Pathogens for the biological control of mite and Collembolan pests

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Summary

There is little information available on the pathogens of redlegged earth mite (*Halotydeus destructor*), blue oat mite (*Penthaleus major*) and lucerne flea (*Sminthurus viridis*) or other Australian mite and collembolan pests, however, pathogens are widely recognized as major factors in the natural control of some overseas mite pests. One fungal product is registered specifically for mite control in the USA but commercial production ceased in 1985 for economic and efficacy reasons. Predator mites are usually not susceptible to pathogens of pest mites and the predator mites can redistribute the pathogens leading to greater efficacy. Consequently, the potential to incorporate pathogens into an integrated biocontrol program is high. The use of chemical insecticides has been linked with the reduction of natural pathogen levels leading to mite population resurgences. Pathogens can be formulated in several ways to give short-term or perhaps longer-term control of mites and Collembola, but commercialization may be limited, in the short-term, by production costs.

Introduction

Bacterial, viral, fungal and rickettsial pathogens of pests are being increasingly utilized for crop protection. There are 13 microbial insecticides (pathogens) currently registered for pest control in various countries around the world. Pests for which microbial insecticides are available include glasshouse aphids and whitefly in the UK (Quillan 1988), cotton pests in Australia (Teakle 1990), sugar cane pests in Brazil (Moscardi 1988), subterranean beetle pests in the USA and New Zealand (Klein 1988, Jackson 1989), and forest defoliating insects in several countries (Lewis 1981). Home gardeners in Australia can use *Bacillus thuringiensis* for the control of a wide range of caterpillars.

The Collembola usually feed on decaying vegetable matter and few are regarded as pests (Wallace and Mackerras 1970). There is no information available on the pathogens of lucerne flea (*Sminthurus viridis*). Mites are one of the most important groups of pests in agriculture but very few pathogens are known which may be utilized in their control (Reed 1981). Petch (1940) has described the fungus *Empusa acaricida* from diseased redlegged earth mite (*Halotydeus destructor*) in Western Australia but this fungus has not been recorded since its initial description (Milner 1985).

To date, the most important role of pathogens in mite control has been in citrus groves in the USA (Burgess 1981). Consequently, this paper will discuss the natural and artificially induced control of citrus mites and briefly discuss the control of other mite and collembolan pests. Conclusions are then drawn from these examples to indicate the potential for pasture mite and collembolan control using pathogens.

Citrus mite control using viruses

Lipa (1971) and Reed (1981) describe the natural control of large populations of citrus red mite (*Panonychus citri*) by a non-occluded virus in the USA. This virus can reduce large populations of mites to levels well below the economic threshold (Lipa 1971) but it is not effective against small populations or during periods of wet, cool weather (Reed 1981). The survival of laboratory formulated viral material in field experiments is poor (2 – 4 hours) compared to natural infective material (8 – 28 days). Reed (1981) concluded that the only method which could be used to improve the efficacy of the virus is to increase the spread of infected mites. This is achieved by taking them from epizootic areas and transferring them to areas with lower levels of infestation. However, this is not practical because of labour costs. Consequently, agricultural extension officers currently advise Californian citrus growers to delay application of chemical miticides to try and allow the natural build-up of virus which may lead to epizootic control (Reed 1981).

Citrus mite control using fungus

In 1981, Mycar® (a product based on the fungus *Hirsutella thompsonii)* was registered in the USA to control the citrus rust mite, *Phyllocoptruta oleivora*. Commercial production was terminated in 1985 after production of several hundred kilograms of technical material (McCoy 1986). Several factors were responsible for this, including, variable mite control in the field, the limited commercial use of the fungus in agriculture and the lack of a quick and reproducible bioassay method for the mites (McCoy 1986). However, the requirement for cold storage and transporting of the product is cited by McCoy (1986) as the main reason for termination of commercial production.

Although the commercial success of Mycar® has been poor, *H. thompsonii* can naturally suppress mite populations. This fungus is "even more striking" (Lipa 1971) in its suppression of the mite population than the virus disease discussed earlier. Mites move from the old foliage to the new foliage and fruit in spring and as mites reach peak densities in summer, regular epizootics occur. Diseased mites result in a high fungal residue that usually prevents further mite build-up during the autumn and winter. McCoy (1981) summarizes by stating that *H. thompsonii* is a key factor in natural control but the control is disrupted by the use of pesticides, including miticides, which can suppress the fungus leading to mite resurgences. This has led to the development of integrated pest management strategies which utilize selective pesticides and predictive modelling to enhance natural fungal control and eliminate unnecessary pesticide treatments.

