Section 6 – Harvest and post-harvest control

Overview

Effective snail management in summer, autumn and winter will minimise, but not eliminate, snails present at crop maturity. At harvest, snails resting above cutting height in the plant canopy can enter the harvester, clogging machinery and contaminating grain. Harvest and post-harvest controls involve:

1. Minimising intake of snails into the harvester;

2. Maximising separation of snails and grain within the harvester; and

3. Cleaning infested grain after harvest.

The optimal mix of harvest and post-harvest controls is best determined on individual farms, considering the snails present and the costs and benefits of different cleaning options (Table 6.1). To avoid value downgrades or rejection, all grain must be delivered according to quality standards for snail presence set by Grain Trade Australia and local grain handlers[1].

Snail contamination risk

At harvest, snails resting in the upper crop canopy above the target cutting height can contaminate grain (Figure 6.1). The risk of snail contamination at harvest is difficult to assess as it depends on snail densities, their shape (round or conical) and size relative to grain being harvested, and their location in the crop canopy (Box 6.1). Snails similar in size and shape to grain are most difficult to separate.

Seasonal weather affects the growth rates of snails and their movement into plant canopies. Wetter conditions in autumn and spring can lead to higher populations of juvenile snails in spring[2,3]. Round snails can be crushed by adjusting thresher settings in cereal grains, but are more likely to reach the sample intact in pulse grains. Conical snails are more likely to reach the sample intact in all grains.

Figure 6.1: Snails in a mature pea crop canopy.

Image: Kym Perry

BOX 6.1: SNAIL BEHAVIOUR AND CONTAMINATION RISK AT HARVEST

- More snails rest in the upper crop canopy as harvest progresses. They climb plants seeking resting sites in response to warm and dry weather.
- Smaller snails often remain on the ground later into harvest than larger snails.
- Early in the harvest season, snails often respond to light rain (<2mm) by descending to the ground for a short period. Snails become less responsive to rain as harvest progresses.
- Later in the harvest season, snails become more difficult to dislodge from crop plants.
- Conical snails are often found in sheltered locations on plants (for example, between leaf and stem) or grain heads and are less readily dislodged by harvest operations than round snails.

Minimising snail intake

Early harvest

Early in the harvest season, fewer snails are present in the crop canopy, and they are more easily dislodged with less grain shattering. Early harvesting after light rainfall (<2mm), when snails have descended plants, can reduce snail intake without excessive grain moisture absorption. However, timing the harvest to avoid snails while harvesting at the correct grain moisture content can be difficult.

Table 6.1: Key actions.

Actions	Considerations
Spring (3 to 4 weeks pre-harvest)	
Monitor (Section 3) snail densities to plan harvest tactics and set up the header	• Consider snail densities, shape (round or conical) and size, in relation to grain type • Identify problem areas for early harvest or separate harvest and storage • Set up sieves and screens to maximise snail/grain separation within the harvester
Spring and summer (harvest)	
Consider windrowing or direct-heading	• Windrowing or direct-heading can dislodge round snails and reduce snail intake if harvested before snails invade windrows • Windrowing pulse and canola crops, cut green, may increase snail intake; green windrows are attractive refuges for snails • Direct-heading canola can reduce the intake of conical snails, which often shelter at the plant base
Consider early harvest	• Early harvest can reduce snail intake and dislodge snails with less grain shattering • Harvesting early after light rain (<2mm), when snails move down canopies, can reduce snail intake; ensure correct grain moisture content
Consider cutting height	• Stripper front harvesters can reduce snail intake by 50%; most suitable for even crop canopies on level terrain • Raising cutting height with open-front machines can reduce snail intake • However, more standing straw may require a second pass to cut stubble lower
Harvest and store grain from heavily infested areas separately from clean grain	• Areas of higher snail densities may include fencelines or calcareous outcrops • Avoid contaminating clean grain
Maintain farm hygiene	• Avoid parking in snail-infested areas; snails dislodged in summer readily climb vehicles • Thoroughly clean vehicles and machinery before moving • Restrict property access and erect farm biosecurity signage at all entries • Ensure contractors follow hygiene protocols
Summer (post-harvest)	
Clean infested grain after harvest	• A combination of snail crushing rollers and screen cleaners is usually required to meet delivery standards for snail presence • Estimate costs and benefits of different cleaning solutions • Storing grain for several weeks before cleaning can desiccate snails and increase cleaning throughput

