Fortuitous biological control as a sustainable provider of pest control

Summary
Population dynamics of slugs and predation by native beetles were investigated with a view to facilitating integrated control of establishment pests in southern Australian canola. Accurate monitoring remains critical in any integrated control program because no single agent or method controlled slugs. Reliable monitoring is problematic due to slugs’ aggregated distribution and the presence of four species. Predation by *Notonomus gravis* reduced *Deroceras reticulatum* populations, but not below damage thresholds established for canola of one a square metre. Control of slugs via biological control agents requires management changes including decreased tillage, reduced insecticide usage and provision of native grasslands as a refuge for beetles (beetle banks).

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Conclusions
The ability of Australian growers to adapt to a marginal production environment is highlighted by the adoption of stubble retention and the move to no-till systems. The emergence of slugs as a pest in the moisture-limited environment common in much of the wheat belt should be viewed as a bio-indicator of the effectiveness of Australian agriculture in adopting more appropriate farming practices that retain moisture. The integration of ecological understanding, improved diversity and limitation of deleterious chemical usage, assessed using a well-calibrated metric, will assist in limiting the impact of slug populations on the establishment of canola. Robust, integrated control of slugs can be achieved without compromising good agronomic practice or sustainability by utilising the forgotten providers (native invertebrates) of biological control.

A perception that the biological control component of integrated pest management (IPM) lacks robustness has contributed to growers’ reliance on chemicals to control problems, even though the idea of IPM has been around for half a century. Chemical control alone will not eliminate slugs from farming systems retaining stubble. This is due to the lack of efficacy of chemicals, often resulting from ignorance about slugs and their interaction with the environment. Herbivorous slugs pose an intractable threat to a wide range of arable crops in temperate conservation tillage systems world-wide. To achieve future food security, agriculture needs to move away from simplistic monocultures towards sustainable non-tillage management systems in which crop residues are retained. The retention of crop residues (stubble retention) increases invertebrate diversity. Increased understanding of interactions between pests, beneficials and farm practices may enable harmonisation of the productive and ecological functions of agricultural landscapes into an integrated agricultural ecology.

Recommendations
Guidelines established in this project suggest burning of stubble will reduce populations of only the surface-active slug species Deroceras reticulatum, D. panormitanum and Lehmannia nyctelia. This reduction is mainly due to the reduction in summer volunteers that provide moist surface refuges. Control needs to be targeted on the basis of results from current-season monitoring. To be effective, it needs to be informed by an understanding of seasonal and cultural factors and previous slug problems encountered. Replicated monitoring needs to be undertaken ahead of seeding with 50 monitoring points per 40 hectares of crop needed to ensure accurate data. Where slug numbers are high, the only option will be not to sow canola, especially when sowing is delayed and conditions cold. Chemical control has low efficacy at this time on slugs and so is not a reliable option.

The most effective chemical control method is spreading of molluscicidal baits on the soil surface. The number of baits is the most important factor, not the amount of product applied. Early application of baits is not recommended. Monitoring is needed so chemical control can be targeted to slug activity. Molluscicidal baits are best timed to coincide with slug activity when the crop needs protection, which in the case of canola is after sowing when the cotyledons and first true leaves appear. One well-timed bait application when slugs are active can be as effective as two ill-timed applications.

Cultural methods play an important role in effective slug control. Removal of summer volunteer plants either by herbicides or cultivation, tillage and rolling all remove slug refuges, especially in clay soils that form clods when worked up. Rolling after
sowing also improves germination by increasing soil-seed contact. The importance of quick establishment of canola to effectively outgrow establishment pests cannot be over-emphasised. Reduction of the time for which seedlings remain susceptible to slug attack decreases crop damage by reducing seedling mortality. Canola seedlings that survive slug grazing can readily compensate for the loss of nearby plants by establishing larger canopies.

Tillage is not recommended as a means of slug control due to the benefits of no tillage systems that support increased populations of predatory beetles. The effectiveness of biological control will be enhanced by growers moving towards retention of stubbles, establishment of crops without tillage and reducing reliance on pesticides to control a range of establishment pests, which will minimise adverse impacts on non-target species such as predatory beetles. Trial results to date suggest growers cannot rely only on biological slug control and still need the backup of chemical control, but less-toxic iron-based molluscicidal baits are required to gain maximum benefit from the biological component of slug integrated pest management.

No single method will provide effective slug control in southern-Australian canola crops sown in high-rainfall zones using no-tillage systems, especially on clay-dominated soil types. A fully-integrated control program needs to be developed for this environment and the above recommendations provide the basic foundations for a robust pest management strategy for slugs.

**Outcomes**

This project provides vital ecological data on exotic pest slugs that will facilitate better control efficacy with a decreased reliance on chemical control methods. The economic benefit of decreasing chemical usage was not analysed, however reduced inputs translates into reduced pest control costs to growers. The project also provided guidelines for chemical control of slugs.

The ecological benefit of reduced non-target impacts resulting from reduced use of chemicals has been well demonstrated previously.