Other pathogens of mites

Balazy and Wisniewski (1986) have described two new species of mite-pathogenic *Hirsutella* from temperate regions in Poland. Isolates of *Verticillium lecanii* (the active constituent of the fungal products Mycotal® and Vertalec®) are infective to some species of mites (Quillan 1988) and some isolates may be suitable for study in Australia. *Neozygites* spp. have been isolated from mites (Smitley *et al.* 1986) including *N. acaridis* from predatory mites introduced into Australia (Milner 1985).

N. acaracida has been cited by several authors (James 1991, Ridsdill-Smith 1991) as infecting redlegged earth mite and blue oat mite in the field. When the fungus is present, control ranges from 8 to 50%. The fungus has a widespread distribution in Australia, having been found in Western Australia, New South Wales and Tasmania (J.E. Ireson, personal communication). The fungus description has yet to be published. Hyphomycete fungi, including *Beauveria bassiana* (Lipa 1971) and *Metarhizium anisopliae* (Schabel 1982, Goettel *et al* 1990, Reinecke *et al* 1990) have also been found infecting mite species. These last two species are the most commonly studied fungi around the world and are already registered for use in some countries (though not against mites). Ireson and Rath (1991) have been able to infect redlegged earth mite with several isolates of *Beauveria bassiana* and *M. anisopliae* including the DAT F-001 isolate of *M. anisopliae* which is being commercialized for redheaded cockchafer (Coleoptera: Scarabaeidae: *Adoryphorus couloni*) control (Rath 1991).

Pathogens of Collembola

There is a scarcity of literature addressing the microbial control of this group. Purrini (1983) has recorded the occurrence of entomogenous viral, bacterial, fungal and protozoan diseases of 12 collembolan species in Europe. The host range of *Verticillium lecanii* includes the collembola (Quillan 1988) but Reinecke *et al.* (1990) found that the developmental Bayer product, BIO 1020® (based on an isolate of the fungus *Metarhizium anisopliae*), could not infect Collembola. Neither of the two latter authors mention the species of Collembola tested. Ireson and Rath (1991) found that lucerne flea was susceptible to *M. anisopliae* DAT F-001 at doses of 10, 34 and 120 kg bait (10% a.i.) per hectare with up to 100% mortality being recorded after 17 days at 12º and after 12 days at 15ºC.

Discussion

The non-occluded virus and the fungus disease of the citrus mites are major factors in the natural reduction of populations of these pests. This has led to the development of integrated control programs which enhance the effectiveness of the natural control and reduce the use of chemical insecticides (McCoy 1981). Natural control of agricultural pests by pathogens also occurs in Australia. Outbreaks of the fungus *Cordyceps aphodii* can account for 95% mortality in blackheaded cockchafer (*Aphodius tasmaniae*) populations (Coles 1979) and underground grass grub (*Oncopera* spp.) populations can be decimated by the fungus *Microhilum oncoperae* (Martyn 1960, Yip and Rath 1989).

The development, in Australia, of biocontrol programs using pathogens for mites and lucerne flea is hindered by a lack of information. Apart from *N. acaracida*, the pathogens which naturally occur in populations of such species are unknown. This is probably a result of lack of searching effort rather than the lack of pathogens present. Consequently, the natural incidence of diseases in these populations should be studied to assess their impact.

Pathogens isolated from redlegged earth mite (RLEM), blue oat mite and lucerne flea may be required for biocontrol studies because the host range of entomogenous diseases is generally very limited. Viruses, in particular, are often restricted to species which are closely related to the host from which the disease was isolated. Consequently, the virus disease of citrus red mite may be ineffective against RLEM and blue oat mite. However, Reed (1981) concludes that there must be important viruses in other mite pests which warrant investigation. Similarly, commercial isolates of *H. thompsonii* and *V. lecanii* may be of little use in Australia. However, there is a range of isolates of *H. thompsonii* which differ in their pathogenicity to a range of mite species (Surli *et al.* 1989) and these should be tested against RLEM and blue oat mite. Research should be extended to include Australian isolates of *M. anisopliae* and *B. bassiana.*

Pathogen control of these pests will be most effective if it can be integrated into the classical biocontrol programs currently being implemented in Australia. These programs include the use of predator mites to control RLEM and lucerne flea (Michael 1989, Ireson 1990). The host specificity of selected isolates of pathogens will determine the level of integration of the two types of biocontrol program. Reed (1981) reports that the virus disease of citrus red mite did not cause mortality in ten other species of mites including three predator mite species. McCoy (1981) stated (though he cited no reference) that *Typhlodromalus peregrinus* was the only predator mite found to be susceptible to the fungus *H. thompsonii. M. anisopliae, V. lecanii* and *N. acaridis* have also been found to infect some non-target mite species (Goettel *et al.* 1990).

