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The biology and behaviour of redlegged earth mite and blue oat mite on crop plants

Garrick McDonald[A], **Kylie Moritz**[A], **Eve Merton**[B] and **A.A. Hoffmann**[B]
[A] Plant Sciences and Biotechnology, Agriculture Victoria, La Trobe University, Bundoora, Victoria 3083, Australia.
[B] School of Genetics and Human Variation, La Trobe University, Bundoora, Victoria 3083, Australia.

Summary

Earth mites are one of the major deterrents to the successful establishment of winter oilseeds, particularly canola. In order to understand how crop management practices may impact on mites and their damage, we have commenced a study of the relationships between the mites and oilseed, grain legume and cereal crop plants. *Halotydeus destructor* were shown not to be attracted to lupins, wheat or oats, and their survival and fecundity were significantly lower on these than on other plant types. This suggests that such crops, particularly lupins, used in rotations prior to canola, could minimize the in-paddock infestations of mites. Preliminary screening tests for *H. destructor* resistance has also shown that some northern hemisphere varieties of *Brassica napus* are prone to significantly less cotyledon damage than local varieties. Notably, survival and fecundity of *H. destructor* on *B. napus* was low even on susceptible varieties, indicating that the species already has a level of partial resistance. On the one variety tested (Oscar), *Penthaleus major* caused only half the damage of *H. destructor*.

Introduction

Winter oilseeds are highly vulnerable to pest damage during the first weeks after germination. The most significant pest is the redlegged earth mite (*Halotydeus destructor* Tucker) although blue oat mite (*Penthaleus major* Duges), true wireworms (Fam. Elatridae), false wireworms (Fam. Tenebrionidae), cutworms (*Agrotis infusa*) and slugs are also important.

The aim of our research is to evaluate various cultural control and plant resistance options to minimize the impact of pests on the establishing crop, particularly canola (*Brassica napus*). We are, for example, interested in how different rotation sequences may affect the build up in earth mite populations prior to a canola planting.

Earth mites are regarded as ubiquitous pests of most field crops including cereals although there is anecdotal evidence that *H. destructor* has a low preference for the latter. Thus, a crop rotation sequence with wheat preceding canola should reduce mite populations, possibly to below damage threshold levels, for subsequent crops. Another pest management option for mites in winter oilseeds may be the development of resistant plant varieties. In this paper, we summarize our progress in laboratory studies of the relationships between mites and crop and crucifer weed plants. We include preliminary results from feeding/choice studies of mites on oilseed, legume and cereal crop plants, studies of *H. destructor* population growth characteristics on crop and pasture plants,

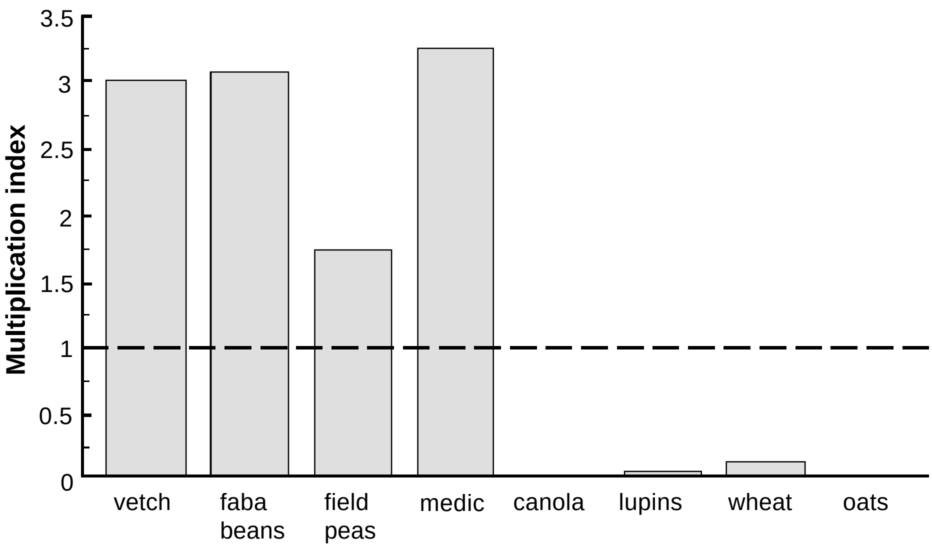

Figure 1. Net reproductive rate of *H. destructor* on various crop and pasture hosts. The dotted line indicates the net population replacement rate.

and screening experiments for *H. destructor* resistance in a variety of oilseed brassicas and weedy crucifers.

