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Slug Damage and Control of Slugs in Horticultural Crops

Slugs can cause severe losses in many horticultural crops. Slug activity, slug damage and control strategies differ considerably between countries or regions of Europe. This brochure summarizes recent research on novel methods for slug control. It gives a general overview for Europe; regionally experienced specialists are encouraged to adapt the knowledge to their local situation, and to incorporate it into their existing horticultural advisory system. Snails can also be important pests. Snails are only briefly mentioned in this brochure, but control methods are similar, because they are closely related to slugs.

This brochure lists the most important species of pest slugs and the major crops concerned. Strategies for slug control in integrated crop management (ICM) and organic horticulture are presented, which integrate novel and established methods, and ensure optimal protection and minimum impact on the environment.



How to use this brochure

This brochure is the outcome of an EU-funded research project on «Novel technologies for integrated control of slug damage in key horticultural crops» (details on the last page). It describes new control methods that were investigated in this project, and how they can be combined with existing control strategies. The aim is to achieve optimal protection against slug damage with minimal impact on the environment.

This brochure was written for horticultural consultants, extension services, plant protection officers and the horticultural press. We encourage regionally experienced specialists to adapt the knowledge to their local situation, to incorporate it into their existing horticultural advisory system and to transfer the knowledge to the horticulture industry in this way. When advising farmers, only a small subset of the information presented here will be appropriate in each situation (depending on the season, the crops, the species of pest slugs and their life cycle and activity in that region, regional horticultural practices and national molluscicide registration). We therefore do not address farmers directly. If you have any questions or encounter difficulties with the implementation of this information, please consult the literature listed on the last page or the project's website, or contact one of the participants of the project (via the website; see last page).



Photo: FiBL

The proportion of green manure crops in crop rotations increases. These crops provide excellent conditions for survival and growth of slugs.

The importance of slug control

Slug control has become more important in recent years for a number of reasons:

- Reduced soil cultivation, which favours slugs, is frequently used.
- Increasing acreages of land are under setaside, which is favourable for slugs.
- Increased use of green manure crops such as oilseed rape and forage rape (*Brassica napus* sbsp. *Oleifera* (Metzg) Sinsk), fodder radish (*Raphanus sativus* subsp. *Oleiferus* (DC) Metzg) and white mustard (*Sinapis alba* L.) in crop rotations.
- Consumers and trade have elevated their quality standards, resulting in lower tolerance for slug damage and presence of slugs or slug faeces.



Regions concerned

Slug damage is, on average, most frequent and most severe in Great Britain, Ireland, The Netherlands and France (■). In many other regions of Europe, slugs can also be serious pests, but slug damage occurs less regularly (●). In dry, cold, or very continental climates and at high altitudes, slug damage is uncommon (□). Individual farms or fields may deviate from the general pattern. Whether slug damage occurs depends on climate, soil type, distribution of slug species, crops grown and on management practices.

Slugs, snails and the environment

The great majority of all slug and snail species are harmless to crops, and many snails are rare or endangered, mostly because of habitat destruction. Molluscicides should only be used to control the pest species among slugs and snails.

Slugs have a large number of natural enemies, for example many species of carabid beetles. Conservation of species-rich, undisturbed habitats promotes, among others, the natural enemies of slugs.

Groups of pest slugs

From the practitioner's point of view, four groups of pest slugs can be distinguished. If you wish to identify slugs to species, please use the literature listed on the last page.

Life cycles and patterns of activity depend greatly on precipitation and climate, and differ widely among the regions of Europe.

Field slugs and relatives

mainly *Deroceras reticulatum*, *D. panormitanum* (= *D. caruanae*), *D. laeve*

Large roundback slugs

(mainly *Arion lusitanicus*, *A. ater*, *A. rufus* and *A. subfuscus* (note: *A. rufus* is often considered as a synonym or as a subspecies of *A. ater*)



These slugs are active above and below ground, even at low temperatures, and prefer a very wet climate. *D. reticulatum* is distributed almost worldwide and is a pest in horticultural crops, as well as in many others.

These slugs are mainly active above ground, at temperatures above 10 °C. Their activity is less dependent on ambient moisture, and they can move considerable distances within one night.

Small roundback slugs

mainly *Arion hortensis*, *A. distinctus*, *A. circumscriptus*, *A. silvaticus*

Miscellaneous

Milax gagates, *M. sowerbyi*, *Limax flavus*, *L. maximus*, *Tandonia budapestensis*, *Lehmannia valentiana* and *L. marginata* sometimes cause damage.



These slugs are active above and below ground, mainly at temperatures above 10 °C.

In glasshouses, other slugs including some tropical species occasionally cause damage. In Southern Europe especially, several snail species from the family *Helicidae* are also important pests, but these are not dealt with in detail in this brochure.

Slug damage

Types of damage

Slugs reduce the vigour of some crops by killing seeds or seedlings, by destroying stems or growing points, or by reducing the leaf area. This may slow down crop development and/or reduce yield. In other crops, the harvest is devalued by feeding damage, mucus trails, faeces or presence of slugs. Slug feeding may also initiate mould growth or rotting.

Damage by slugs is not always easily distinguished from insect feeding. Clear, silvery mucus trails indicate slug activity.

