a significant impact on *T. pityocampa* except possibly during endemic phases. Unlike such conventional natural enemies, many predaceous ants possess the unique attributes of being able to survive abundantly even when prey is scarce and to respond quickly to prey density (Way & Khoo, 1992). This is based on a dependable source of energy food from homedew-producing Homoptera (Way, 1954, 1963). For example, a *Formica rufa* diet comprised 62% of homedew (Wellenstein, 1952). In some intimate relationships, particular species of Homoptera are essential for success (Way, 1954; Khoo & Chung, 1989). *Linepithema humile*, however, is a more
conditions there is intense fighting along transitions between competing colonies (Way & Khoo, 1991, 1992).

A predatory ant because it occurs as multiqueen super-colonies with many closely spaced nests throughout large areas some-
times covering at least 2000ha. Within and between such colonies there is no aggression between workers, even when isolated by sea (Way et al., 1997). In contrast, species such as Oecophylla and Formica form relatively small spaced-out competing colonies (Way & Khoo, 1991, 1992). Formica spp. have been recognized as beneficial predators since the 19th century (Gosswald, 1990) but, within colony boundaries, their impact on lepidopteran pests, for example, is localized and inversely related to distance from the nest (Wellenstein, 1954; Adlung, 1966). In contrast, our evidence indicates that, in favourable conditions, L. humile can completely and uniformly protect very large pine plantations. Linepithema humile is unable to colonize certain soil types in Portugal, particularly those based on metamorphic rocks (Way et al., 1997; Paiva et al., 1998). Otherwise it can flourish and displace the native ants where ground vegetation is sparse or frequently disturbed, but is absent where such vegetation is thick and undisturbed (Way et al., 1997). In some undisturbed pine plantations a commonly occurring undisturbed ground mat of moss overlying a peaty layer of partly decomposed needles also seems to inhibit L. humile, especially in dense pine plantations. In intermediate conditions there is intense fighting along transitions between L. humile- and native-occupied plantations (Way et al., 1997).

Our transects across boundaries between L. humile and native ants were made in conditions where the understory vegetation was intermediate, with bare patches and sometimes with wild shrubs, as well as herbaceous ground vegetation or undisturbed moss-covered peat. Simple soil cultivations to restrain ground vegetation, as is done in many Portuguese oak and eucalyptus plantations, should encourage the spread of L. humile into some commercial pine plantations now occupied by native ants. There are, therefore, opportunities for exploiting its predatory role. The effects on L. humile of pine stand density and soil disturbance are subjects of current research which also involves work on the predatory behaviour of L. humile, including its possible effects on ovipositing T. pityocampa. Linepithema humile is not disseminated by winged queens so there is no reason to believe that encouraging it within pine plantations will favour its incidence as a pest in other habitats.

Acknowledgements

We gratefully thank Messrs C. Collingwood and M. Corley for ant and moth identifications, a reviewer for valuable comments on the manuscript. Mrs Pam Cammell and Mrs Isabel Way for technical and editorial assistance, respectively, and Mr and Mrs Santos Paiva for logistic support. We are indebted to the Administration of Mata Nacional de Leiria, DRABL, Marinha Grande, for permission to work in Pinhal de Leiria. The work was financed by the Portuguese Foundation for Science and Technology, Programme PRAXIS XXI, contract no.2/2.1/BIA/221/94, and by Centro de Ciência/DCEA.

References


Frazer, B.D. & Van Den Bosch, R. (1972) Biological control of the walnut aphid in California; the interrelationship of the aphid and its parasitoid. Environmental Entomology, 2, 561–568.


Accepted 27 November 1998