The data provided here on beneficial invertebrates, particularly native carabids, supports previous work and contributes to development of a library of sound ecological information. Drawing on this information will facilitate development of integrated pest management strategies for application across the whole of the grains industry to a variety of pests. These concepts extend far beyond slugs in canola.

This is one of the first studies to demonstrate transferability of ecological theories developed in Europe to production systems in drier, more marginal conditions. It is also one of the first to demonstrate that maintaining diverse plant populations adjacent to crops can support populations of invertebrates capable of providing natural bio-control. The results achieved in this project suggest some Australian growers’ environmental management would be considered favourably under British stewardship schemes.

The introduction of a metric to assess the non-target impact of insecticide usage by individuals provides industry with a much-needed tool for assessing the negative effects of chemical inputs. However, this metric, based on one developed by the International Organisation for Biological Control (IOBC), needs further development.

Conservation of existing remnant grasslands appears to provide ecosystem services to growers and environmental benefits. Maintaining biodiversity benefits rural communities and is in line with government policies and Environmental Management Strategies (EMS). For example, EMS best practice program objectives include:

- vegetation and biodiversity
- indigenous vegetation cover existing and planted - how much is there?
- the natural structure of indigenous vegetation - are all layers present?
- planning and linking vegetation - size matters
- threats/impacts
- habitat protection
- wildlife

By demonstrating the impact of native predators in controlling exotic species, this project has shown the importance of
Achievements/Benefits

The primary aim of this study was to develop the biological component of an integrated approach to the control of slugs in broadacre crops of canola (Brassica napus L. ssp. Oleifera) in southern Australia. Changes towards more sustainable management practices in canola have seen an increase in slug numbers and damage. The project has highlighted the dynamic and diverse nature of apparently uniform agricultural systems and the need for holistic solutions to production threats such as slugs. Understanding the impact of neglected indigenous invertebrates on agricultural crop production has been a particular focus. The project has considered ways to optimise predator effects on slug pests and how to link predator-prey dynamics to plant hosts. This information will facilitate the adoption of sustainable farming practices, leading to more stable production and reduced threats from pests as a result of reliable and cost-effective biological control.

Can natural enemies be harnessed to benefit production through control of pests such as exotic pest slugs and how are they impacted by management practices? To tackle these questions, the emergence of exotic slugs, in particular Deroceras reticulatum (Gastropoda: Stylommatophora), as pests of canola in south-west Victoria was examined. A monitoring scheme for growers was developed and this revealed insights into slug behaviour in a relatively dry environment. Accurate monitoring of slug numbers is required by growers so they can identify when taking action to control slug pests will provide an economic benefit (economic threshold). An economic threshold was determined to enable industry to assess the cost/benefit ratio of various pest population control measures.

To examine the feasibility of fortuitous biological control, in particular the control of pests by indigenous natural enemies, the dynamic coupling of a pest, D. reticulatum, and a predator beetle, Notonomus gravis (Chaudoir) (Coleoptera: Carabidae), was tested. Effects on plants were investigated to link pest control to predator abundance. To understand the interactions between farm management and N. gravis, and hence potential impacts on slug control, the effects of pesticide usage, tillage and provision of habitat were considered.

D. reticulatum and M. gagates are an emerging problem in southern Australian cropping areas as stubble retention is increasingly adopted to improve soil moisture-holding capacity. Sampling techniques for slugs have been developed overseas but need modification for Australian conditions, where slugs have different seasonal activity patterns (Nash 2003). The number and spatial pattern of 300 mm x 300 mm terracotta paving tiles for sampling slugs was tested across arable fields each of 40 ha. Sampling proved difficult because slugs were aggregated in local areas and so distributed unevenly. This supported the utility of a systematic sampling scheme for assessing slug populations. Sampling guidelines involving use of 50 tile refuges were formulated and validated on four properties. However, growers were reluctant to use the large number of tile refuges needed for accurate population estimates. Application of the guidelines to a particularly dry year (2006) proved problematic because of a marked shift in slug species composition and the differing behavioural responses of the species present. This indicates moisture availability needs to be considered when assessing slug populations.

Low slug populations proved to be particularly difficult to monitor due to aggregation of populations and the different responses of species to limited moisture.

Differences in species biology have to be considered when devising control options for slugs, particularly as M. gagates has the highest tolerance to molluscicides. Slugs are predominantly controlled at crop establishment using molluscicidal baits formulated with metaldehyde or methiocarb, although new molluscicides with iron as the active toxin have been developed to decrease non-target effects and meet the requirements of organic agriculture. A single application of chelated iron baits at sowing provided greater control of the slug species D. reticulatum and L. nyctelia than one application before sowing. Applying baits before and at sowing did not further improve control. Canola seedling densities showed a negative response to D. reticulatum numbers; with seedling numbers reduced to below optimum densities when monitoring

N. gravis, a generalist predator, was widely distributed across western Victoria. Background knowledge of the life cycle of this species suggested that it has the potential to contribute to the biological control of slugs. Other large potential predator species, including different carabids, spiders and rove beetles, were also recorded but there is almost no information on the biology of these groups. The study focused on the pest D. reticulatum, which is well studied overseas because it is the dominant pest slug of canola in northern Europe. D. reticulatum was encountered at all sites with three other species also common: Milax gagates (Draparnaud - black keeled slug) which is also considered a pest species, D. panormitanum (Lesson and Pollonera) which may have pest potential and Lehmannia nyctelia (Bourguignat) which should not be considered a pest.
produced just one individual per refuge trap, a finding in concordance with other results. European guidelines for slug monitoring appear to be at least partly applicable to Australian conditions. Thistles and other vegetation were associated with increased numbers of surface-active slugs.

