Snail management - learnings from recent studies

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Key messages

- **Baiting efficacy requires adequate pellet densities (30-60 m^2).**
- **To minimise bait degradation, avoid baiting in significant rainfall or high temperatures and consider bait storage temperatures.**
- **Sound, evidence-based science is reinforcing the best practice management: baiting efficacy is higher earlier in the season than in spring.**
- **A better predictive ability around the optimal conditions for baiting in 2020 is expected to be gained when extensive analysis of snail video footage and microclimate data is completed.**
- **Baiting is a crucial snail management tool but often does not achieve high order control. Consequently, implementation and development of other integrated strategies remains important.**

Background

Four introduced snail species of European-Mediterranean origin remain a significant challenge for grain growers; the vineyard or common white snail, *Cernuella virgata*, the conical snail, *Cochlicella acuta*, the small pointed snail *Cochlicella barbara*, and the white Italian snail, *Theba pisana*. These species are advantaged by modern low-disturbance farming systems and pose an increasing market access threat. Over the past six years, GRDC investments (DAS00134 and DAS00160; led by SARDI) have aimed to improve snail management with a focus on molluscicidal baiting (products, rates, timing), evaluation of novel molluscicides and improving the parasitism success of the introduced parasitoid fly, *Sarcophaga villineaveana*, against the conical snail (CSE00061, CSIRO/SARDI). This work has provided guidelines to improve snail control using baits. However, further development of integrated controls is still required and is becoming more feasible with new technologies. Provided in this article is a brief overview of key learnings on snail management from recent projects and new directions for snail research and development.

Baits - products and rates

Australian grain growers are heavily reliant on a single molluscicidal active ingredient, metaldehyde, for snail control. This molluscicidal is marketed under various product formulations with different pellet characteristics (for example bran or flour-based pellets) and concentrations of active ingredient (ranging from 1.5 to 5% a.i. metaldehyde). Iron chelate (iron EDTA complex) has an alternative mode of action and is less common in baiting programs which is possibly due to its higher cost.

Baits are not considered attractive to snails, and therefore, efficacy relies on snail movement activity and sufficient pellet densities to ensure active snails encounter pellets and consume a lethal dose. During 2014 and 2015, SARDI conducted field arena trials investigating bait efficacy for two metaldehyde products (Metarex® and Meta®) and one iron-chelate product (Eradicate®) for different snail species at a range of snail densities. Snails were placed in the field within 0.2 m^2 bare earth arenas at one of five densities (40, 80, 160, 320, 640 snails/m^2) and exposed to one of five treatments (nil and 4 different pellet densities).

These trials found:

- At least 30 pellets per m^2 were required for optimal baiting efficacy. In areas of higher snail densities, up to 60 pellets per m^2 may be required to avoid complete consumption of pellets and maintain adequate rates of encounter.
- Across all trials, using more than 0.5 pellets per live snail per unit area did not greatly increase efficacy (Figure1); however, snail mortality often varied substantially between individual trials.
- Registered rates of some products gave fewer than 30 pellets per m^2 (Table 1), suggesting that repeat applications may be necessary in some instances.

- Trials conducted by SARDI and the Yorke Peninsula Alklaline Soils Group (YPASG) showed that bait spread was often uneven. It is important for bait spreaders to be calibrated for the selected bait product, then checked to ensure spread is occurring as expected (check for under-dosed strips and bait shattering).
- The SARDI snail and slug baiting guidelines assist growers with baiting decisions (see 'Useful Resources' section of this paper).
- Baits often do not achieve high order control; other integrated control methods are required.

Baits - timing

Pellets are considered a superior bait form compared with sprays for molluscs; they have the advantage of persisting in the field during periods of inactivity. One drawback is that successful baiting requires an element of prediction; baits must be applied just before prolonged periods of snail activity (driven by weather conditions) to ensure pellet encounter. Additionally, baiting aims to control populations by knocking out mature snails before significant reproduction has occurred.

