SLUG CONTROL FACT SHEET

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

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Successful crop protection from slugs

Slugs are an increasing problem in the high-rainfall zones, especially where conservation agriculture is practised. No single control method will provide complete protection against pest slugs: an integrated approach is best.

KEY POINTS

- Understand the context in which slug controls are being applied
- Moisture availability is a key regulator of slug populations
- Wet winters and cool springs provide ideal conditions for numbers to build up
- The grey field slug and the black keeled slug are the main pest species, but brown field slugs can also pose a threat
- No single control method will be completely effective; for successful crop protection, an integrated approach is needed

Photo: Michael Nash

Grey field slug.

Introduction

Slugs are a major pest of crops globally and have become a more significant pest group attacking Australian grain crops as farming practices have changed. Slug infestations cause crop damage and yield loss from their feeding and incur considerable field control costs. Slugs will eat all parts of a crop plant. However, seedlings are the most vulnerable and this is the time when major economic losses can occur, even where populations are relatively low.

Slugs are present in all major grain growing regions of Australia. They pose the biggest threat to growers in the southern and western high-rainfall zones.

The cost slugs pose is best estimated by expenditure on molluscicides. Sales in the Australian market continue to increase annually by more than $440,000, with $20.5 million spent in 2020-21 (APVMA). This increased expenditure suggests the slug and snail threat is increasing, which is associated with changes to cropping practices. Cultivation and stubble-burning previously kept numbers down, but the widespread adoption of minimum-till and stubble retention (conservation agriculture) has provided slugs with a more favourable habitat.

Slugs do not have a distinct life cycle

Slugs are hermaphrodites, meaning both individuals of a mating pair lay eggs. Slugs breed whenever moisture and temperature conditions are suitable, which varies depending on the species. Breeding generally occurs over winter and spring. Each individual lays eggs

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in clutches over one to two months when the soil surface is moist enough. Generally, eggs are laid when gravimetric soil moisture is greater than 25 per cent.

Eggs hatch within three to six weeks as neonates, dependent on soil temperature. Optimum soil temperature for egg development is between 10°C and 16°C for grey field slugs. Neonates grow slowly, developing into juveniles that can grow quickly.

Juvenile growth rate depends on moisture, temperature and food availability. Juveniles' sizes vary greatly and can be the same as adults within the same population.

Generally, juveniles develop at 4°C to 21°C and reach sexual maturity after 10 to 40 weeks depending on species/conditions. Development times vary between individuals hatched from the same clutch; that is, within a population there are slow and quick breeders. Their staggered breeding is an adaption to survive difficult conditions.

Slugs survive dry conditions as adults by seeking refuge in the ground and lowering their metabolism, re-emerging once the soil subsurface wets up. Generally, this occurs after 75 to 100 millimetres of rain, but is often staggered with not all slugs of a population being active on the soil surface at the same time.

Pest species

All slug species found in agricultural areas are exotic, originating from Europe and the US. There are only a few species considered major crop pests in Australia: the black keeled slug, the grey field slug and, to a lesser extent, the brown field slug, which comprises two species that cannot be determined without dissection. Refer to the *GRDC Slugs in Crops – The Back Pocket Guide* to identify them.

For all slug species, movement during autumn and winter varies and is dependent on soil type, moisture, species and reproductive state, but generally occurs during periods when volumetric soil moisture at 0–10 centimetres is at least 0.05–0.45 per cent and when the ground level

Photo: David Paul

Carabid beetles eating a slug.

Photo: Michael Nash

The eggs of the black keeled slug, laid in a clod of moist soil. Slug eggs hatch within three to six weeks. A pair of black keeled slugs can lay up to 200 eggs per year, but some species are able to produce up to 1000 eggs per year.

Table 1: Understanding slug risk.