Windrowing or direct-heading

Windrowing (swathing) cereal crops can reduce the number of round snails eventually entering the harvester. Windrowing may dislodge 55 to 75 per cent of round snails[4]. Windrowing cereals early and in cool conditions dislodges more snails[4]. In pulse and canola crops that are cut green and left to dry, snails may move into windrows, resulting in more snails entering the harvester. Leaving windrows for any length of time, or moisture events, can cause more snails to invade windrows. Snails can be dislodged from faba bean windrows immediately in front of the harvester by gently brushing the windrow with a length of iron or flat conveyor belt, which is attached to an extension arm carried by a separate vehicle.

As a last resort in heavily infested areas, crops can be harvested directly behind the windrower to dislodge snails and reduce snail intake, but this dual operation incurs higher costs. When harvesting windrows with open fronts fitted with crop lifters, fitting PVC pipe covers over the cutter bar can mask the unused width of the front. This improves feeding uniformity of material into the machine and minimises intake of snails attached to stubble. Open-raking pick-up designs can reduce snail intake by 50 per cent compared to belt-type pick-ups[4]. In canola, direct-heading can reduce the intake of conical snails, as they often aggregate around the base of plant stems[5].

High cutting height

Using rotary stripper-front harvesters, which mostly harvest the grain heads, is one of the most effective methods of reducing snail intake. Stripper fronts can reduce snail numbers reaching the grain sample by 50 per cent relative to open fronts in wheat crops, and increase harvest capacity by 25 per cent or more[4]. Stripper fronts are most suitable in thick standing cereal crops of even height on even terrain. Drawbacks include higher cost and reduced versatility.

A cheaper, but less effective, method is to raise the cutting height of open fronts to reduce bulk crop intake. Conversely, in crops heavily infested with snails, more straw intake can absorb moisture from crushed snails and facilitate ejection over the chaffer.

Both systems result in more standing straw, which provides snail resting sites and may affect sowing operations. Straw can be cut lower (Section 5) using a second pass with the harvester, or a slasher, to manage stubble and kill some snails.

Dislodger bars

Snail dislodger bars can be used to dislodge snails in front of the harvester. This practice is now uncommon as the benefits of snail removal are often outweighed by high grain losses. However, dislodger bars may be useful as a last resort or for perimeter rounds in areas of high snail density. Dislodger bars are most suited to cereal crops harvested early. A dislodger bar is attached to the windrower, or approximately 2m in front of the cutter bar on the harvester. Rigid steel or lighter flexible PVC can be used. Bar designs and settings are described in the *Bash'Em, Burn'Em, Bait'Em* booklet[4] (pages 27 to 30).

Maximising snail/grain separation

Threshing intensity

Increasing threshing intensity can be used to crush larger round snails. Crushed snails can be removed using air separation. Combining higher threshing intensity with a higher intake of straw can help to minimise recycling as crushed snails attached to straw are ejected as rear losses. These techniques can cause clogging of the grain transfer and sieve components, or physical damage to the grain.

Set-up of sieves and screens

When there is a significant difference in the size of snails and grains, the set-up of sieves within the harvester can be adjusted to maximise snail/grain separation.

Many harvesters are fitted with adjustable louvre sieves in the chaffer (upper sieve) and shoe (lower sieve). These rely primarily on air separation and are most suitable for larger grains, such as faba beans. For smaller and medium grains, replacing louvre sieves with fixed aperture sieves can improve separation. Fixed aperture sieves rely more on physical screening and less on air separation. The set-up of sieve and screens (type and size) can be optimised for the snails and grain being harvested to maximise removal while minimising losses. Recommended settings and specifications are detailed in the *Bash'Em, Burn'Em, Bait'Em* booklet[4] (pages 31 to 34).

Replacing sieves and screens is becoming less common with increased automation and throughput of modern harvesters. Manufacturers can often recommend optimal harvester settings for different conditions. Some growers use blanking plates or shut off concaves to increase grain threshing and snail crushing, although this can reduce throughput and increase screenings[5].

Post-harvest cleaning

Infested grain may require cleaning to meet delivery standards for snail presence[1]. Post-harvest separation relies on differences in the physical properties of snails and grain, such as size, shape, mechanical strength, bulk density and terminal velocity.

