National workshop on redlegged earth mite, lucerne flea and blue oat mite.

Selected papers from a workshop held at Perth, Western Australia, 9 – 11 September 1991, on the pasture pests *Halotydeus destructor* (Tucker) (redlegged earth mite), *Sminthurus viridis* (L.) (lucerne flea) and *Penthaleus major* (Dugès) (blue oat mite).

Edited by T.J. Ridsdill-Smith,
CSIRO Division of Entomology,
Private Bag, Wembley, WA 6014, Australia.

Biology and ecology of redlegged earth mite, blue oat mite and lucerne flea

T.J. Ridsdill-Smith, CSIRO Division of Entomology, Private Bag, PO Wembley, WA 6014, Australia.

Summary

The level of taxonomic information available for lucerne flea is adequate, but it is not known if redlegged earth mite and blue oat mite can be distinguished from other species or subspecies in Australia. All three species feed on the upper surface of leaves, LF eating leaf tissue and RLEM and BOM feeding on liquid cell contents. RLEM feeds on a wide range of host plants, and their different responses probably depend on differences in nutritive content of the plants. RLEM, BOM and LF are winter active, passing the summer as diapausing eggs. All three species have two peaks of abundance in the winter, which for LF are regulated by temperature and moisture, by natural enemies, and by density effects. LF prefers fine textured soils while RLEM and BOM prefer sandy soils. More ecological information is required for RLEM to assist in its management.

Introduction

The redlegged earth mite (RLEM) *Halotydeus destructor* (Tucker) (Acarina: Penthaleidae), blue oat mite (BOM) *Penthaleus major* (Dugès) (Acarina: Penthaleidae) and lucerne flea (LF) *Sminthurus viridis* (Linnaeus) (Collembola: Sminthuridae) are pests of pastures in southern Australia. They also cause damage to a wide range of crops and vegetables.

This paper summarizes what is known of the biology and ecology of RLEM, LF and BOM. A knowledge of the factors affecting the occurrence and abundance of a pest is essential to be able to plan its control effectively, whether the control be with chemicals or with biological techniques. It is also possible that studies of the pest in the field may lead to novel methods of control.

Distribution

The BOM and LF are both very widely distributed in the world (Narayan 1962, Wallace 1974), while RLEM is restricted to southern Africa, Australia and New Zealand (Jeppson *et al.* 1975). All three species appear to have been accidentally introduced, RLEM probably from South Africa, BOM and LF probably from Europe. Biological control is more likely to succeed when a pest has been introduced to a country without its natural enemies, than if it has become a pest in the country where it evolved with its natural enemies.

The distribution of the three species in Australia has been described by Wallace and Mahon (1971a, 1971b). RLEM and LF occur where there is a Mediterranean-type climate with winter rainfall, but BOM extends into regions with a drier climate, where it can also tolerate some summer rainfall.

Allen (1987) ranks both RLEM and LF as important pasture pests; LF is a major pest in Victoria, Tasmania, SA and WA, RLEM is a major pest in NSW, Victoria, SA and WA, and BOM is a major pest only in NSW. However, the more detailed survey by Sloane, Cook and King (1988) showed that RLEM is thought to be the most severe pest of temperate pastures in Australia, being a major pest in 14 agricultural zones as defined by the Australian Bureau of Agricultural and Resource Economics and minor in two, while LF was a major pest in five zones and minor in five, and BOM was a minor pest in three regions only. These assessments on pest status are mostly subjective, and better data are required.

Taxonomy

It is fairly clear that the LF found in Australia is the same species as that in Europe, which is important information when considering biological control (Wallace 1974). In contrast, while it is known that RLEM and BOM both occur in Australia, it is not known whether other similar species or subspecies are also present (Halliday 1991). Modern methods of pest control depend on specific treatments, both for reasons of economy, and to minimize damage to non-target species. It is therefore important that the pest species can be distinguished from related species. If RLEM, for example, was found to comprise several sibling species, each would have to be tested separately for their responses to RLEM-resistant sub. clover varieties.

Reproduction

All three pest species are probably capable of sexual reproduction. The sex ratio of three females: one male observed for RLEM in the field (T.J. Ridsdill-Smith, unpublished data) is typical of a haplo-diploid system of sex determination, but there is no description of the genetics of sex determination to confirm this for any of these species. Male RLEM probably carry out web-spinning (Solomon 1937, M.M.H. Wallace, personal communication). Webs are commonly seen on the soil surface and sometimes on the plants, in pots containing RLEM (T.J. Ridsdill-Smith, unpublished data). Wallace (unpublished data) suggests that sperm packets are placed on the webbing for females to pick up. In LF the male attaches a globular spermatophore by a stalk to the soil or low vegetation, which the female straddles to pick up in her genital opening. If mites and flea do have sexual reproduction, the high densities that are present in the field will provide them with a great capacity to develop biotypes which can adapt to resistant plants or to specific pathogens, particularly where the resistance is due to a single factor.