High risk	Reduced risk	Low risk
Annual rainfall Irrigated and/or >500mm	450–500mm	<450mm
Above-average spring/autumn rainfall	Dry spring, hot finish	Drought
Cold, wet establishment conditions	Warm, dry establishment conditions	
No-till stubble retained	Burnt only	Tillage and burnt stubbles
Insecticide usage high: neonicotinoid seed treatments plus high rates of chlorpyrifos	Moderate insecticide usage	
Press wheels, raised beds, cloddy seed bed		Full disturbance sowing, compacted seedbed
No sheep in enterprise	Sheep on stubbles	
Soil with improved moisture-holding capacity, that is increased clay content and organic matter		Poor moisture-holding capacity, that is sand with no organic matter
Summer volunteers		No volunteers
Slow crop establishment	Quick establishment due to earlier sowing of hybrid cultivars	
Previous paddock history Slug damage Beans/canola Sclerotinia	Clean cereal crops Linseed	No slugs No sclerotinia Poor cereal crop

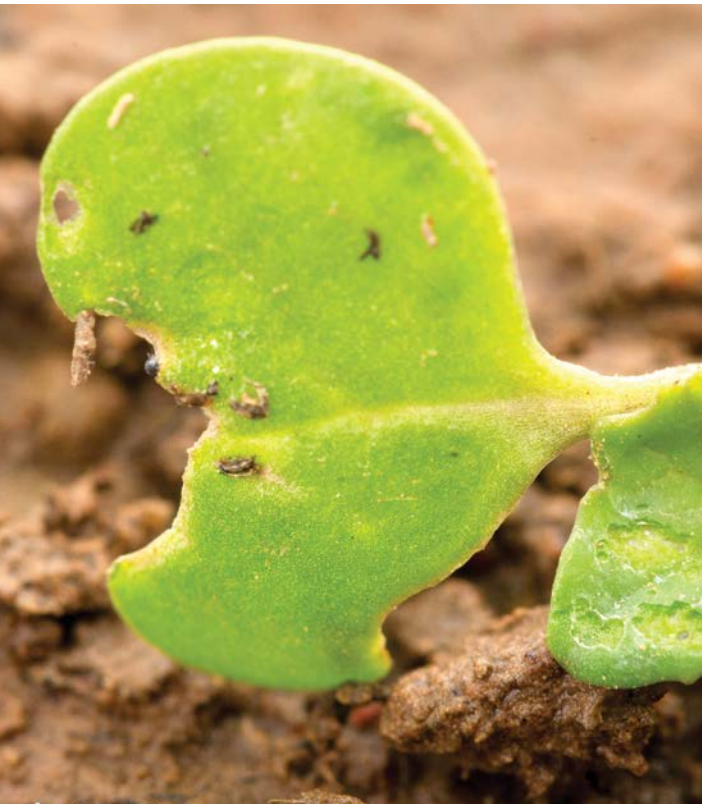


Photo: Michael Nash

Slugs will attack all plant parts but seedlings are the most vulnerable. Damage to the cotyledons in canola seedlings can mean major economic losses.

Photo: Michael Nash

Patchy emergence of this canola crop is evidence of extensive slug damage. Baiting can continue at this time, but it will only serve to minimise additional damage.

relative humidity is greater than 96 per cent. Black keeled slugs tend to emerge from the soil later in the season than grey field slugs, once moisture reaches the depth at which they are seeking refuge; for example, after 50–70 millimetres rain has soaked to 500–600mm of depth in light sandy soils with a sodic B horizon. Slug activity decreases once air temperature at ground level falls below 4°C or increases above 21°C.

Crop damage

Slugs can be underestimated as pests because they shelter during dry conditions and are nocturnal, so are not generally visible during daylight hours. Slugs will attack all plant parts, but seedlings are the most vulnerable crop stage and can suffer major economic damage. Populations as low as one grey field slug per square metre can inflict severe damage on a canola crop at establishment.