Since 2017, a GRDC project (DAS00160) led by SARDI together with DPIRD, has investigated the seasonal activity patterns of snails with respect to weather, in order to improve prediction of optimal bait timing. Eight field sites were established across Western Australia (WA) and South Australia (SA). Approximately 45 snails were collected at monthly intervals and dissected to determine their reproductive status. Time lapse video was used to monitor snail movement continuously together with logging of climate variables.

The work has found:

- Snails show a highly seasonal reproductive cycle. Enlarged 'albumen' glands indicate that snails are (or are about to become) reproductively active.
- For common white snails in SA, reproduction generally occurred from April to mid-spring (Figure 2). Increasing proportions of snails 'shut down' breeding between August to October depending on the finish to the season.
- The timing of the onset of reproduction can vary greatly from year to year, driven largely by rainfall (for example; common white snails at Gairdner WA, Figure 3).
- Currently, climatic triggers for reproduction and snail movement are being investigated through statistical analysis (March 2020 completion).
- Interestingly, laboratory trials at SARDI show that baiting efficacy also follows a seasonal cycle. Snails collected in SA from Urania (1.5 years collection period) and Palmer (3.5 years collection period) and exposed to Metarex® in bioassays were killed more efficiently during periods coinciding with snail reproduction (approximately April to August; see Figure 4) compared with other times (for example, spring).
- Together, the results reinforce the need to concentrate baiting efforts in autumn prior to reproduction and when the baits kill the snails most efficiently.

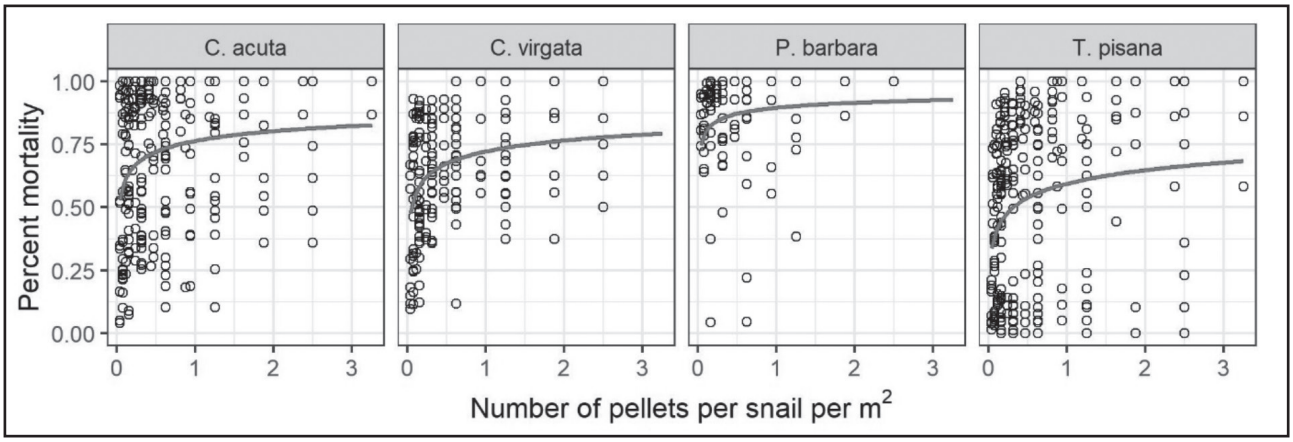

Figure 1. Mortality response versus density of pellets per snail per m² for four snail species (Cochlicella acuta, Cernuella virgata, Prietocella barbara and Theba pisana). Plots show pooled data for nine field cage trials with three different bait products. Circles represent mean mortality per cage; lines represent a crude model fit as an indicative guide.

Table 1. Pellet densities for registered rates of different bait products in Australian broad-acre grain production.