Methods

Assay methods

Single mite and small cohort experiments. A technique to study single or small numbers of mites over protracted periods was developed using 7 cm petri dishes with leaf cuts and mite(s). The dishes were lined with fine grade filter paper containing a moisture pad (a gauze-covered vial cap containing cotton wool) and were sealed with parafilm.

Whole plant experiments. Plants were grown in a sterilized potting mix in 10 cm pots. A 9 cm diameter clear plastic dome, constructed from the middle and upper section of a 1.25 L polyethylene terephthalate (PET) bottle, was firmly fitted into the rim of a pot by means of self adhesive urethanefoam tape. The dome contained four 5 cm diameter gauze vents. Each pot was watered by keeping it in an 11 cm diameter saucer (plastic food container) which was partly filled with water once weekly. The resistance screening experiments were also undertaken in PET bottles, but these had the bottom retained and the neck removed. Sterilized potting mix (10 cm) was added and the seeds were sown directly. The tops were sealed with perforated cling wrap plastic. All experiments, except the resistance screening, used mites from a culture maintained at 11 and 18°C (Ridsdill-Smith 1991) on common vetch (*Vicia sativa* cv Blanchefleur) (K. Gaull personal communication).

Experiments

Feeding preferences. Choice and no choice experiments, replicated six times, were conducted with *H. destructor* and *P. major* on common vetch, canola, lupins, wheat, medic and capeweed. The experiments were conducted in petri dishes containing a thin layer of moistened fine white sand, five young adult mites and the test leaf/leaves. In the no-choice experiment, the mites were offered a single leaf section (4–8 cm), cut from a fully developed leaf of the test plant. In the choice experiment, a leaf cut of vetch and the host plant were offered. The number of mites on or off the plant was recorded every five minutes for an hour.

Population growth characteristics on crop plants. *H. destructor* survival and reproductive rate were measured on each of seven host plants (canola, lupins, faba beans, field peas, wheat, oats, white clover). Four plants of each species were grown in ten replicate 10 cm pots until they were about 14 days old (10–15 cm high). Fifty young adult *H. destructor* were placed on each plant. After 10 days and 14 days, the number of eggs laid and the surviving mites were counted and the latter removed. After a further 28 days, the next generation of mites and their eggs were counted. The experiments were concluded after six weeks when host quality had declined.

Resistance screening experiments. Six distantly related lines of *B. napus* and seven other crucifer species were tested for mite resistance. The latter include weeds which are being evaluated as a source of disease resistance in breeding programs and which will be used in *B. napus* hybrids, if hybridization proves possible. Ten seedlings of each line/species were grown in each of ten replicate containers and maintained for one week at 25°C. Mites were collected from a local pasture and 100 *H. destructor* were added to each pot, except for five pots of var. Oscar which received 100 *P. major* each. Damage scores on the cotyledons were recorded after 2, 5 and 8 days.

Results

Feeding preferences

In the absence of a choice of hosts *H. destructor* spent significantly (P<0.001) more time feeding from vetch, medic and capeweed (>50% of total time) than on canola, lupins or wheat (<10% of total time) (Table 1). When *H. destructor* were offered vetch as a choice to any of the other hosts, significantly more time (P=0.05) was spent feeding on canola and capeweed (>20% of total time) than on lupins, wheat or medic. In both series of experiments, the mites were attracted to the lupins and wheat for less than 10% of the time. *P. major* had less distinct preferences. The mites spent significantly more time (P<0.01) on capeweed than on the other tested plants, and showed least preference for vetch. When offered vetch as a choice to each of the test plants, *P. major* spent significantly less time on lupins than on medic or capeweed (P<0.01). These experiments are being repeated using plant tissue and mites in various stages of growth, and using mites collected from different hosts and with different clonal forms of *P. major* (Weeks *et al.* 1995).