Grey and brown field slugs are mainly surface active, requiring moist refuges at the soil surface such as volunteer crop plants and broadleaf weeds. Black keeled slugs are a burrowing species and can feed directly on germinating seed. This often makes damage more difficult to detect compared with the surface-feeding species.

Seedling canola, soybeans and sunflowers are the crops at greatest risk, particularly on creek flats, heavy sodic soils and where there is zero-till and irrigation.

Control approaches

No single method provides complete control, so an integrated pest management (IPM) approach is required. By understanding the system's complexity and working on pest control year-round, all crops can be established successfully.

In the summer months, remove refuges by controlling weeds and managing stubble through grazing. If summer weed control is not possible, look to control weeds at least two months prior to seeding at the break of season and monitor for the presence of slugs. The most effective time to bait is after sowing, following rolling to consolidate the seedbed.

However, this cultural practice may not fit with a zero-till operation, so assess the scale of the problem and make the management decision appropriate to your operation. Confounding factors to consider with conservation agriculture practices are other pests, such as mice, consuming bait before the slugs. In these situations, appropriate controls need to be applied before slug bait is applied; that is, if mice are present they should be controlled first with mouse bait, not both baits spread at the same time.

During the winter months, continue to monitor for any plant damage during crop emergence. Repeat baiting may be required during crop establishment. Baiting in spring is generally not effective.

Monitoring

Observing plant damage, surface refuges and night observations are the main techniques for monitoring for slugs. Bait lines are a successful and practical alternative to refuges and may be a simpler monitoring method.

To be a reliable monitoring tool, optimum volumetric soil moisture for surface refuges is above 20 per cent. Refuges should be checked in the morning; if refuges heat up during the day slugs tend to move into the soil, making them difficult to count. Fifty monitoring refuges are recommended when paddock size is 40 hectares due to variability of Australian conditions.

THINGS TO CONSIDER WHEN MONITORING FOR SLUGS

1 Checking surface refuges, or nightly observations, only estimate relative activity of slugs, not total density, as slugs reside in the soil and emerge to the surface over extended periods of time. Field trials in South Australia and Western Australia showed that wet, specially made carpet mats with a silver upper surface to reduce heat build-up were favoured by black keeled and grey field slugs over concrete or bathroom tiles, especially early in the season when soil conditions are drier before sowing. Multiple transects of refuges should be deployed in slug-prone areas where patchy slug numbers are detected.

2 When dry sowing, black keeled slug activity may not be detected using surface refuges. Refuges can also underestimate populations, especially where large numbers of juvenile slugs are present as adults prefer to use refuges.

3 Slug size/weight is not a good indicator of age structure as an individual's growth rate within a population varies greatly depending on whether it is a slow or quick breeder. The size of refuge does not alter numbers recorded as the 'area of influence' is greater than the actual dimensions of the refuge; that is, slugs move from between one square metre to two square metres away depending on soil moisture to seek shelter under a 500mm by 500mm mat (0.25m^2).

4 Bait lines can be deployed over larger areas and monitored quickly but require reapplication every two to three weeks. Bait lines should be deployed before sowing to detect slug emergence. For details on using bait lines see www.youtube.com/watch?v=0E306BteGGs

Control methods

Effective control involves a combination of measures: chemical, cultural and biological.

CHEMICAL CONTROL

Baiting is still the only chemical control option. Apply baits after sowing and before crop emergence to protect seedlings.

Choosing the right slug bait for the situation in which slugs are to be managed is critical to ensure continued access to these crop protectants. Newly registered products have been reformulated to have a lower environmental impact and enhanced efficacy.

There are two active ingredients available on the Australian market: metaldehyde and various forms of iron.

The development of new chemical active ingredients is unlikely.

Table 2: Commonly available slug bait product selection guide*.