The limited efficacy of chemical control options (less than 80%) on slug populations has traditionally led growers to use the cultural control methods of cultivation and burning. With the adoption of stubble retention these cultural methods are no longer available, leading to the need to explore other control methods, especially those involving biological control agents.

Several species of Carabidae are pre-adapted to the agricultural environment and are one of the most valuable natural auxiliaries in pest control throughout arable land. The common European polyphagous predator, Pterostichus melanarius (Iliger - Coleoptera: Carabidae), has been negatively correlated with D. reticulatum population growth in long-term studies, providing an example of the impact of a 'lying in wait' pest control strategy. Native generalist predators like N. gravis can provide a vital component in the control of unwanted exotic species like D. reticulatum.

Three methods were used to couple N. gravis predation to prey D. reticulatum: field associations, laboratory feeding trials and exclusion enclosures. Effects on plant growth and establishment were also tested using enclosures. Results supported the potential of this native predator to exert an influence on D. reticulatum populations. However, while N. gravis can contribute to control of slug populations, enclosure experiments suggested slug damage was not reduced below economic thresholds, with no positive seedling response to the presence of generalist predators was observed. Unreliable control of slugs by biological agents has led growers to perceive that predators vary in their effectiveness of pest suppression. However, it seems likely that predator populations is a factor in this perceived variability and there is a need to better understand the complexities of predator-prey-climate interactions so robust guidelines for promoting beneficial predators can be developed.

The conservation and augmentation of a variety of natural enemies is a key requirement in any integrated pest management strategy. In trying to understand the impact of agricultural management practices on predatory carabid beetles, it has become clear that species interact differently with management practices. To evaluate ways of potentially promoting predator numbers, the impacts of three factors on predator communities and N. gravis numbers were considered: conserving strips of vegetation adjacent to farmland, reducing the number of deleterious chemical sprays, changing tillage practices. A simple insecticide metric, based on International Organisation for Biological Control (IOBC) toxicity ratings, was tested to assess the biological impacts of increased agro-chemical usage. Sampling carried out in February-March across 20 western Victorian properties along transects running from adjacent remnant grasslands 200 metres into arable fields revealed high numbers of the dominant carabid species. Overall there was a greater abundance of N. gravis in remnant grasslands, with a reduction in populations as the distance into the field increased. However, patterns at individual properties varied substantially. Ordination analyses were used to assess the structure of predator communities in the field and remnant areas, with population structure correlated to field chemical use and tillage. These results suggest that remnant grasslands can be a resource for natural enemies of crop pests and indicate the potential value of ecosystem service (pest control) provided by conservation of such areas. By understanding the responses of individual species and systems to changes in agronomic practices, growers can augment control of pest slugs by carabid beetles where stubble is retained and the toxicity load of chemical applications is decreased.

**Other research**

Although biological control agents can reduce slug populations, the predator-prey equilibrium identified in this project was below economic control thresholds. One method of lifting the economic threshold is to increase the ability of canola cultivars to resist or recover from pest attack. Development of new herbicide-resistant canola cultivars, either varieties genetically modified to be resistant to Roundup®/Basta® or conventional Clearfield® varieties, are expected to establish more quickly than current varieties. This will shorten the period of time for which canola seedlings are susceptible to chewing pests, thus reducing the number of seedlings lost. Lower pest susceptibility would result in higher control thresholds than the ones established in this project, thus allowing low pest populations that are more likely to be maintained by predatory invertebrates. Host resistance in canola cultivars needs further exploration before integrated pest management strategies relying primarily on the biological component for pest suppression can be adopted.

Future research needs to concentrate on the generalist predator community, not single species. Spiders particularly need to be considered in future research as they are thought to provide an important fortuitous biological control function. Spiders are another group of neglected ecosystem function agents. Development of molecular techniques can facilitate the rapid
screening of specimens for gut contents using multiplex polymerase chain reaction (PCR) to provide vital information on the diets of key species. The establishment of food webs would provide the basic ecological information needed to develop robust integrated pest management strategies.

Additional information

“Know your pest for better control”. Farming Ahead 176: 23-25; 2006


“Notonomus gravis (Chaudoir) (Coleoptera: Carabidae) predation of Deroceras reticulatum Müller (Gastropoda: Agriolimacidae): an example of fortuitous biological control”. Biological Control 47 328-334; 2008

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“Beetles benefit agriculture: how can farmers benefit beetles”. Farming Ahead 203: 50-52; 2008

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