New Zealand Journal of Agricultural Research, 2003, Vol. 46: 141–146
0028–8233/03/4602–0141 $7.00/0

A review of the role of predatory mites in the biological control of lucerne flea, *Sminthurus viridis* (L.) (Collembola: Sminthuridae) and their potential use in New Zealand

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Abstract Research on the role of predatory mites as biological control agents for the lucerne flea, *Sminthurus viridis*, is reviewed and their potential use in New Zealand pastoral systems is discussed. Three predatory mites are considered, the pasture snout mite (*Bdellodes lapidaria*), the spiny snout mite (*Neomolgus capillatus*), and the French anystis mite (*Anystis wallacei*). Of these, only *B. lapidaria* is already present in New Zealand but climate may limit its effectiveness in areas of New Zealand north and west of Palmerston North. Both *N. capillatus* and *A. wallacei* are established in Australia but data currently available suggest that the importation of only *N. capillatus* should be considered, subject to quarantine requirements. *N. capillatus* has been a particularly effective predator of lucerne flea in areas of Tasmania with a similar climate to the northern and western areas of the North Island. A survey of potential mite predators that already exist in New Zealand pastures should also be undertaken.

Keywords lucerne flea; predators; mites; CLIMEX; biological control

A02025; published 30 June 2003
Received 8 April 2002; accepted 23 December 2002

INTRODUCTION

Lucerne flea (or clover flea, *Sminthurus viridis* (L.)) is polyphagous and has been present in New Zealand since at least 1929, probably having been introduced from Australia in soil surrounding imported subterranean clover (*Trifolium subterraneum* (L.)) seed (Dumbleton 1938). Lucerne flea is now found throughout New Zealand (Dumbleton 1938; Somerfield & Burnett 1976), but causes economic damage to the preferred host, white clover (*Trifolium repens* (L.)), only in localised areas in the North Island (Townsend et al. 1979; Wrenn et al. 1983). Damage to clover initially results from the young nymphs eating small holes giving the leaves a speckled appearance; older nymphs and adults eat through the upper and lower epidermis producing characteristic window-like openings. In New Zealand, insecticide application to control lucerne flea damage can increase pasture production by 7–20% (Addison & Pottinger 1991).

Areas of New Zealand where lucerne flea is of particular concern include parts of Northland, Auckland, and Waikato (Pottinger et al. 1985). High densities of the feeding (non-egg) stages of lucerne flea are present in pastures from the end of March through to November/December, after which they are present as eggs or in very low numbers of feeding stages (Dumbleton 1938; Dentener 1985). Lucerne flea eggs laid in late spring undergo a diapause and will not hatch until they have undergone periods of dry conditions (Wallace 1968). This allows the lucerne flea to avoid hatching over the dry summer months when food may be scarce. In the Waikato area, lucerne flea can produce four or five generations per year (Dentener 1985).

MITE PREDATORS OF LUCERNE FLEA

For the purposes of this review, predators are taken to be animals of one species whose sole source of food is individuals of another species. Predators can be specialised to feed on only one other animal or can be more generalist, preying on individuals from a range of other species. In this context, all three of the mites discussed in this review are generalist predators, a characteristic which is an advantage to their use as biocontrol agents, as their populations can be maintained even in times of low lucerne flea numbers.

Although lucerne flea is present in many parts of Europe, little work has been carried out into its biological control potential there because populations do not reach damaging levels. It is likely that at least part of the reason lucerne flea is not a pest in Europe is the presence of a large number of predators that effectively control its numbers (Wallace 1974). Most of the in-depth research into the use of predatory mites as biocontrol agents of lucerne flea has been carried out in Australia and South Africa, so this review will look at the species used in those countries.

The three most commonly studied, and apparently most important, mite predators of lucerne flea are the pasture snout mite *Bdellodes lapidaria* (Kramer) (Bdellidae) (= *Biscirus lapidaria* Kramer), the spiny snout mite *Neomolgus capillatus* (Kramer) (Bdellidae), and the French anystis mite *Anystis wallacei* Otto (= *Anystis salicinus* Meyer and *Anystis* species A). All are able to feed not only on lucerne flea but also on other insects and mites.

Bdellodes lapidaria (Pasture snout mite)

This mite was discovered in Australia in 1931 (Womersley 1933), and in New Zealand in 1937 (Dumbleton 1938). In Australia, the mite was first noticed in association with declining lucerne flea populations in Western Australia and was subsequently distributed to South Australia, Victoria, Tasmania (Currie 1934), and more recently to South Africa (Wallace & Walters 1974). At the same time that mites were being artificially introduced across Australia, naturally occurring populations were noted in the same areas. Control of lucerne flea by naturally occurring populations of *B. lapidaria* was noted from Victoria (Prescott 1937) and Tasmania, but at that time artificially introduced populations did not seem to exert significant control (Evans 1939).