Cleaning methods include snail-crushing rollers, screen cleaners, air separation and gravity separation. All methods are a compromise between snail removal and grain losses. A combination of cleaning methods is usually required to clean grain to delivery standards without excessive grain losses (Figure 6.2).

The optimal combination of cleaning systems is best determined on individual farms. Variables to consider include the numbers, types and size of snails present in harvested grain samples, and the costs and benefits of different cleaning options.

Snail-crushing rollers

Rolling grain is an effective method for cleaning round and conical snails from all hard grains (cereal and pulses) without excessive grain damage[4,6–9]. Cereal and pulse grains have a high mechanical strength compared to snails. Canola seed can be rolled but its lower mechanical strength can result in high seed damage unless the operation is managed carefully.

Snail-crushing rollers consist of opposing parallel rollers constructed from materials varying in hardness (steel, polyurethane or rubber compounds), rotating in the opposite direction, and set to a narrow clearance (less than 1mm, to several millimetres) to crush snails while minimising grain damage as the mixture passes through. Commercial snail-crushing rollers have the capacity to clean 25 to 75 tonnes per hour.

Cleaning performance depends on several variables including the gap between rollers, roller hardness, grain size, grain moisture content, roller speed, and the flow rate of grain into rollers. The size, shape and shell strength of snails present also affects crushing. Performance is maximised by a uniform gap between rollers and by keeping the hopper full to maintain a uniform feed rate of grain into rollers.

Setting up a roller for best performance requires continual monitoring of the rolling operation (Figure 6.3) and fine-tuning the settings as needed to maximise snail crushing, minimise grain losses and maximise throughput. Performance is checked by

Figure 6.2: a) Rotary cleaner, b) snail-crushing roller and c) auger fitted with lower screens to remove small snails and fragments.

a) b) c)

Images: Kym Perry

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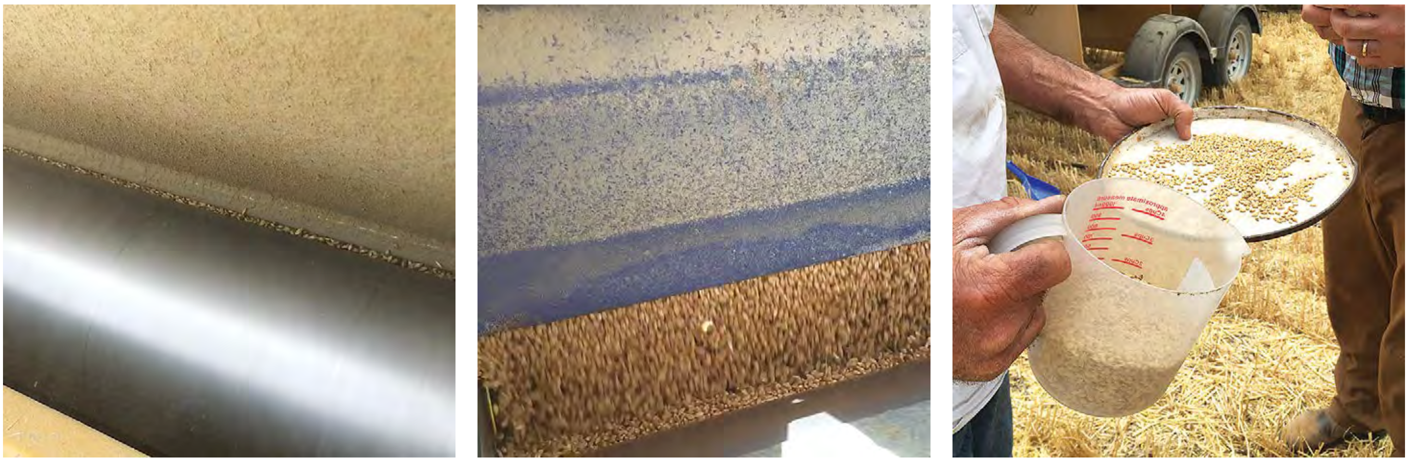
Figure 6.3: a) and b) Snail rollers and c) monitoring the rolling operation.

a) b) c)



Images: Kym Perry

monitoring the rolled grain sample. If there are too many snails, tighten the roller clearance gap, or increase the flow of grain into rollers, or use harder rollers. If there is excessive grain damage, increase the roller clearance gap, reduce flow rate of grain or use softer rollers. Faster roller speeds do not necessarily crush more snails and may cause overheating. Roller temperatures should be maintained at about 50°C and not exceed 65°C[6] to avoid damage to rollers.