BOM and RLEM eggs are orange or pink, and can be easily distinguished for each species. The winter eggs are laid singly on the under surface of leaves close to the ground, or on the soil surface itself. LF lay winter eggs on the soil surface in batches of about 40 eggs with a rough covering of soil particles (Wallace 1968).

Growth and feeding behaviour

RLEM passes through four instars before becoming adults, which are; egg, larva, protonymph, deutonymph, tritonymph and adult, and each takes one to two weeks to complete. Between each moult for up to a day there is an inactive stage, when the legs are held rigidly in front of the body. BOM have only three nymphal stages (larva, protonymph and deutonymph) before becoming adults (Narayan 1962). LF appears to have a variable number from three to nine instars (Walters 1964, Dentener 1985, M.H. Wallace, personal communication).

The amount of feeding varies with mite age. Young RLEM larvae and protonymphs cause less damage to subclover leaves than do tritonymphs and adults, and during their growth the weights of RLEM increase from about one microgram to over 100 micrograms (T.J. Ridsdill-Smith, unpublished data). The adults start to lay eggs after a feeding period.

RLEM and BOM feed on cotyledons, trifoliate leaves and flowers, since all of these plant stages are damaged (Jeppson *et al.* 1975). RLEM use sharp chelicerae to pierce the upper leaf epidermis down to the palisade layer, and feed on the exuded droplet of cell contents (Swan 1934), and BOM feed in a similar way (Narayan 1962). The damage by RLEM and by BOM is seen as silvering of the leaf, as a result of air in the damaged cells (Jeppson *et al.* 1975). LF removes the leaf tissue leaving transparent patches, and can cause holes through the leaf.

BOM prefers to feed on small grains and grasses (Narayan 1962, Jeppson *et al.* 1975), while RLEM and LF prefer legumes and broad-leaved weeds but will also attack a variety of other plants (Solomon 1937, Wallace 1967). RLEM must feed on living plants to survive (T.J. Ridsdill-Smith, unpublished data). RLEM and BOM run actively over the surface of plants and the soil, and appear to be continuously testing the substrate with their palps. RLEM can detect different sugars on filter papers (Solomon 1937), and when feeding through membranes (A.J. Annells, unpublished data). Variation in sugar content could be one factor causing differences in weight gain and numbers of progeny produced on different legume species, but other chemicals and physical factors in the leaf may also be involved.

Diapause

All three species are active in winter during the cool moist period of the year, and produce drought-resistant diapause eggs in the spring, which do not hatch till the following autumn (Norris 1950, Narayan 1962, Wallace 1968, 1970a, 1970b, James and O'Malley 1991b). For LF and RLEM the production of diapause eggs in the spring is probably induced by the physiological state of the plants on which they are feeding (Wallace 1968, 1970a).

The diapause eggs of LF are laid in clumps of about 40 surrounded by a smooth covering of soil (Wallace 1968). Exposure to summer conditions is needed to complete diapause development, and the LF hatch in the autumn following exposure to a combination of low temperatures and adequate soil moisture (Wallace 1968). Female RLEM, in contrast, die with their bodies full of diapausing eggs. An exposure to 52ºC for a month was optimum to break the diapause, and the eggs hatched with a combination of temperatures below 20ºC and adequate soil moisture (Wallace 1970a, 1970b). BOM lay diapause eggs on vegetation or around plants (Narayan 1962). The requirements for initiation and termination of BOM diapause are unknown.

The mites and lucerne flea can cause high seedling mortality in annual pastures if they emerge from diapause eggs at the time of germination. Clover needs significant rainfall for germination, while for RLEM and LF eggs to hatch this rainfall must be accompanied by low temperatures.

Timing of population events

Populations of LF usually build up in the autumn, fall to a trough in mid-winter, probably as a result of heavy rain and low temperatures, and there is a second peak in spring (Dumbleton 1938, Davidson 1944, Wallace 1967). RLEM has an autumn peak and a spring peak (Norris 1938), and the increases in abundance result from periods of egg-laying in the autumn and spring (T.J. Ridsdill-Smith, unpublished data). BOM has one peak in mid-winter and another in spring (Narayan 1962). Abundance of LF and RLEM may be greater either in autumn or spring, and the sizes of the peaks vary considerably between sites and years (Norris 1938, Wallace 1967). Activity starts in the autumn with low temperatures and significant rainfall, and ceases in the spring when the soil dries and the temperatures rise. Observations at Perth suggest that RLEM survival falls in spring when the daily maximum moves above 25ºC.