Product	Registered rate (kg/ha)	Pellets per m²
Meta (15 g/kg metaldehyde)	7.5	25
Metarex (50 g/kg metaldehyde)	5	35
Eradicate (60 g/kg Iron EDTA complex)	10	25

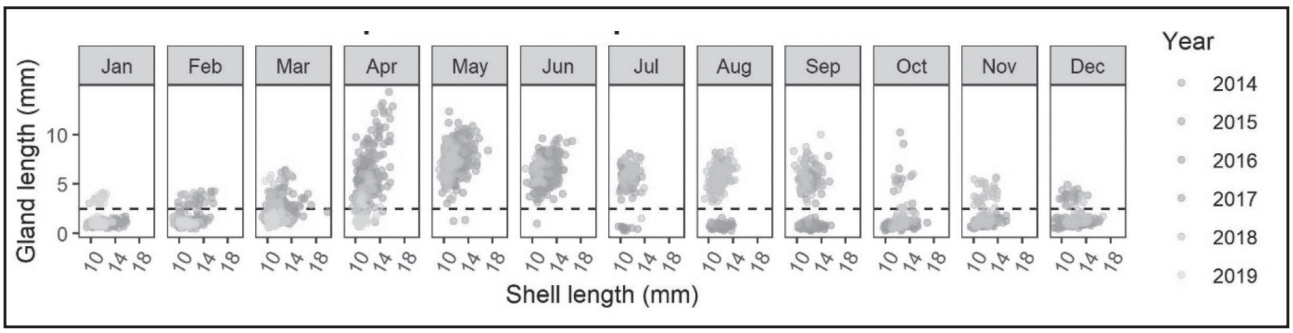

Figure 2. The seasonal reproductive cycle of common white snails at Palmer SA, shown by changes in the size of albumen glands over time. Each point represents one snail.

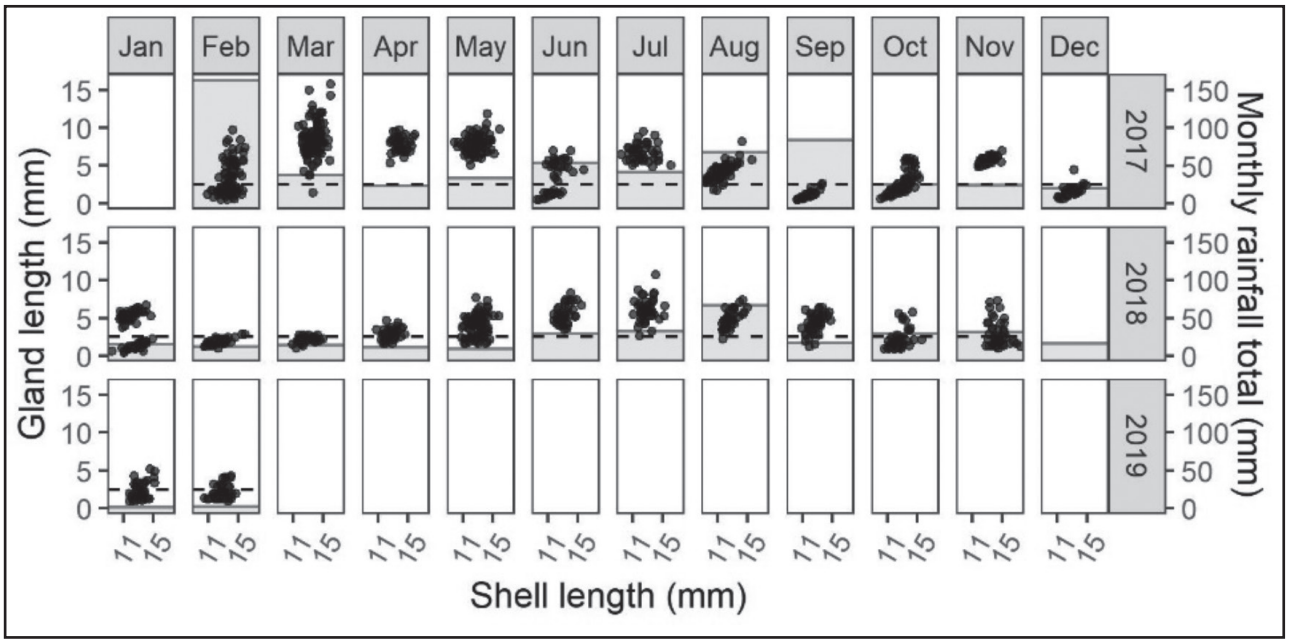

Figure 3. The seasonal reproductive cycle of common white snails at Gairdner WA together with total monthly rainfall (shading). Note that gland enlargement commenced in February of 2017 coinciding with high summer rainfall, compared to May of 2018 coinciding with a dry start.