Predator and other mite species are important vectors for the spread of viral (Reed 1981) and fungal pathogens (Schabel 1982, Zimmerman and Brode 1983) regardless of whether or not they are susceptible to the disease. Balazy *et al.* (1987) listed 24 species of entomogenous fungi which were transported by soil-dwelling mites in Poland. Consequently, there is a high probability of finding pathogens which will be infective for the pest species and not for the predator species. Predator mites are likely to enhance the spread and efficacy of pathogens, and consequently, the combined effect of the two biocontrol programs is likely to be more effective than each separately.

In the USA, the fungus *H. thompsonii* (Mycar®), has been unsuccessful as a commercial microbial insecticide (McCoy 1986) and the virus disease of citrus mites has limited potential as a commercial product (Reed 1981). Commercialization of entomogenous pathogens is the major limiting factor to the development microbial insecticides. The recent entry of Bayer AG into the entomogenous fungal market, with BIO 1020® (Andersch *et al.* 1990, Reinecke *et al.* 1990), suggests that rapid developments in the production of many entomogenous fungi will occur, making the commercialization of microbial products for mites economically sound.

Future research

Pathogens form the focus of integrated mite control programs in the USA. These programs are aimed to assist the development of natural disease outbreaks. Similar utilization of pathogens for RLEM, blue oat mite and lucerne flea is limited by a lack of knowledge of their natural disease agents and this should be studied. Field efficacy problems with Mycar® suggest that these should be addressed during the development of pathogens for these pests. Compatibility with other control measures, including chemical pesticides and predator species, should be examined to help determine whether pathogens would be suited to short-term and / or long-term control.

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References

Andersch, W., Hartwig, J. Reinecke, P. and Stenzel, K. (1990). Production of mycelial granules of the entomopatho-genic fungus *Metarhizium anisopliae* for biological control of soil pests. Proceedings of the 5th International Colloquium on Invertebrate Pathology, ed D.E. Pinnock, p. 2-5 (Society for Invertebrate Pathology, Adelaide, Australia).

Balazy, S. and Wisniewski, J. (1986). Two new species of *Hirsutella* infecting mites in Poland. *Transactions British Mycological Society* 86(4), 629-35.

Balazy, S., Wieniewski, J. and Kaczmarek, S. (1987). Some noteworthy fungi occurring on mites. *Bulletin of the Polish Academy of Sciences, Biological Sciences* 35(7-9), 199-224.

Burgess, H.D. (1981). Strategies for the microbial control of pests in 1980 and beyond. *In* 'Microbial control of pests and plant disease 1970-1980', ed H.D. Burgess, pp. 797-836 (Academic Press, London).

Coles, R.B. (1979). The biology of *Cordyceps aphodii* (Sphaeriales: Clavicipitaceae). Proceedings of the 2nd Australian Conference on Grassland Invertebrate Ecology, ed T.K. Crosby and R.P. Pottinger, pp. 207-12 (Government Printer, Wellington).

Goettel, M.S., Poprawski, T.J., Vandenberg, J.D., Li, Z. and Roberts, D.W. (1990). Safety to non-target invertebrates of fungal biocontrol agents. *In* 'Safety of microbial insecticides', ed M. Laird, L.A. Lacey and E.W. Davidson, pp. 209-32 (CRC Press, Boca Raton USA).

Ireson, J.E. (1990). Studies on lucerne flea, *Sminthurus viridis* (L.) (Collembola: Sminthuridae) and other Collembola in the Tasmanian culture steppe. Unpublished Ph.D. Thesis, University of Tasmania, Hobart, Australia. 377 pp.

Ireson, J.E. and Rath, A.C. (1991). Preliminary observations on the efficacy of entomopathogenic fungi for control of the lucerne flea. *Sminthurus viridis* (L.) and the redlegged earth mite. *Halotydeus destructor* (Tucker). Proceedings of redlegged earth mite workshop, Perth, September 1991.

Jackson, T.A. (1989). Development of *Serratia entomophila* as an inundative biological control agent for the grass grub, *Costelytra zealandica*. Proceedings of the 5th Australian Conference on Grassland Invertebrate Ecology. ed P.P. Stahle, pp. 55-62 (D & D Printing, Victoria).

James, D.G. (1991). Prospects for integrated management of earth mites in pasture. Proceedings of redlegged earth mite workshop, Perth, September 1991.

Klein, M.G. (1988). Pest management of soil-inhabiting insects with microorganisms. *Agriculture, Ecosystems and Environment*, 24, 337-49.

Lewis, F.B. (1981). Control of the gypsy moth by a baculovirus. *In* 'Microbial control of pests and plant disease 1970-1980', ed H.D. Burgess, pp. 363-78 (Academic Press, London).

Lipa, J.J. (1971). Microbial control of mites and ticks. *In* 'Microbial control of insects and mites, ed H.D. Burgess and N.W. Hussey, pp.357-73 (Academic Press, London).

