Psocids as a global problem

Nayak, M.K.*#[1,2]
[1]Department of Agriculture, Fisheries and Forestry, Ecosciences Precinct, Brisbane, QLD 4001, Australia
[2]Plant Biosecurity Cooperative Research Centre, Bruce, ACT 2617, Australia

*Corresponding author, Email: manoj.nayak@daff.qld.gov.au
#Presenting author, Email: manoj.nayak@daff.qld.gov.au

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Abstract

Over the last two decades, we have witnessed the emergence of psocids (Psocoptera); in particular, several species belonging to genus *Liposcelis* as a major pest group of stored products across the globe. The main cause of the elevated pest status of this previously obscure pest group is still not clear. However, several research reports from Australia, USA and Asia are now available that lead us to believe that the conventional pest management practices designed to control major beetle pests are failing against the psocids. For example, strong level of resistance to the major fumigant phosphine has been detected in populations of *Liposcelis bostrychophila* and *L. entomophila* in Australia and Asia; whereas comprehensive research in Australia and USA have established *L. entomophila* to be naturally tolerant to a range of contact insecticides. Research on ecology and behaviour of these pests are still in a preliminary stage. Comprehensive research in these areas along with new research including development of new grain protectants and fumigants would be required for successful management of these pests.

Keywords: psocids, grain protectants, fumigants, phosphine, resistance

1. Introduction

From an obscure group of contaminants, psocids belonging to Psocoptera have emerged as major pests of stored commodities over the last couple of decades. Out of approximately 100 reported, 4 wingless *Liposcelis* species are considered economically significant worldwide: *L. bostrychophila* Badonnel, *L. decolor* (Pearman), *L. entomophila* (Enderlein), and *L. paeta* Pearman. Other minor pests of regional importance include *L. corrodens* Heymons, *L. brunnea* Motschulsky, and *L. rufa* Broadhead. Their upsurge became prominent in the 1980s in the humid tropics of Southeast Asia followed by Australia and more recently in the USA. Severe infestations have been reported in these countries from bulk grain storages, food-processing facilities, feed and flour mills, tobacco-processing, museums and bakeries. Pest management treatments and practices that have traditionally targeted at the major beetle pests have been reportedly failing against psocids. Over the last decade, there has been a great deal of interest among entomologists across the globe in studying these pests and in particular, developing management strategies against them. Over this period, the biology and control strategies have been extensively pursued by several researchers in the USA and Australia. A recent review by Nayak et al. (2014) has outlined a range of aspects related to psocids in an attempt to better understand these pests and to look into the future in regard to their management. This paper briefly summarises some of the aspects discussed in the review, only a few references are provided here as the detail information is available in the review.

2. Key attributes

A key attribute for survival of psocids is their ability to actively absorb water from the atmosphere (Knulle and Spadafora, 1969) and a small number of individuals can reach to a unmanageable plague proportion with a sudden increase in ambient humidity (>70%) during monsoon or an increase in moisture content (>13%) of the stored product in any storage environment. Other important characteristics include their small size (approximately 1 mm), which enables them to exploit cracks and crevices and to remain concealed and unnoticed; short development period (2–3 weeks at 30–35°C and 75% r.h.), long adult stage; and the ability to survive adverse conditions, such as a lack of food, for relatively long periods (Turner and Maude-Roxby, 1988). Moreover, some species such as *L. bostrychophila* are predominantly parthenogenic, a unique reproductive system with all eggs developing into females, enabling a rapid increase in population (Lienhard and Smithers, 2002). The combination of these key characteristics enables *Liposcelis* species, particularly, *L. entomophila*, *L. decolor*, and *L. paeta*, to successfully colonize and repeatedly reinfest stored commodities even when control treatments are applied.

3. The cause of their upsurge

The change in the pest status of psocids suggested to be strongly linked to changes in the management tactics of the major coleopteran pests of stored products during the 1980s. Some researchers believed that due to their higher tolerance to pyrethroids, psocids have flourished in stored rice treated with permethrin, and moreover, they would have benefitted from the reduction of predators and competitors (Pranata et al., 1983). A series of studies in Australia confirmed later the natural tolerances of several *Liposcelis* species to a number of registered chemical treatments including the pyrethroids (Nayak et al., 2014), although the response to chemicals by these pests is complex and varies across species. The upsurge of psocids in the 1990s was linked to the industry transitioning from broad use of contact insecticides to reliance on fumigant phosphine (Rees, 1998). The development of phosphine resistance and the greater tolerance of eggs to phosphine may also explain the surge of control failures in countries in South and Southeast Asia (Nayak et al., 2003).

