Summary
Exotic snail and slug species cause grain growers significant losses. The objective of this project was to provide new knowledge about the distribution of these invasive pests and the efficacy of chemical control options.

Data from distribution surveys in five states have been compiled for modelling of the geographic distribution of each pest species.

Field trials have tested various bait products against snails and slugs and alternative chemicals for killing and repelling snails. These results, along with the findings of a review of the molluscicide literature, provide valuable direction for future chemical efficacy studies to optimise mollusc control in Australian grain crops.

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**Conclusions**

**Distribution surveys**

While the survey data still await modelling analysis, distribution expansions of several snail and slug pest species are evident since surveys in the 1990s.

**Baiting**

When comparing the same active ingredients, baits provide better efficacy than contact sprays.

Bait performance is variable between products, often mediocre and - for a given product - dependent on the target pest (species, age and density), field environment and conditions (influencing snail and slug activity) and baiting method (timing, bait density and evenness of distribution).

Results vary between trials - presumably reflecting the complex interplay between these dependent factors - and will require a large set of trials under a wide range of conditions to determine a bait product’s efficacy relative to other products.

It is unlikely that any one product will consistently outperform others in all situations.

There is preliminary evidence that reduced stubble levels will improve baiting efficacy.

Three factors require specific attention to optimise bait performance:

* Bait timing

New knowledge is required about timing of snail activity and reproduction and their environmental cues, and bait persistence under different seasonal conditions.

* Bait density

* Concentration of metaldehyde\(^\#\) active ingredient.

Methodologically, similar bait efficacy results were obtained using 0.2m\(^2\) arenas versus large plots, which have the advantage of allowing better control over and standardisation of treatment factors.

**Alternative chemicals**

The tested novel products (two sprayable, one granular) so far have provided poor control or have regulatory and agronomic impediments and restrictions.
Recommendations
Investigate iron as an active ingredient in smaller bran-based bait products.

Investigate 3% w/w metaldehyde in cheaper-to-manufacture bran-based baits.

Research the placement (bait density and distribution by spreaders) and timing of bait application under Australian climatic and cropping environments.

Establish the best bait application strategies against the range of species under Australian conditions, including stubble and trash effects.

Quantify the triggers for summer-autumn activity of snails to improve bait timing.

Field investigation of novel sprayable molluscicides (e.g. niclosamide) may be warranted.

Outcomes
Economic
Increased grain value because of decreasing snail and slug contamination, fewer grain rejections, less risk of losing valued markets, reduced production costs (monitoring, baiting, applying mechanical control methods and cleaning grain at harvest) and yield losses.

Improved risk assessment based on new knowledge of pest snail and slug species distributions.

Environmental
Improvements in snail and slug control reduce soil erosion and decrease the frequency of baiting and other chemical controls, which are potentially disruptive to grains integrated pest management (IPM) and have poor ecotoxicological and human health profiles.

The recommendation to bait earlier during summer-autumn will decrease the risk of metaldehyde contamination in water run-off.

Achievements/Benefits
Several exotic snail and slug species cause grain growers significant losses from direct crop damage and the cost of field control. Snails can also cause additional costs at harvest through machinery modifications and damage, grain cleaning, grain value loss, receival rejections and market access threats. The objective of this project was to provide new knowledge about the distribution of these invasive pests, the efficacy of chemical control options and direction for further research to improve efficacy of molluscicide treatments.

New pest snail and slug species distributions knowledge
There have been no comprehensive surveys undertaken in recent decades to determine the distribution of these exotic snail and slug pest species. The distribution of these pest species in southern Australia is unlikely to have reached ecological limits. In this project, field surveys following rainfall gradient transects out from known infestation areas have been conducted in five states and are continuing in Western Australia (WA) and South Australia (SA). Sample locations at 50km to 100km have been examined with some bias towards townships and vehicle resting points. So far, 384 historical presence records in WA, Victoria (Vic) and New South Wales (NSW) from 1,873 survey points, along with 889 existing survey records - WA, SA, Vic, NSW and Tas - have been databased for predictive modelling of the geographic distributions of each pest species, and to examine environmental factor correlates, such as soil type, pH, moisture index, precipitation and temperature. This information will be used to assist with market access, regional management and on-farm hygiene planning.