McCoy, C. W. (1981). Pest control by the fungus *Hirsutella thompsonii*. *In* 'Microbial control of pests and plant disease 1970-1980', ed H.D. Burgess, pp. 499-511 (Academic Press, London).

McCoy, C.W. (1986). Factors governing the efficacy of *Hirsutella thompsonii* in the field. *In* 'Fundamental and applied aspects of invertebrate pathology', ed R.A. Samson, J.M. Vlak and D. Peters. pp. 171-4 (Foundation of the 4th International Colloquium of Invertebrate Pathology, Wageningen, The Netherlands).

Martyn, E.J. (1960). The ecology of *Oncopera intricata* Walker and *Oncopera rufobrunnea* Tindale (Lepidoptera: Hepialidae). Research Bulletin No. 3, Department of Agriculture, Tasmania.

Michael, P.J. (1989). Biological control of the red-legged earth mite, *Halotydeus destructor*, blue-oat mite, *Penthaleus major* and lucerne flea, *Sminthurus viridis*. Australian Wool Corporation Research Review Conference. Abstracts p. 50, Ballarat, Australia.

Milner, R.J. (1985). *Neozygites acaridis* (Petch) comb. nov.: An entomophthoran pathogen of the mite, *Macrocheles peregrinus*, in Australia. *Transactions of the British Mycology Society*, 85(4), 641-7.

Moscardi, F. (1988). Production and use of entomopathogens in Brazil. *In* 'Biotechnology, Biological Pesticides and Novel Plant-Pest Resistance for Insect Pest Management', ed D.W. Roberts and R.R. Granados. pp. 53-60 (Cornell University, N.Y.).

Petch, T. (1940). An *Empusa* on a mite. *Proc. Linn. Soc. N.S.W*. 65(3-4), 259-60.

Quillan, R.J. (1988). Use of fungi to control insects in glasshouses. *In* 'Fungi in biological control systems', ed M.N. Burge. pp. 19-36 (Manchester University Press, Manchester).

Purrini, K. (1983). Comparison of pathogenic agents in Collembola (Insecta, Apterygota) from different forests in the Federal Republic of Germany, Austria and Spain. *Pedobiologia* 25, 365-71.

Rath, A.C. (1991) *Metarhizium anisopliae* for control of the Tasmanian Pasture Scarab *Adoryphorus couloni*. *In* 'The use of Pathogens in Scarabs Pest Management' ed. T.J. Jackson and T.R. Glare,. Chapter 18. (Intercept Press U.K.) (in press).

Reed, D.K. (1981). Control of mites by non-occluded viruses. *In* 'Microbial control of pests and plant disease 1970-1980', ed H.D. Burgess, pp. 427-31 (Academic Press, London).

Reinecke, P., Andersch, W. Stenzel, K. and Hartwig, J. (1990). BIO 1020, a new microbial insecticide for use in horticultural crops. Brighton Crop Protection Conference - Pests and Disease - 1990. pp. 49-54.

Ridsdill-Smith, T.J. (1991). Biology and ecology of redlegged earth mite, blue oat mite and lucerne flea. Proceedings of redlegged earth mite workshop, Perth, September 1991.

Schabel, H.G. (1982). Phoretic mites as carriers of entomopathogenic fungi. *Journal of Invertebrate Pathology* 39, 410-12.

Smitley, D.R., Kennedy, G.G. and Brooks, W.M. (1986). Role of the entomogenous fungus, *Neozygites floridana*, in population declines of the twospotted spider mite, *Tetranychus urticae*, on field corn. *Entomologia experimentalis et applicata* 41(3), 255-64.

Surli, J.A., Jegorov, A., Zachardiva, D. and Landa, Z. (1989). Comparisons of various isolates of *Hirsutella thompsonii*. Proceedings of the international conference - biopesticides, theory and practice, ed A. Jegorov and V. Matha. pp. 202-12. (Ceske Budejovice, Czechoslovakia).

Teakle, R. (1990). Research Report. *Australasian Invertebrate Pathology Working Group Newsletter* 10, 11.

Wallace, M.M.H. and Mackerras, I.M. (1970). The entognathus hexapods. *In* 'The insects of Australia' ed. The Division of Entomology, CSIRO Canberra. (Melbourne University Press Melbourne).

Yip, H.Y. and Rath, A.C. (1989). *Microhilum oncoperae* gen. et sp. nov. (Deuteromycotina: Hyphomycetes): The cause of mycosis on the larvae of *Oncopera intricata* (Lepidoptera: Hepialidae). *Journal of Invertebrate Pathology* 53, 361-4.

Zimmerman, G. and Bode, E. (1983). Investigations on the dispersal of the entomopathogenic fungus *Metarhizium anisopliae* (Fungi Imperfecti, Moniliales) by soil arthropods. *Pedobiologia* 25, 65-71.