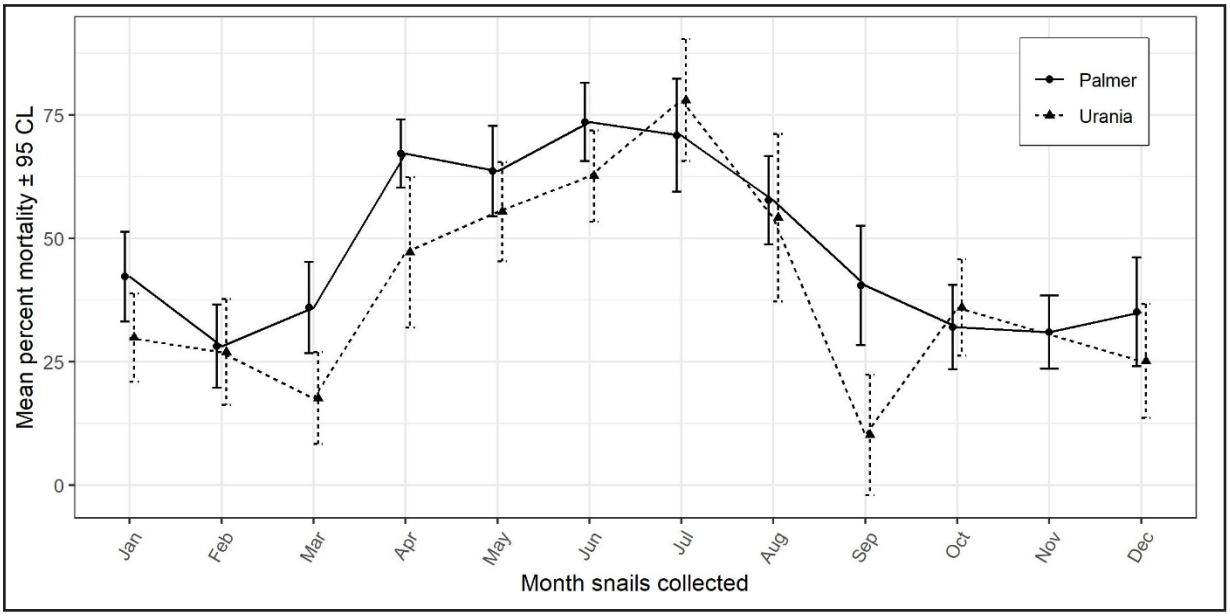

Figure 4. Mortality of common white snails exposed to Metarex baits in laboratory trials, for snails collected in each month of the year. Results from samples taken at Palmer include combined data for 2016-2019; Urania includes combined data for 2018-2019.

Baits - degradation

In recent years there has been more interest in baiting opportunistically during late summer following rain events. To investigate the possible effects 'baiting opportunistically' has on bait persistence, laboratory assays were conducted to test efficacy of baits exposed to ultra violet light (UV), high temperatures and rainfall. In each trial, eight pre-exposed baits were placed into arenas with five white Italian snails for three days and snail mortality recorded after eight days.

These trials found:

- There was no evidence that UV exposure degrades baits.
- High rainfall (35 mm) on iron chelate products reduced bait efficacy.
- Meta and Metarex baits stored at high temperatures for seven days had reduced snail mortality following use.
- Third party laboratory analysis of the heat-treated Meta and Metarex pellets revealed a significant reduction in active ingredient following the heat treatments (20°C (stored) to 60°C). The concentration of metaldehyde in Meta baits declined at an approximately linear rate of 1 g/kg lost for every 10°C above 20°C during the seven days of storage. Metaldehyde in Metarex baits degraded at a faster rate of approximately 4 g/kg lost for every 10°C above 20°C during the seven days of storage.
- Baits should be stored in cool conditions and consideration given to the forecast weather for the period following bait application.