Population growth characteristics of H. destructor on crop plants

There were major differences in *H. destructor* response to the various host plants. Vetch and faba beans were relatively good hosts; juvenile and adult survival and oviposition rate were significantly higher (P<0.05) than on other hosts (Table 2). However, we observed that the rate of juvenile development was slower on faba beans than on vetch. At the conclusion of the experiment (six weeks), the second generation mites on vetch were mature and had laid large numbers of eggs; on the faba beans most mites were deutonymphs or immature adults.

Table 1. The amount of time *Halotydeus destructor* and *Penthaleus major* spent on six test plants in choice and no choice experiments.

Test plant	Average time spent (mins) (± SEM) feeding/resting on a test plant			
	when offered the test plant alone (no choice)		when offered choice of test plant and vetch	
	H. destructor	*P. major*	*H. destructor*	*P. major*
Vetch	31.2 ± 4.7	9.3 ± 2.4	na	na
Canola	5.3 ± 2.8	15.7 ± 1.8	12.0 ± 5.1	7.7 ± 3.8
Lupins	2.7 ± 1.4	24.5 ± 3.6	3.0 ± 1.6	1.0 ± 0.6
Wheat	6.7 ± 1.6	14.0 ± 2.8	0.5 ± 0.3	7.8 ± 1.6
Medic	31.7 ± 2.0	23.0 ± 2.6	2.3 ± 1.0	14.2 ± 4.0
Capeweed	37.2 ± 2.8	35.8 ± 5.1	12.7 ± 5.7	19.8 ± 2.9

na = not applicable

Table 2. Population growth characteristics for *Halotydeus destructor* maintained on various crop/pasture plants.

	Vetch	Faba beans	Field peas	Lupins	White clover	Canola	Wheat	Oats
Adult survival after 10 d (%)	56.0^{cd}	55.0^{cd}	41.0^{bc}	30.0^{ab}	63.0^{d}	23.0^{ab}	27.0^{ab}	20.0^{ab}
Adult survival after 14 d (%)	49.0^{cd}	54.0^{d}	34.0^{bc}	18.0^{ab}	48.0^{cd}	3.0^{a}	9.0^{a}	11.0^{a}
Oviposition (eggs/week)	4.6^{cd}	5.3^{d}	1.8^{ab}	0.8^{ab}	1.9^{ac}	1.6^{ab}	0.0^{a}	0.1^{a}
Juvenile survival (%)	65.0	54.0	78.0	5.0	84.0	0.0	na	0.0

na = not applicable

Numbers with the same letters across the rows are not significantly different (P<0.05).

Table 3. Average mite numbers and damage scores (±SEM) on six *Brassica napus* lines and seven crucifer weeds.

	Mites on plant	Damage score
B. napus variety		
Oscar (*H. destructor* only)[A]	34.5 ± 4.1	4.15 ± 0.16
Oscar (*P. major* only)[A]	9.0 ± 2.6	2.66 ± 0.12
Narendra (WA)[A]	26.9 ± 4.6	4.08 ± 0.12
Jet Neuf (French)	24.3 ± 5.3	2.88 ± 0.17
Bronowski (Polish)[A]	26.2 ± 5.8	3.52 ± 0.16
Chituzen (Japanese)	25.9 ± 4.8	2.07 ± 0.21
Cyclone (Danish)[A]	21.3 ± 5.1	2.84 ± 0.21
Crucifer weeds		
H. incana	3.2 ± 0.8	2.71 ± 0.14
B. juncea	26.5 ± 1.4	2.46 ± 0.18
S. arvensis	8.9 ± 2.3	0.65 ± 0.15
S. alba	31.4 ± 1.3	1.75 ± 0.11
B. tournefortii	10.2 ± 1.8	1.83 ± 0.12
B. carinata	14.5 ± 4.1	1.44 ± 0.06
E. sativa	33.0 ± 3.1	2.61 ± 0.12

Least significant difference ($P<0.01$) for mite number = 17.3, damage = 0.66.
[A] low glucosinolate levels in seed.