Product name	Active ingredient	A.I. g/kg	APVMA product no./ label no.	Label rate kg/ha	No. pellets/m^2 at label rates	Pellet type	Pellet weight (mg) [Co-efficient of variation within batch]
Sabakem Metaldehyde® Snail and Slug Pellets®	Metaldehyde	15	86284/115239	10	22–28	Dry bran	40 [43%]
Snailex Slug and Snail Pellets	Metaldehyde	15	68580/110574	5–7.5	13–20	Dry bran	42 [36%]
SlugOut® All Weather Slug and Snail Bait	Metaldehyde	18	49324/58633	10	88–112	Granule	12 [56%]
Delicia® Sluggoff lentils®	Metaldehyde	30	60931/0409	3	30	Wet extruded	11 [28%]
Axcela® Slug and Snail Bait	Metaldehyde	30	87576/118701	5–7	36–51	Wet extruded	14 [21%]
Metarex Inov® Slug and Snail bait	Metaldehyde	40	88160/120463	4–5	24–30	Wet extruded	17 [14%]
Imtrade Metakill® Snail & Slug Bait	Metaldehyde	50	64990/117488	5–8	30–60	Wet extruded	14 [31%]
Imtrade Transcend® Molluscide and Insecticide	Metaldehyde + 1.5g/kg fipronil	50	87832/125262	4–8	28–55	Wet extruded	14 [33%]
Eradicate® Snail and Slug Killer	Iron EDTA complex	60	68634/58804	5–16	14–45	Steam process bran	37 [30%]
IRONMAX Pro® Slug and Snail Bait	Iron as iron phosphate	9	89908/126325	5–7	31–43	Wet extruded	17 [17%]

* As at November 2024.

- Data comes from testing conducted by Michael Nash unless otherwise stated. Pesticide labels must be consulted for full application instructions. Adhere to all label directions including constraints and withholding periods. Refer to APVMA's PubCRIS database for current registrations and product labels (portal.apvma.gov.au/pubcris).

Pellets/m^2 applied can vary depending on the rate (kilogram per hectare) applied and the number of pellets/kg, the variation in pellet weight within and between batches and the pellets' ability to remain intact when broadcast as determined by hardness.

For slug baits to work, some basic principles must be met. Individual slugs must first encounter a pellet, which requires:

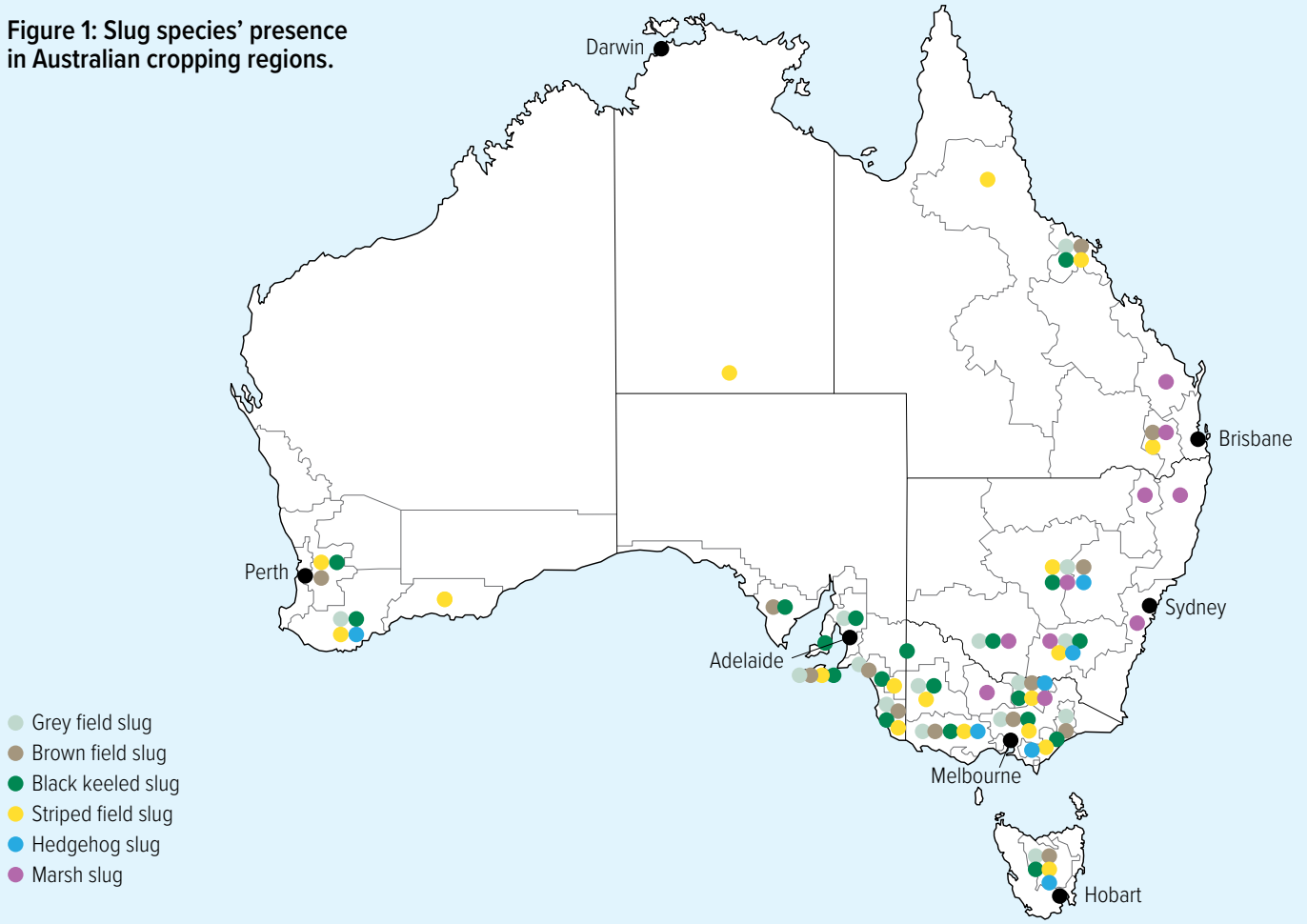
- individual activity – slugs must be actively searching for food;
- even distribution of baits per unit area – the focus on an increased pellet density alone has resulted in the manufacture of small pellets that increase the likelihood of individuals consuming a sub-lethal dose. Pellets have to be evenly applied across the full width of application. Consistent pellet size, weight and density ensure no area is missed. Patchy control can occur when products with high variation in weight and size are used and/or application equipment is not calibrated; and
- attractiveness of bait – slugs display non-random movement towards attractive pellets (true definition of bait) compared with seedlings. Most products contain ingredients that cue olfactory organs leading to feeding individuals moving to baits in preference to seedlings. Attractive products result in a greater likelihood individuals will encounter a bait than a seedling.

Once individuals have encountered a bait, they must consume a lethal dose, which requires:

- palatability – addition of feeding enhancers ensures individuals consume enough active ingredient to ingest a lethal dose. In the case of metaldehyde, which causes paralysis, consumption of a sub-lethal dose can be an issue with some products because individuals cannot continue to ingest enough to destroy their mucous cells;
- enough bait for the target population – if a product is gone a couple of days following application, it is usually due to large numbers of slugs consuming it all. Reapplication to those hot spots will be required; and
- enough toxicant in the bait – the loading of active ingredient determines the amount required to be consumed; hence low loadings require more total product to be applied. In wet conditions, small pellets with greater surface area to volume ratios lose more active ingredient hence less toxicant will be consumed. *Growers adhering to the International Sustainability & Carbon Certification (ISCC EU 202-2 or ISCC Plus 202-02) programs and use products containing metaldehyde, need to ensure they meet the requirements for maximum application rates, in accordance with these programs.*

Having a persistent bait that slugs will consume to receive a lethal dose allows for application before individuals are active. This timing often coincides with

Figure 1: Slug species' presence in Australian cropping regions.