Bdellodes lapidaria, in common with lucerne flea, produces eggs that are able to diapause and survive hot, dry conditions over summer (Wallace 1971). Mite eggs can remain dormant for 4–30 weeks and only hatch with increasing moisture and declining temperature conditions, as occur in early autumn. This mite, therefore, has a virtually identical over-summer survival mechanism to that of lucerne flea, ensuring newly hatched mites will have a suitable food source in autumn.

In Western Australia, Wallace (1967) showed a clear reduction in lucerne flea densities by *B. lapidaria* and he concluded that mite densities over 20 m^{-2} in early winter (i.e., before the end of June) were sufficient to prevent lucerne flea outbreaks later in the season. Although *B. lapidaria* occurs in New Zealand, it has not been observed to be exerting a clear effect on lucerne flea populations. Dentener (1985) observed populations of mites of c. 80 m^{-2} in paddocks near Huntly (Waikato) in April and again in the following January, but they were found only in low numbers (range 0–27 m^{-2}) at the seven intervening sampling times through the winter and spring, despite observed lucerne flea populations in excess of 10 000 m^{-2}. The movement activity of *B. lapidaria* was greatest (as measured by pitfall trapping), however, during periods of low lucerne flea activity and least when lucerne flea was most active, suggesting the mite does actively seek lucerne flea and that it must search hardest when prey is scarce (Dentener 1985).

In Australia, the distribution of *B. lapidaria* corresponds fairly well to that of lucerne flea, especially in areas where the mean July temperature does not exceed 17.5°C (Wallace & Mahon 1971). Rainfall further delimits the distribution of *B. lapidaria* in Australia, with its winter dry limit (i.e., the amount of rainfall below which *B. lapidaria* will not survive) being above 260 mm cumulatively from May to October. Wallace & Mahon (1971) suggested that the summer wet limit (i.e., the amount of rainfall above which *B. lapidaria* eggs will hatch prematurely and nymphs will not survive) was below 225 mm from December to March, but Ireson (1982) found the mite in areas of Tasmania that received 312 mm during this period.

Ireson (1982) also observed that *B. lapidaria* was uncommon in one of the main dairying areas of Tasmania where lucerne flea was a pest. This region was characterised as having greater than 1200 mm annual rainfall and comparatively small annual temperature fluctuations (i.e., mean minimum 4–6°C in July and mean maximum 20–22°C in summer). New Zealand conditions would easily satisfy the temperature and wet limits for *B. lapidaria*, although summers in some areas may not be dry enough (e.g., Ruakura Research Station, Waikato, receives c. 335 mm of rain from December to March, well above even the upper limit given for Tasmania).

A survey to delineate the distribution of *B. lapidaria* in Tasmania was conducted by Ireson (1982). As well as identifying areas where the mite was effective, he also found that the mite was present in the north-western corner of Tasmania, but that it was an ineffective predator of lucerne flea in that area. To explore how these findings might relate to the New Zealand situation we have used the CLIMEX computer program, developed by CSIRO in Australia for climate matching (Sutherst & Maywald 1985). It calculates a formula that combines temperature and rainfall into an index which can be used to indicate relative similarity of climates. In this case, climates were matched between New Zealand locations and three Tasmanian locations: Smithton in the far north-west (where *B. lapidaria* was found to be uncommon); Launceston in the north-east and Hobart in the south-east (both where *B. lapidaria* is well established). An arbitrary limit of 75% was imposed on the climate matching to ensure only those areas with a high degree of similarity were chosen.

It would appear from this climate matching that although *B. lapidaria* is present in New Zealand, its effectiveness as a biocontrol of lucerne flea might be limited to areas of eastern and southern North Island, but extend to virtually all of the South Island (Fig. 1). In the matches above, Wanganui and Palmerston North not only match the climate of Smithton, but also have a >70% match with both Launceston and Hobart, suggesting that they may be near the north-western limit of effectiveness of *B. lapidaria*. This is an interesting finding as the prevalence and severity of lucerne flea damage appears to decrease in eastern and southern North Island and South Island areas. Such a result must be tempered by the fact that *B. lapidaria* may have been in New Zealand long enough to exhibit some climatic adaptation, thereby extending its effective distribution northwards. Confirmation of these predictions of the distribution and effectiveness of *B. lapidaria* in New Zealand would require strategic sampling of both host and predator in representative areas throughout the country.