Efficient cleaning using rollers depends on the set-up and grain moisture content. Example roller setups are provided as a starting point (Table 6.2). To minimise grain damage and losses, grain should be rolled at the optimum moisture content of 13 to 16 per cent. Canola is rolled at lower speeds than harder grains by reducing the feed rate of grain into the rollers and reducing roller speeds. Typical rolling speeds are about 550 revolutions per minute (rpm) for cereals and 400rpm for canola[5], but should be adjusted as needed.

Optimal roller settings should crush most snails with approximately two per cent grain loss in cereals and pulses[4]. In canola, up to 43 to 91 per cent of small conical snails can be removed with up to nine per cent losses[7]. Storing grain for several weeks before rolling can desiccate snails, making their shells brittle and easier to crush and increasing cleaning throughput[5]. Rolling fresh grain during harvest is also successful[5].

To meet delivery standards, a screen cleaner is often required either side of the rolling operation to pre-scalp larger snails and post-screen smaller snails and snail fragments. Augers fitted with lower screens help remove small snails and fragments (Figure 6.2). If snail numbers are high, grain can be rolled twice, but this incurs higher costs.

Screen cleaning

Screening and scalping rely on a size difference between snails and grain. Screening removes snails smaller than grain, whereas scalping removes snails larger than grain.

Table 6.2: Example roller set-up and grain moisture content from trial work[4].

Grain type	Grain moisture content	Roller clearance gap	Roller hardness
Cereals	12–14%	Less than 1mm	Hard
Peas	14–15%	1 to 2.5mm	Soft
Lentils	12–14%	1mm	Soft
Faba beans	14–15%	Less than half seed width	Soft

Separation to delivery standards using screen cleaning alone results in unacceptably high grain losses[4,10]. Rotary screen cleaners (Figure 6.2) are often used in combination with snail-crushing rollers and air separation (aspiration). Using finer sieves to remove more snails incurs higher grain losses.

In cereal and lentil grains, screening can remove up to 50 per cent of snails with five to six per grain losses (Table 6.3). For lentils, an aspirator is recommended to remove crushed shells and pods before entering a screen cleaner. In canola, rotary screen cleaners can remove up to 95 per cent of small conical snails with 5.5 per cent grain losses[6]. The size of canola seed can vary substantially and should determine the optimal screen size[5].

Air separation

Air separation (aspiration) is useful for pre-cleaning dust and light material from a sample, and for removing dried snail and shell fragments from grain after using a snail-crushing roller. Aspiration is often incorporated into rotary grain cleaners. Air separation results in high grain losses in barley, canola and lentils, which all have similar terminal velocities to round and conical snails[10]. Air separation is more effective in removing snails from larger grains, such as peas and beans[8].

Figure 6.4: Snails hitchhike on a) harvesters and b) other vehicles in summer.

a)

b)

Images: Kym Perry

Table 6.3: Typical results for screen tests to remove snails from grain[4,5,6]

Grain type	Screen size and type	Grain loss	Snail removal
Barley, wheat	25mm x 2.6mm slot	5%	50%
Peas	5.15mm diameter round	2%	10%
Lentils	25mm x 2.65mm slot	6%	48%
Canola	2.2mm diameter round	5%	12%
Canola*	2.5mm slotted sieve	less than 1%	19% small pointed snails
Canola*	2.2mm slotted sieve	6%	95% small pointed snails

* Average seed size 1.85mm

Gravity separation

Gravity or density separation can separate snails from grain. There is a significant difference between the bulk density of round (3 to 12mm) and conical (2 to 8mm) snails, and canola, barley, peas and lentils[10]. As snails dry out, they become lighter and differences in bulk density between snails and grain increases. However, conical snails in harvested grain can take some months to die. After complete drying, loss of body mass is approximately 66 per cent for round snails (3 to 12mm) and 57 per cent for small pointed snails (2 to 8mm)[11].