Three generations are completed during the year by LF (Davidson 1944) and RLEM (Norris 1938, T.J. Ridsdill-Smith, unpublished data), but BOM has two generations a year (Narayan 1962). Currently in WA, eggs and instars of RLEM are being identified and counted from samples, to give more detailed information about the timing of population events than has been previously available (T.J. Ridsdill-Smith, unpublished data).

Methods to investigate abundance

Satisfactory techniques are available for population studies of these pests. These include a soil corer which is easy to use in pastures, inexpensive, and accurate under both wet and dry conditions (Wallace 1956), and a mechanical vacuum sampler which is effective for sampling mites on recently cultivated land (Wallace 1972).

Factors affecting abundance

Wallace (1967) investigated factors influencing LF populations in pastures. In summary he found that:

a) LF populations fall if exposed to high temperatures or desiccation;
b) Fine-textured soils favour LF populations;
c) Areas with broad-leaved plants, including clovers, are preferred to grassy areas;
d) Density-dependent cannibalism at high LF densities causes populations to fall rapidly and
e) Native bdellid predatory mites are important in reducing LF populations.

RLEM and BOM, in contrast, are reputed to be more abundant on sandy soils (Tucker 1925, Norris 1938), and are also susceptible to high temperatures or desiccation (Jeppson *et al.* 1975). The fungal disease, *Neozygites acaracida* Petch (Entomopthorales) attacks both RLEM and BOM (R.J. Milner, personal communication). However, the importance of fungus and virus diseases in population regulation has not been studied for any of the species, and the potential for their use in biological control should be investigated.

It has been suggested that RLEM populations are greater in pastures with high capeweed content (Norris 1938), hence implying that control of capeweed would reduce their abundance. In pastures, however, RLEM do not preferentially lay their eggs on capeweed (T.J Ridsdill-Smith, unpublished data), and it appears that any benefit from capeweed might be more a result of the favourable microclimate that it offers under its large leaves, than from any superior nutritional value (R. Chapman, personal communication). Ridsdill-Smith and Annells (unpublished data) could find no evidence that patchiness of RLEM within a pasture was associated with differences in pasture composition.

The planning of treatments for the control of RLEM would be made easier if the potential size of mite winter populations could be anticipated before the first rains in autumn. At Keysbrook, Western Australia, there were 12,000 RLEM m^{-2} in spring 1990, and 2,000 dead bodies m^{-2} containing 71,000 eggs m^{-2} in summer, which produced a mite population in autumn 1991 of 10,000 m^{-2} (T.J. Ridsdill-Smith, unpublished data). Thus many over-summering eggs die. Summer rainfall can have a deleterious effect on the survival of oversummering eggs (James and O'Malley 1991a), and particularly the rainfall that occurs early in the summer (Annells and Ridsdill-Smith 1991).

Laboratory rearing

These pests are only active in the field for approximately six months of the year. It is therefore necessary to rear animals in the laboratory if experimental and biological research is to continue year round. Ridsdill-Smith (1991) has now reared RLEM for seven generations continuously over ten months in the laboratory. This is the first time RLEM has been reared through the summer. The average number of eggs produced per adult female mite was low, and methods to increase their fecundity through providing more nutritive plants are being tested (A.J. Annells, unpublished data). RLEM are gregarious and feed in groups on a leaf both in the laboratory and the field, possibly responding to tactile stimuli (Solomon 1937), and their survival appears to be enhanced by the presence of other mites. It has proved very difficult to keep single mites alive in the laboratory, and mites for rearing are maintained at densities equivalent to 15,000 m^{-2} (Ridsdill-Smith 1991). BOM has been successfully reared in small containers for biological studies (Narayan 1962), but there is no record of LF having been reared continuously.

Acknowledgements

Drs John Scott and Bruce Halliday are thanked for helpful comments on the earlier draft of this paper, and the Wool Research and Development Corporation for helping to support these studies.

References

Allen, P.G. (1987). Insect pests of pasture in perspective. *In* 'Temperate pastures: their production, use and management' (eds. J.L. Wheeler, C.J. Pearson and G.E. Roberts). Australian Wool Corporation, pp. 211-25.

Annells, A.J. and Ridsdill-Smith, T.J. (1991). The effect of moisture on aestivating eggs of *Halotydeus destructor* (Tucker) (Acari: Penthaleidae). Proceedings of redlegged earth mite workshop, Perth, September 1991.

Davidson, J. (1944). On the growth of insect populations with successive generations. *The Australian Journal of Experimental Biology and Medical Science* 22, 95-103.

Dentener, P.R. (1985). The ecology of the lucerne flea, *Sminthurus viridis*, in the South Aukland / Waikato area. PhD thesis, University of Waikato.