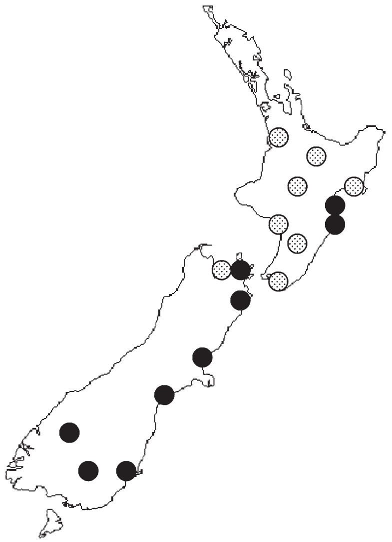

Fig. 1 Outline map of New Zealand showing areas that have a ≥75% climate match to areas in Tasmania, Australia where pasture snout mite (*Bdellodes lapidaria*) is effective (solid circles) or ineffective (hatched circles) at controlling lucerne flea populations.

Neomolgus capillatus (Spiny snout mite)

Extensive surveys and feeding observations led to *N. capillatus* being imported from Morocco and the south of France in 1969 and successfully established in Western Australia and South Africa (Wallace 1974). A second successful importation and establishment into Australia, this time in Tasmania, was made from 1985–90 with mites from northern France, and Switzerland (Ireson & Paterson 1991). These introductions demonstrate the benefits of climate matching when determining the best sources of biocontrol agents for importation. In these cases, the hot, dry climate of Western Australia is obviously close to that of the mediterranean conditions in Morocco and southern France whereas Tasmanian conditions are more akin to the temperate climate of the Brittany region of north-west France. As far as is known, this mite is not present in New Zealand.

Wallace (1974) observed *N. capillatus* in Europe from Scandinavia to southern Morocco and noted that it was an active predator of lucerne flea, having been observed feeding on it in many localities. On this basis the decision was made to import the mite to Australia. Some 17 500 mites were sent to Western Australia where they were released at 10 sites infested with large populations of lucerne flea. The mites were confined to small areas within the release sites to allow their numbers to build up without dispersing, to ensure good establishment. Once established at the release sites, mites were suctioned off infested pasture and spread to other areas (Wallace 1974). Between 1988 and 1990 almost 150 000 mites were redistributed around Western Australia (Michael et al. 1991a).

In north-west Tasmania, where *B. lapidaria* has been observed to be ineffective, approximately 33 500 *N. capillatus* were released onto eight sites between 1985 and 1990, resulting in the establishment of permanent populations (Ireson & Paterson 1991). Over 900 000 *N. capillatus* from the release sites were redistributed to almost 500 other sites in Tasmania between 1988 and 1995 (Ireson & Webb 1996). *N. capillatus* successfully established at a large number (c. 90%) of the redistribution sites, with most sites receiving c. 2000 mites. Mites were released into areas of lush ryegrass/white clover pasture (15–20 cm high vegetation) where lucerne flea was known to be a problem (Ireson & Webb 1996).

After the introduction of *N. capillatus* to Tasmania, it has been estimated that autumn populations of lucerne flea were reduced by 95%, but that late spring lucerne flea populations were not controlled (Ireson & Webb 1995). The lack of spring control is probably due to winter inactivity of the mite and hence a much delayed predator response (Ireson et al. 2002). In Western Australia, *N. capillatus* has been observed to reduce lucerne flea populations by about 80% (Wallace 1981; Michael et al. 1991a).

Anystis wallacei (French anystis mite)

This mite was introduced into Western Australia in 1965 from southern France as a biocontrol agent for the red-legged earth mite (*Halotydeus destructor* (Tucker)), which is a serious pest of clovers in that part of Australia (Wallace 1981). *A. wallacei* is found in the same areas of southern France as *B. lapidaria* and *N. capillatus* and in laboratory conditions prefers to feed on lucerne flea over the red-legged earth mite when lucerne fleas are abundant (Otto & Halliday 1991). Because of this observed preference for lucerne flea, *A. wallacei* was introduced into Tasmania from Western Australia in 1993, and has apparently established (Ireson & Webb 1995). *A. baccarum*, a similar species to that introduced to Australia, has been reported from pasture in Nelson, New Zealand (Martin 1983) but the report did not identify its prey. *A. wallacei*, in common with the snout mites, produces eggs that are able to survive dry conditions (Michael et al. 1991b).

In Western Australia, complex interactions have been observed among *N. capillatus*, *A. wallacei*, lucerne flea, and red-legged earth mite, a situation which has made it difficult to quantify the effect of *A. wallacei* on lucerne flea (Michael et al. 1991b). However, in field experiments Michael et al. (1995) found that the combined effects of *N. capillatus* and *A. wallacei* reduced populations of lucerne flea by 70–90% and increased legume herbage and seed production by c. 100%.