Relative to vetch, survival of adults and oviposition rate on field peas was significantly lower; survival of juveniles was higher while their development rates were also slower. Survival of adults and juveniles on white clover were similar to those on vetch but oviposition rate was significantly lower.

Canola, lupins, wheat and oats were all inferior hosts. Adult and juvenile survival were consistently low on these plants and there were few if any eggs laid. Of these hosts, the highest oviposition rate was on canola, and most eggs were laid on the cotyledons. However, none of the neonate larvae survived. Once the cotyledons had senesced, no further eggs were laid. No eggs were laid on wheat.

Resistance screening experiments

There was significant variation in damage scores across the varieties: var. Chitzen had a significantly lower damage rating ($P=0.01$) than all other varieties. Var. Cyclone and var. Jet Neuf had significantly less damage than Oscar, the Western Australian variety Narendra or var. Bronowski. *P. major* caused significantly less damage to var. Oscar than did *H. destructor*. There was no significant difference between *H. destructor* numbers recorded on each *B. napus* variety on day 2, although there were significantly fewer *P. major* than *H. destructor* on var. Oscar (Table 3).

Of the other weed and agronomic crucifer species, *H. incana*, *S. arvensis*, *B. tournefortii* and *B. carinata* had significantly fewer mites on their leaves than did the other species. Cotyledon damage scores also varied widely although none of the species were damaged as much as *B. napus*. *S. arvensis*, *S. alba*, *B. carinata*, and *B. tournefortii* had the lowest damage scores.

Discussion

Our results, while being preliminary, have shown the potential of two separate approaches for minimizing mite impact on canola: the use of lupins or wheat in rotation prior to canola to reduce population pressures of earth mites, and the development of mite resistance in *B. napus*.

H. destructor is not attracted to wheat and will not survive or breed on it, making this species an ideal crop to plant before canola. Despite the anecdotal evidence that *P. major* has a preference for graminaceous plants (Jeppson *et al.* 1975), including wheat, this preference was not evident in our studies. They were, however, more attracted to wheat than lupins. The disadvantage of using wheat prior to canola in crop rotations is that canola requires high soil nitrogen, so pasture or grain legumes are generally preferred. Thus, lupins may be a promising alternative in crop rotations. Unlike the other grain legumes tested, lupins were not attractive to *H. destructor* and the poor survival and fecundity of mites should result in a rapid decline in population densities in the season prior to the canola crop. Field data appear to support this (Merton *et al.* 1995). Chickpeas are a possible alternative to lupins in a crop rotation prior to canola. Thackray (1995) has observed that chickpeas are not colonized by *H. destructor*, in the presence or absence of other host species.

Farmers and advisers often question results such as the above. They cite examples of young canola crops, planted into paddocks previously cropped in wheat, lupins or chickpeas, but in which *H. destructor* infestations had turned out to be severe. There are various possible explanations for the higher than expected populations:

i. the particular crop of wheat, chickpeas or lupins contained a heavy weed infestation (as in Merton *et al.* 1995), thereby providing mites with acceptable alternative hosts for breeding;
ii. the mites were surviving and breeding on other non-vascular plants such as algae, fungi or mosses in or on the soil surface (we have preliminary evidence which suggests that at least juvenile survival is possible on non-vascular plants);
iii. these crop plants become more acceptable to the mites in the post-vegetative stages. The first two options are more probable and are being investigated further.

The initial screening of lines of *B. napus* with *H. destructor* showed extensive variability in resistance; some varieties received less than half the damage of commercial varieties such as Oscar. A further promising outcome was the demonstration that *B. napus* var. Oscar may be significantly less susceptible to *P. major* than *H. destructor*, although this work is preliminary. Considering that even susceptible cultivars of *B. napus* are poor hosts to both species of mite, it should not be difficult to develop, through selection, adequate resistance to prevent crop loss.