Dumbleton, L.J. (1938). The lucerne flea (*Smynthurus viridis*) in New Zealand. *New Zealand Journal of Science and Technology* 20, 197A-211A.

Halliday, R.B. (1991). Taxonomic background of the redlegged earth mite *Halotydeus destructor* (Tucker) (Acarina: Penthaleidae). Proceedings of redlegged earth mite workshop, Perth, September 1991.

James, D.G. and O'Malley, K.J. (1991a). Oversummering of eggs of *Halotydeus destructor* Tucker (Acari: Penthaleidae): diapause termination and mortality. *Australian Entomological Magazine* 18, 35-41.

James, D.G. and O'Malley, K.J. (1991b). Phenology of egg production and diapause in *Halotydeus destructor* Tucker and *Penthaleus major* Dugès (Acari: Penthaleidae) in New South Wales during 1988 / 89. *General and Applied Entomology* (In press).

Jeppson, L.R., Keifer, H.H. and Baker, E.W. (1975). Mites injurious to economic plants. University of California Press, Los Angeles.

Narayan, D.H. (1962). Morphological, biological and ecological studies on the winter grain mite, *Penthaleus major* (Dugès), Penthaleidae: Acarina Part I. *Journal of the Zoological Society of India* 14, 45-63.

Norris, K.R. (1938). A population study of the red-legged earth mite (*Halotydeus destructor*) in Western Australia, with notes on associated mites and Collembola. *C.S.I.R. Pamphlet No.* 84, 1-23.

Norris, K.R. (1950). Aestivating eggs of the red-legged earth mite. *C.S.I.R.O. Bulletin No.* 253.

Ridsdill-Smith, T.J. (1991). Laboratory rearing of *Halotydeus destructor* (Tucker)(Acari: Penthaleidae). *Journal of the Australian Entomological Society* (In press).

Sloane, Cook and King (1988). The economic impact of pasture weeds, pests, and diseases on the Australian wool industry. Australian Wool Corporation, 71 pp.

Solomon, M.E. (1937). Behaviour of the red-legged earth mite, *Halotydeus destructor*, in relation to environmental conditions. *Journal of Animal Ecology* 6, 340-61.

Swan, D.C. (1934). The red-legged earth mite *Halotydeus destructor* (Tucker) in South Australia: with remarks upon *Penthaleus major* (Dugès). *South Australian Journal of Agriculture* 38, 353-67.

Tucker, R.W.E. (1925). The black sand mite: *Penthaleus destructor* n.sp. *Department of Agriculture of South Africa Entomology Memoirs* No. 3, 21-36.

Wallace, M.M.H. (1956). A rapid method of sampling small free-living pasture insects and mites. *Journal of the Australian Institute of Agricultural Science* 22, 283-4.

Wallace, M.M.H. (1967). The ecology of *Sminthurus viridis* (L.)(Collembola) I. Processes influencing numbers in pastures in Western Australia. *Australian Journal of Zoology* 15, 1173-206.

Wallace, M.M.H. (1968). The ecology of *Sminthurus viridis* (Collembola) II. Diapause in the aestivating egg. *Australian Journal of Zoology* 16, 871-83.

Wallace, M.M.H. (1970a). Diapause in the aestivating egg of *Halotydeus destructor* (Acari: Eupodidae). *Australian Journal of Zoology* 19, 295-313.

Wallace, M.M.H. (1970b). The influence of temperature on post-diapause development and survival in the aestivating eggs of *Halotydeus destructor* (Acari: Eupodidae). *Australian Journal of Zoology* 18, 315-29.

Wallace, M.M.H. (1972). A portable power-operated apparatus for the field-collecting of epigaeic Collembola and Acari. *Journal of the Australian Entomological Society* 11, 261-3.

Wallace, M.M.H. (1974). Present and probable world distribution of *Sminthurus viridis* and prospects for its biological control. *Pedobiologia* 14, 238-43.

Wallace, M.M.H. and Mahon, J.A. (1971a). The distribution of *Halotydeus destructor* and *Penthaleus major* (Acari: Eupodidae) in Australia in relation to climate and land use. *Australian Journal of Zoology* 19, 65-76.

Wallace, M.M.H. and Mahon, J.A. (1971b). The ecology of *Sminthurus viridis* (Collembola). III. The influence of climate and land use on its distribution and that of an important predator, *Bdellodes lapidaria* (Acari: Bdellidae). *Australian Journal of Zoology* 19, 177-88.

Walters, M.C. (1964). A study of *Sminthurus viridis* (L.) (Collembola) in the Western Cape Province. *Department of Agriculture Technical Services Entomology Memoirs, Department of Agriculture of South Africa* No. 16.