Source: GRDC

rainfall. Bran-based products, which break down after rain and have low initial loadings of an active ingredient, need to be reapplied after heavy rainfall.

Modern rain-fast products continue to kill for up to a month after application and rainfall.

Combining what is known about the factors that make a good snail and slug bait has led to the development of products that achieve faster and more efficient mortality, leading to longer periods of crop protection. The continued improvement of delivery technologies with the same active ingredients applied has lowered environmental loadings. Better crop protection using less active ingredient results in better returns on growers' investment in slug bait.

CULTURAL CONTROL

Some crops, such as canola, soybeans and sunflowers, are more susceptible to slug damage than others. If planting a susceptible crop, increase seeding rates in paddocks where slugs have been present and follow good agronomic practices to get the crop established.

Rotation can play a role in reducing slug numbers in the season before growing a susceptible crop; for example, linseed and barley do not favour slug growth.

Controlling weeds removes vegetation cover, food and shelter for slugs. Keep paddocks as weed-free as possible. Strategic cultivation may be effective in reducing slug numbers as it destroys surface habitat in some soil types; however, this is not an option in zero-till operations where the aim is to conserve soil moisture.

Stubble burning is another option as it aids crop establishment in cold environments but is not always desirable or failsafe. Other options to improve canola establishment include: increased seeding rate, the use of large seed greater than 2mm, hybrid seed, non-triazine tolerate cultivars, placement of seed away from fertilisers, applications of seed treatments that do not retard seedling vigour and, most importantly, early sowing into warm, moist soil.

Rolling after sowing to consolidate the seedbed is an important component of an integrated slug control program. Rolling improves the establishment of many crops and reduces surface clods that provide habitat for slugs.

Heavy rolling can reduce emergence in crops such as soybeans, but lighter (selective) rolling can be carried out in well-structured soils. Rolling is also at odds with minimum-till practice, so decide whether the size of the slug problem means the outcome justifies this change of approach.

The application of gypsum to sodic soils will aid crop establishment and can be used as another tool to reduce slug threats.

The best approach is to incorporate appropriate cultural controls for your operation into a broader IPM strategy; however, in some scenarios all controls are needed for successful crop establishment.

BIOLOGICAL CONTROL

Predatory insects and organisms play a role in limiting slug populations. Carabid (or predatory ground) beetles feed on both plant and ground-dwelling pests and have been linked to increased canola yields in areas where slugs are a known threat. A free-living, single-celled ciliate has been found to cause high levels of slug mortality in Australia.

As natural enemies are disrupted by some pesticides, including broad-spectrum insecticides and seed treatment, reducing pesticide use will aid in limiting slug numbers.

GRDC CODE

Communication and extension of slug management in the southern region.
MAN2204-001SAX

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USEFUL RESOURCES

Snail Bait Application Fact Sheet. grdc.com.au/resources-and-publications/all-publications/factsheets/2015/01/snail-bait-application

Slugs in Crops – The Back Pocket Guide. grdc.com.au/resources-and-publications/all-publications/publications/2024/slugs-in-crops-the-back-pocket-guide

A Snug Blog. asnugblog.wordpress.com

GCTV17 Video, **Snail Bait Monitoring Test**. www.youtube.com/watch?v=0E306BteGGs

GRDC Video, **Slug control: best management practices and the hunt for smarter controls**. www.youtube.com/watch?v=FjcD2ksaPDA

PestNotes. **Black keeled slug**. cesaraustralia.com/pestnotes/slugs/black-keeled-slug

PestNotes. **Grey field slug**. cesaraustralia.com/pestnotes/slugs/grey-field-slug

Slug control across southern Australia (podcast). grdc.com.au/news-and-media/audio/podcast/slug-control-across-southern-australia

Nail the Snails. grdc.com.au/resources-and-publications/all-publications/publications/2023/nail-the-snails

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