Anystis wallacei was introduced into Tasmania in 1993 in the hope of preventing spring outbreaks of lucerne flea, which *N. capillatus* had been unable to do (Ireson & Webb 1995). No published information is available, however, on the efficacy of this introduction, either alone or in combination with *B. lapidaria* and *N. capillatus*.

Limitations to mite success

All three predatory mites discussed here are very slow to spread, as they do so only by crawling and are not distributed by animals or wind (Ireson & Webb 1996). Furthermore, these mites are unable to cross even small barriers such as streams, roads, and cultivated ground (Wallace 1974; Ireson & Webb 1996). Nineteen years after the release of *N. capillatus* in Western Australia, at one release site it was found to have spread to cover only 216 ha (Michael et al. 1991b), and has been observed to spread at the rate of about 70 m per year in Tasmania (Ireson & Webb 1996; Ireson et al. 2002).

In Western Australia and Tasmania, successful redistribution programmes have been undertaken using suction machines to collect and transfer live predatory mites from established to new sites (Ireson & Webb 1995; Michael et al. 1991b). Suction machines that may be suitable for this purpose are readily available in the form of "blower-vac" machines sold to home gardeners for dispersal and collection of leaves. Some experimental work may be needed to determine the most suitable of these machines for collecting mites, if a distribution programme were envisioned for New Zealand.

Hard grazing has been found to have a more serious effect on mite survival than on survival of the lucerne flea in Western Australia (Michael et al. 1991b). In New Zealand, lucerne flea is predominantly a problem in rotationally grazed pastures, especially those under dairy cattle grazing (P. Addison pers. comm.). Laxly grazed areas may need to be maintained, at least at sites of establishment, if predatory mites are to successfully spread. Thereafter, careful attention may need to be paid to grazing management in addition to maintenance of areas favourable for mite survival (refugia). Predatory mites appear to be no more susceptible to some insecticides than lucerne flea (Michael et al. 1995) but further work would be needed to confirm this, especially in New Zealand conditions.

CONCLUSIONS

To prioritise the research effort into biological control of lucerne flea in New Zealand, it first needs to be established whether suitable predatory mites are already present here. Extensive field surveying will give the answer to this question, and is currently being undertaken (B. E. Willoughby pers comm.). In particular, climate and its effect on predators, may partially explain the distribution of damaging populations of lucerne flea, but it does not explain the very localised outbreaks of this pest. For example, outbreaks of lucerne flea on the Dexcel (formerly DRC) dairy farm in Hamilton are extremely rare, yet just c. 15 km away outbreaks are common and serious (B. E. Willoughby pers. obs.). Climate cannot account for this micro-distribution and it may be that predatory mites are in part responsible. Comparison of such contrasting areas, in close geographic proximity, would be an obvious starting point in any search for effective predatory mites in this country.

If it were found that suitable predatory mites already exist in New Zealand then their geographical distribution could be investigated and re-distribution programmes instigated if a lack of spatial coverage were apparent. If it were found that predatory mites were widely distributed but ineffective, then options such as habitat enhancement and provision of refugia may be investigated to try and improve their effectiveness.

An option more likely to succeed in the circumstance of a widely distributed ineffective predatory mite being already present in New Zealand would be importation of another mite to improve lucerne flea control. Convincing efficacy data for *Anystis wallacei* against lucerne flea is lacking, so this mite should not be considered as an importation candidate until further work is carried out. From Tasmanian studies, the importation and release of *Neomolgus capillatus* from Tasmania appears most likely to succeed due to its affinity for lucerne flea and climatic requirements. Strong evidence of the benefits which would accrue to pasture productivity from release of a predatory mite would need to be made before importation and release could be considered due to the high cost of such a programme. Costs would include research effort to demonstrate efficacy and host range, particularly in regard to New Zealand's native fauna. Such research is time consuming, an example of which is given by the parasitoid wasp for control of Argentine stem weevil which was released into New Zealand in 1991, 3 years after importation to quarantine and host testing began (McNeill et al. 2002).

A well-structured programme, beginning with surveying the predatory mites already present in New Zealand pastures, will determine the future use of these biological control agents for lucerne flea in this country.

ACKNOWLEDGMENTS

The authors thank the Northland Clover Pest Interest Group for allowing publication of the report on which this review is based. We also thank P. Addison, B. Cooper, and two anonymous reviewers for their comments on an earlier version of the manuscript.

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