4. Impact of infestations

Only few reports are available on the direct physical damage caused to grain by psocids. McFarlane estimated a weight loss of 5% and of milled rice as a direct result of heavy infestations of *L. bostrychophila* over a six-month period, whereas Kuˇcerov´a measured an average weight loss of 9.7% of broken wheat kernels due to infestations from the same species over a three months period. However, due to the increasing sensitivity of markets to live insects in commodities, it is often the mere presence of psocids rather than any measurable damage that triggers control interventions and threatens market access. A fairly old report is available on damage attributable to heavy psocid infestation in commercial rice storage in India (40,000 tonnes) and Indonesia (150,000 tonnes), where annual costs were estimated to be £115,000 (US$180,000) and £50,000 (US$75,000), respectively, in 1994 (Kleih and Pike, 1994). Psocids pose safety risks to workers by swarming over storage walkways and ladders, making them slippery. Psocids belonging to *L. bostrychophila* are commonly found in homes, specifically kitchens in the UK (Turner and Bishop, 1998). Although properly not substantiated, psocids have been implicated in the development of allergies in workers, suspected to be responsible for transmitting bacterial diseases (Turner et al., 1996).

5. Control options

As mentioned earlier, there seems to be an apparent tolerance to contact insecticides in a number of *Liposcelis* species. Variable degrees of tolerance of *L. bostrychophila* to pyrethroids, including permethrin, cypermethrin, and deltamethrin; *L. entomophila* and *L. bostrychophila* to the organophosphates fenitrothion, malathion, and pirimiphos-methyl; and *L. bostrychophila* to the insect growth regulators methoprene and fenoxycarb have been well established (Nayak et al., 2014). These studies have confirmed the view that treatments registered to control beetle and moth grain pests have been failing against several *Liposcelis* species at registered rates.

These studies have also shown that *L. bostrychophila* and *L. decolor* could be effectively controlled by fenitrothion, chlorpyrifosmethyl, and pirimiphos-methyl and by bioresmethrin and bifenthrin synergized with piperonyl butoxide. However, both species were tolerant to deltamethrin, carbaryl, and methoprene (Nayak et al., 2014). The stand out species was *L. entomophila* and *L. paeta*, both of which were tolerant to all the treatments listed in the preceding paragraph (Nayak et al., 2014). These interspecific differences in response to chemical treatments have serious practical implications for control of psocids, as a typical infestation often involves more than one species, particularly if either *L. entomophila* or *L. paeta* is involved. Some efforts to combine treatments to overcome this problem have yielded mixed results. A combination of chlorpyrifos-methyl and bifenthrin+piperonyl butoxide applied to sorghum in a silo-scale trial in Australia provided up to 7 months of protection against *L. bostrychophila* and *L. decolor*, but only 3 months of protection against *L. paeta*, and failed to achieve complete control of *L. entomophila* (Daglish et al., 2003). In some other experiments, a mixture of chlorpyrifos-methyl + deltamethrin and pirimiphos-methyl were proven better than either spinosad or pyrethrum alone at protecting wheat, rice, and maize against *L. paeta*, *L. entomophila*, and *L. bostrychophila* (Athanassiou et al., 2009).

The active movement pattern of *Liposcelis* species provides storage managers an opportunity to control infestations by treating storage structures with contact insecticides. A series laboratory studies of several registered fabric treatments in Australia demonstrated the difficulties in achieving long-term control (6–9 months) of *L. bostrychophila*, *L. decolor*, *L. entomophila*, and *L. paeta* on concrete surfaces (Nayak et al., 2014). However, a very high level of success was achieved when carbaryl combined with an organophosphate such as chlorpyrifos-methyl, pirimiphos-methyl, or azamethiphos was applied to galvanized steel that provided control all four species for 9 months (Nayak et al., 2014).

Over the last two decades, widespread resistance to the key fumigant phosphine was reported for *L. bostrychophila* species in China, India and Australia (Nayak et al., 2014). Apart from being the most tolerant stage to phosphine eggs of this species have shown delay in hatching when exposed to the fumigant; and the length of the delay correlates with phosphine concentration (Nayak et al., 2003). Follow-up studies have characterised this strong resistance and new fumigation protocols are now available to manage the resistant populations at a range of temperatures (Nayak and Collins, 2008).

Only few non-chemical options are available for psocids. Exploiting their preferred RH of 70–85% and by reducing it below ~60% can prove fatal for the populations. For example, *L. knullei*, *L. rufus*, and *L. bostrychophila* cannot survive more than 10 days if their ambient RH is kept below 58% r.h. (Knulle and Spadafora, 1969). In another study, a significant drop in *L. entomophila* populations was observed in tobacco-processing buildings on farms in Zimbabwe after once the humidity and temperature levels in the storage structure were kept below 70% r.h. and 18°C, respectively (Mashaya, 2001). Several studies have established the potential of heat treatments in psocid control. Studies conducted in the laboratory showed that 46°C over a period of 35 h controls eggs of *L. bostrychophila*, *L. decolor,* and *L. paeta*. *Liposcelis decolor* was the most tolerant species at 46–51°C and *L. paeta* was most tolerant below 46°C but most susceptible at 47–51°C (Beckett and Morton, 2003).

6. Conclusion

For the stored products entomologists, psocids are a new pest group and although the recently published review has been a good attempt to help our understanding of these pests, a lot more is unknown. Future research is required to understand movement patterns of psocids in the landscape and initiation of colonization of stored products; which will help us devising strategies to control them. A better understanding of genetic basis for adaptations such as heat stress, growth and development, and development of resistance to chemical treatments is needed; so as ongoing research on effective pest management tactics, including new chemical and non-chemical options.

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