Novel molluscicides

Between 2015 and 2016, numerous potential molluscicides have been evaluated on snails in the field and laboratory. Tested products have included: copper oxychloride, copper oxide (Cu_2O), copper sulphate ($CuSO_4$), iron sulphate ($FeSO_4$), paraquat, diquat, omethoate, thiodicarb, caffeine, UAN, Perlka®, methomyl, carbendazim and *Bacillus subtilus*. Unfortunately, these products all gave nil or low or highly variable (carbendazim) effects on snail mortality. Usage of the fungicide carbendazim, against snails has increased in recent years, but growers must strictly adhere to registered crop situations to avoid chemical residue violations and market access risks. The above-mentioned products are only to be used in accordance with the label Directions For Use including the crop, rate and all withholding periods being followed.

In the hope of discovering a new control tool, any suggestions or observations regarding other novel molluscides are welcome.

Biological control of the conical snail

A parasitoid fly, *Sarcophaga villeneuveana*, was imported from Europe, reared at SARDI and released in SA during 2001-2004 at 21 sites (19 on Yorke Peninsula and two sites on the Limestone Coast) to control the conical snail, *C. acuta* (Leyson *et al*. 2003; Hopkins 2005; Coupland & Baker 2007). The fly has established on Yorke Peninsula, but has only dispersed approximately 20 km from its original release sites on the southern 'foot', and it displays low parasitism rates (0-25%) (Muirhead, Brodie, Baker and Perry, unpublished). Under a current GRDC investment (CSE00061, CSIRO, SARDI), a geographic strain of the fly that is better matched genetically and climatically to *C. acuta* in Australia, was imported in early 2020 for host specificity testing which will be followed by a rear-and-release program in snail-affected regions.

Synthesis and directions

Baiting programs can be optimised by achieving adequate pellet densities (30 to 60 m^2), monitoring the effectiveness of spreader settings and taking care to minimise bait degradation before snails encounter them by avoiding high temperatures or significant rainfall. The science is providing a sound, evidence base which is reinforcing best practice management (for example, baiting causes higher mortality earlier in the season, and therefore, avoid spring baiting). It is expected that a better predictive ability around the optimal conditions for baiting will be gained on the completion of DAS00160 (March 2020). Baiting is a crucial management tool, but it often does not achieve high order control Therefore, continuing to implement and develop other integrated strategies remains important.

Future risks for the industry include the tightening of delivery standards for snail/grain contamination for export markets and the heavy reliance on a single molluscicide active ingredient (regulatory risks and potential for resistance to evolve). Behind the scenes, researchers, growers and funding bodies around Australia are working together to identify and integrate new technologies that can provide transformational change for snail control in modern farming systems (Perry 2018, Perry *et al*. 2019). In the foreseeable future, new systems approaches involving biological, sensing and mechanical solutions are likely to be required to meet the challenges posed by snails.

Acknowledgements

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We also acknowledge the contribution of Michael Richards (formerly NYNRM) who initiated the use of time-lapse cameras to spy on snails and assisted with the establishment our own monitoring sites.

GRDC project codes: DAS00134, DAS00160, CSE00061, DAS300, DAS00174, YPA0002.

Useful resources

SARDI snail and slug baiting guidelines http://www.pir.sa.gov.au/__data/assets/pdf_file/0004/286735/Snail_and_slug_baiting_guidelines.pdf

https://grdc.com.au/__data/assets/pdf_file/0024/117249/grdc-fs-snailbait-south_lr-pdf.pdf.pdf

https://grdc.com.au/__data/assets/pdf_file/0016/109060/snail-management-fact-sheet.pdf.pdf

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