Alternatively, the other crucifer species tested also showed promising levels of resistance to *H. destructor*. Some of these species have been successfully hybridized with *B. napus* to introduce resistance to the disease 'blackleg'. This program may also permit the incorporation of earth mite resistance.

Future directions

Some productive areas for future research include:

i. development of *H. destructor* and *P. major* resistant cultivars by screening several thousand lines of *B. napus* germplasm held in the Australian Oilseeds Collection at Horsham,
ii. assessment of the role and tissue-specific activity of glucosinolates in the most promising of these lines, and
iii. determining the mode of inheritance of this resistance.

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Biological control of redlegged earth mite and lucerne flea by the predators *Anystis wallacei* and *Neomologus capillatus*

Phil Michael, Department of Agriculture, Baron-Hay Court, South Perth, Western Australia 6151, Australia.

Summary

***Anystis wallacei* preferred redlegged earth mite and *Neomulgus capillatus* preferred lucerne flea in the insectary. Feeding tests showed that 100 *A. wallacei* per square metre can kill 16 000 redlegged earth mites in one pest generation. Two types of field trials were conducted using a novel barrier system. The addition of both predators into ungrazed plots reduced peak pest numbers by more than two thirds, while vegetative and seed yields were more than doubled. Pest numbers were low in mown plots but peak populations of redlegged earth mite and lucerne flea were reduced by 80 and 60% respectively. *A. wallacei* was reared in field cages for two years at greater densities than naturally occurring in the field. Predators survived in much greater numbers than pests after sprays of common pesticides.**

Introduction

Control of redlegged earth mite (*Halotydeus destructor*) and lucerne flea (*Sminthurus viridis*) would increase pasture, animal and crop production but farmers have largely decided against the chemical control option. Continuously operating and compatible control strategies such as resistant varieties and biological control would be the ideal alternative to chemical control.

Wallace (1981) collected *Anystis wallacei* Otto and *Neomolgus capillatus* (Kramer), releasing them separately in a few locations in Western Australia. He had observed them as predators around the Mediterranean where they coexist in some areas. He examined the effects of each introduced predator in Australia and concluded that they are useful control agents of redlegged earth mite and lucerne flea.

It was demonstrated that colonies of these predators could be established in new areas where they would spread slowly. Evidence that the predators reduced pest numbers was also reported (Michael *et al.* 1991a).

This project was commenced with the major objective of accelerating the spread of the two predators. Further assessments on predator effectiveness were also planned and sites for this had been established. However the emphasis of this project was altered substantially following the presentation of research findings at the previous National Workshop (Michael *et al.* 1991a). The new objectives became:

i. to determine the impact of the two predators on the pests in the insectary and in the field,
ii. to assess the effect of the predators on pasture production and quality,
iii. to develop techniques for continuous small-scale predator rearing,
iv. to determine predator survival after treatment with insecticides commonly used on pasture,
v. to monitor predator survival and spread at release sites.

Methods

Insectary feeding trials

In view of the large range of possible prey types and combinations of prey for the feeding preference work, only simple testing of a few prey types was undertaken. This was performed in small tubes, allowing careful counting of the individual predators and prey as they were added and as they were recovered after the feeding period. Predators were separated and starved 24 hours prior to testing. A second method was to count redlegged earth mite and *A. wallacei* into boxes with growing pasture plants. The invertebrates were removed with a suction sampler at the end of the test. Conditions in the insectary were standardized for all the testing at 13°C and 70% humidity.

Field trials testing predator effectiveness

The two types of field trials set up to determine the effects of the predators on pest populations and pasture were complete block designs with four replications and the same treatments: chemical control, untreated and biological control.

i. The 'Addition' trial had 2 × 2 m plots which were separated so that they could be managed totally from the outside. The same plots were used over two years. Predators were collected from elsewhere and counted before adding them to the biological control treatment.
ii. The 'Elimination' trials had contiguous 10 × 10 m plots separated only by a common barrier. One of these trials was located on an area colonized by *A. wallacei* and the other was on an area