Molluscicide efficacy trials
A series of field trials have tested various bait products for the control of four snail and three slug species, and several
alternative chemicals for killing and/or repelling snails. These results, together with the findings of a comprehensive review of the molluscicide literature, provide valuable insights for the direction of future chemical control trial work.

Thirteen snail trials have been conducted.

* Four trials to assess the relative efficacy (knockdown, not persistence) of a range of proprietary bait products.
* One trial to assess the effect of bait density and size on efficacy.
* One trial to assess the effect of summer-autumn weathering on bait efficacy (four assessments: early summer, mid-late summer, early autumn and mid-autumn).
* One laboratory and three field trials to assess the efficacy of Perlka® for snail control.
* Four trials to assess the efficacy of low-biuret urea, (n=2) and caffeine (n=2) for snail control and repellence.

Key findings

1. Control levels with baits in the field have generally been mediocre, typically 40-60%.
2. Significant, but variable, differences in the performance of individual bait products.
3. Baiting performance is dependent on snail species, age and density, field conditions which influence snail activity and feeding behaviour, including type and quantity of alternative food, temperature, moisture and bait density. Bait size had nil or only slight effect on their efficacy.
4. Baits are highly toxic to young juveniles (e.g. 2mm long pointed and 2mm diameter round snails). Therefore, the perceived poor field control may be caused by other factors, e.g. less mobility of the juveniles, resulting in less frequent bait encounters.
5. The bait study will require large data sets, with trials run under a range of conditions to make sound product recommendations.
6. Bait timing: The development of improved timing strategies will require new knowledge on the timing of snail activity and reproduction, and the environmental cues that trigger them; bait persistence under different seasonal conditions, including summer UV and rainfall.
7. Alternative molluscicide treatments: In a 2012 field trial, 250kg/ha Perlka® (calcium cyanamide)# did not reduce snail densities. However, in a small laboratory trial, no snail eggs hatched in the Perlka®-treated arenas. Low-biuret urea treatments at high rates (10% and 20%) neither killed nor repelled snails in a wheat crop or windrowed canola. High rates of caffeine (5% and 10%) were ineffective in removing snails on a dense mass of windrowed canola, but did repel snails on desiccated peas. The results, however, were variable and often transient.

Three slug chemical efficacy trials have been conducted. These trials (two field plot design, one cage design), which included up to seven bait products, Perlka® and three spray treatments - including caffeine - were conducted on adult and juvenile populations of grey field slug, black keeled slug and brown field slug (slug species are considered most damaging to establishing crops). Significant interactions between species, life stage and treatment were detected using cages, but methodologies need improvement. Field results were inconsistent because of moisture interacting with treatment. Spray application of molluscicides did not reduce population densities in these trials. This is concordant with literature and trials conducted in 2011.

Chemical control options report

A review of the scientific literature regarding control of snails and slugs was undertaken to determine factors influencing molluscicide efficacy and to help guide future research.

The overall efficacy calculated from reviewed data was unimpressive with an overall reduction in abundance of only approx. 50%. This is similar to the level of control recorded in the 2012 bait trials.

There were no new active ingredients identified in the review that the authors claimed to be significantly more efficacious than established molluscicides. When comparing the same active ingredients, baits provide better efficacy than contact sprays, but further field investigation of novel sprayable molluscicides, e.g. niclosamide#, may be warranted.

The efficacy of iron-based baits was equal to methiocarb# and superior to metaldehyde#, which contradicts previous assessments. Investigation of iron as an active ingredient in smaller bran-based bait products is recommended.