Economic costs and benefits of grain cleaning

If snail presence will result in a price discount at delivery, growers can either accept the discount or clean the grain. The costs and benefits of different methods for cleaning small conical snails from barley and canola can be estimated using the Grain Cleaning Calculator For Small Conical Snails. This tool is based on an economic analysis from grain cleaning trials in Western Australia[6,9] and considers the grain price discount, capital costs of equipment, machinery depreciation, labour and fuel costs, changes to grain/seed quality, estimated grain/seed losses, and changing costs according to grain volumes cleaned. Estimated cleaning costs per tonne of grain cleaned with screen and snail-crushing rollers are available in GRDC *Managing Small Conical Snails Fact Sheet* (GRDC 2021).

Farm biosecurity and hygiene to prevent snail spread

Pest snails are highly invasive. New infestations start small and spread rapidly through hitchhiking[5]. Snails are readily transported on vehicles, infested hay or fodder, or by contractors. In summer, especially, snails that are dislodged will immediately climb onto nearby substrates, which may include machines, silos, augers, field bins and vehicles[5] (Figure 6.4).

Areas at high risk of potential new infestations include around sheds, gates and other areas where vehicles or machines are often parked. High-risk areas should be monitored regularly and baited if emerging snail infestations are observed. Ensure contractors do not bring snails on to the farm. Restrict paddock access and erect farm biosecurity signage at all entries. Ensure fodder brought into paddocks from elsewhere is free of snails.

Harvest operations are a key source of snail spread between paddocks[5]. Snails become attached to harvester fronts and to vehicles parked in paddocks (Figure 6.4). To minimise contamination, thoroughly clean harvesters before moving. Ideally clean, park overnight, then check and clean again before moving[5]. Another option is to harvest cleaner areas before more infested areas.

References

1. Grain Trade Australia trading standards. https://www.graintrade.org.au/commodity_standards

2. Baker, G.H., 2008. The population dynamics of the mediterranean snails *Cernuella virgata*, *Cochlicella acuta* (Hygromiidae) and *Theba pisana* (Helicidae) in pasture-cereal rotations in South Australia: a 20-year study. *Australian Journal of Experimental Agriculture*, 48(12), pp. 1514-1522. https://doi.org/10.1071/EA08031

3. Baker, G.H., 2012. The population dynamics of the mediterranean snail, *Cernuella virgata* (da Costa, 1778) (Hygromiidae), in continuous-cropping rotations in South Australia. *Journal of Molluscan Studies*, 78(3), pp. 290-296. https://doi.org/10.1093/mollus/eys015

4. Leonard, E., Baker, G.H., and Hopkins, D.C., 2003. Bash Em Burn Em Bait Em: Integrated snail management in crops and pastures. South Australian Research and Development Institute. URL: https://grdc.com.au/resources-and-publications/all-publications/publications/2003/12/bashem-burnem-baitem-integrated-snail-management-in-crops-and-pastures

5. Smith, A., 2019. Mitigating snails, slugs, and slaters in southern Western Australia. Grains Research and Development Corporation. URL: https://grdc.com.au/resources-and-publications/all-publications/publications/2019/mitigating-snails,-slugs-and-slaters

6. Smith, A., and Dovey, N., 2020. Investigating snail rollers to clean small conical snails out of barley and canola (SCF1906-003SAX). Final report for GRDC. Stirlings to Coast Farmers.

7. Smith A (2020). Removing small conical snails from barley. Fact Sheet. Stirlings to Coast Farmers. scfarmers.org.au/publications1

8. GRDC, 2021. Managing small conical snails: Options to remove small conical snails from harvested canola and barley grain in WA. Fact Sheet. *Grains Research and Development Corporation*, February 2021. URL: https://grdc.com.au/managing-small-conical-snails-factsheet

9. Grain Cleaning Calculator for small conical snails. Stirling to Coast Farmers. https://www.scfarmers.org.au/calculator

10. Sharma, S., 2002. Post-harvest solutions for quality grain (USA28). Final report for GRDC. https://grdc.com.au/research/reports/report?id=2845

11. Perry, K.D., Brodie, H., Muirhead, K.A., Fechner, N.K., Baker, G.J., Nash, M.A., Micic S., Ruggiero K., et al., 2020. Biology and management of snails and slugs in grains crops (DAS00160-BA). Final report for GRDC. South Australian Research and Development Institute.