Metaldehyde was generally more effective killing adults, compared with juveniles, and length of efficacy is generally approx. two weeks. The use of 1.5% w/w metaldehyde is less effective than using 3-5% w/w baits. Investigation of 3% w/w
metaldehyde in cheaper-to-manufacture bran-based baits, especially under drier Australian conditions, is recommended.

Molluscicidal seed treatments tested with a range of active ingredients (e.g. 3,5-dimethoxycinnamic acid, cinnamamide#, methiocarb) provided inconsistent snail or slug control.

The placement and timing of bait applications has received substantial research attention in Europe, but requires more research for Australian climatic and cropping environments.

**Slug recommendation:** Broadcast applications at sowing provide most effective control of surface active slug species, such as *Dendrodoris reticulatum*. If baits for slug control are drilled (e.g. in dry conditions with black keeled slugs the dominant species), treatments need to be reapplied (broadcast) when conditions are moist at crop emergence after sowing.

**Snail recommendation:** The environmental triggers for snail activity must be quantified to improve snail bait timing, particularly pre-season.

For slugs and snails, understanding the best bait application strategies against the range of species specific to Australian conditions, including stubble and trash effects, is needed.

In summary, this project has provided the industry with new knowledge about the efficacy of different chemical control options for snails and slugs, and a better understanding of their existing and potential distribution across southern Australia. This knowledge helps the Australian grains industry to more cost effectively manage snails and slugs and assist growers and industry with market access. It also helps researchers with future management studies of these exotic mollusc pests.

**Other research**

**Bait spreaders**

The research team identified bait density as a key determinant of snail and slug bait efficacy, and presented results highlighting this at the GRDC Adviser and Grower Updates in February, 2013. This encouraged Ashley Wakefield, from Yorke Peninsula Alkaline Soils Group (YPASC) to successfully apply for a GRDC Regional Fast Track Project, ‘Improving snail bait distribution’, to examine bait spreader performance. With assistance from Russell Nichol, from the Australian Food Sovereignty Alliance (AFSA) and Chris Saunders, of University of South Australia (UniSA), the YPASC-SARDI team has quantified the distribution of baits (bait number per unit area), optimal bout width and bait losses through bait disintegration using four common spreader types and four bait products.

The flow rate and bout width distribution of all tested baits significantly differed compared to fertiliser granules. The bout width generally needed to be reduced by between 10% and 30%, depending on spreader and bait combination, to provide an acceptable bait distribution, and each spreader required specific calibration to provide the required kg/rate/bait/ha.

To varying degrees, the tested baits were broken into smaller fragments by the spreaders. There were differences between the tested spreaders in the degree of bait fragmentation caused, however what level of bait disintegration is a benefit - increased bait number/unit area - versus a cost (fragments too small to be effective and accelerated decomposition) requires further study.

**Remote snail monitoring**

Michael Richards, from YPASC, Northern and Yorke Natural Resources Management (NY NRM) and Ag Excellence Alliance, has assembled the camera hardware for remote, automated, flash photography of the ground movement of snails. A sequence of photographs, at 10 to 30-minute intervals, provides photographs of a 4m² ground area with sufficient resolution for computer-assisted analysis (Dr Sharolyn Anderson, UniSA Geospatial Analyst) of the diurnal patterns of snail movement. Located alongside weather stations, this system provides a valuable tool for studying the timing and amount of snail movement - and potentially reproductive behaviour - and the associated environmental conditions, including temperature, relative humidity (RH) and soil moisture. The SARDI research team is collaborating with Mr Richards and Dr Anderson to investigate the timing of these snail behaviours, and to investigate whether snails are attracted to baits and, if so, over what distances.
Additional information


GRDC Adviser Updates 2013: 'Slug monitoring and management in modern farming systems'.

GRDC Adviser/Grower Updates 2013: 'Snail chemical control trials and distribution surveys'.


The molluscicide literature review will be submitted to 'Crop Protection' for peer-reviewed publication.