Four groups of crops suffer slug damage most frequently, but almost every horticultural crop can be attacked by slugs, as well as many arable and fodder crops and ornamentals. In

general, crops grown on relatively heavy soil are especially susceptible, as slugs have better conditions for survival and growth in this type of soil.

Photo: Albert Ester



Brassicas

- Most brassicas are highly susceptible to slug attack. Most importantly, Brussels sprouts buttons, green and white cabbage often suffer nibbling by slugs, which renders them unfit for sale.
- In white cabbage, slug damage may also occur during the first weeks of storage and render the cabbage unsuitable for the fresh food market.
- Freshly planted plantlets of many brassicas are highly susceptible to defoliation.

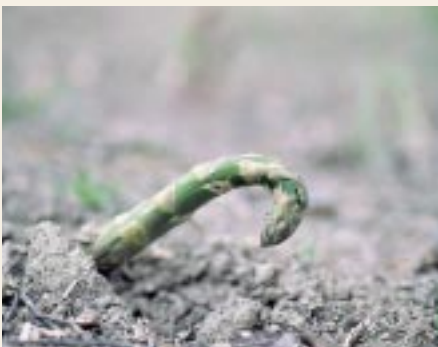


Photo: Bernhard Speiser

Leaf vegetables

- Most cultivars of lettuce are highly susceptible to leaf feeding by slugs throughout their development.
- More importantly, the presence of slugs in lettuce heads (mostly during mid-summer) or in spinach leaves renders the crop unfit for sale.

Photo: Albert Ester



Green asparagus

- Asparagus shoots are affected mainly below soil level, although some are attacked when they appear above the ground.
- Although slugs cause only tiny feeding marks, the entire shoot becomes deformed and thus unfit for sale. In the Netherlands, Belgium and Germany, slug damage to asparagus occurs regularly.



Photo: Bernhard Speiser

Strawberries

- Slugs chew holes in ripe strawberries.
- Such fruit are not only unfit for sale but also promote mould, which subsequently attacks healthy berries.

Cultural control and management strategies

Many cultural practices reduce slug activity, but their application is limited, as they can be labour-intensive and may affect crop performance and/or the environment. In general, rough seed beds and continuous, dense vegetation cover favour slugs, and should therefore be avoided.



Photo: Hansjell Dierauer (FiBL)

Soil cultivation reduces slug populations.

Effective cultural practices:

- Soil cultivation can reduce slug populations drastically. Machinery, timing and intensity have to be adjusted to the soil type and to the needs for soil conservation. The aim is to obtain a fine seed bed, which reduces movement of slugs between their shelter in the soil and the crops.
- Soil cultivation at low temperatures exposes slugs or slug eggs to freezing.
- Sowing or planting susceptible crops at a distance of at least 3–5 m from setaside, meadows or hedges reduces damage by immigrating large slugs.
- Optimal fertilization, use of vigorous plantlets and changes in sowing or planting dates may reduce the duration of the susceptible phase of crops, or shift it to dry periods, when slug activity is low.
- There are hardly any slug-resistant cultivars of horticultural crops.

Slug control in integrated crop management (ICM)

Principles

- Prevent slug damage with cultural practices, if possible.
- Use molluscicides if necessary (restrictions see below).
- Limit slug damage to economically acceptable levels, but do not attempt to completely eradicate slugs from fields.

Methods

- There is some potential to improve prevention by cultural control, but its significance is limited in ICM horticulture.
- Slug pellets containing metaldehyde or carbamates are most widely used. There is some potential to improve the efficiency of their application (see page 6).

Other methods are less effective and/or more costly and therefore only recommended in the following cases:

- Nematodes may be used in high value crops and where good control underground is essential (e.g. asparagus).
- Iron phosphate may be used where use of low toxicity products and avoidance of mucus trails on produce are required.

Restrictions

- Use of molluscicides according to national registration (range of products, range of crops, dosage and number of applications differ greatly among countries).
- In some countries, nematodes are also subject to registration requirements.
- Additional restrictions by national and private guidelines for ICM and by marketing schemes.

Slug control in organic horticulture

Principles

- Prevent slug damage with cultural practices as far as possible.
- Potential for direct control of slugs is very limited (restrictions see below).
- Severe losses are sometimes inevitable and must be calculated.

Methods

- Prevention by cultural control has paramount importance in organic horticulture, but will only partially solve problems.
- Nematodes may be used where economic.
- Iron phosphate may not be used at the moment.
- The other methods presented in this brochure, particularly ducks and slug fences, may be used where economic.
- Metaldehyde pellets can be used in some countries, but only in slug traps (see below).
- Carbamate pellets are not allowed.

Restrictions

- National registration (see ICM, left).
- EU regulation 2092/91, annexe II currently (but possibly not in the future) allows the use of metaldehyde baits in traps, but not directly on the soil.
- National and private guidelines for organic production (note: in many countries national guidelines do **not** allow metaldehyde in organic production).
- Nematodes: no restrictions by organic production guidelines.
- Iron phosphate: not allowed at present, but possibly in the future.

Established methods of slug control

What you should know

- «Slug pellets» are baits which contain slug attractants, an edible matrix and a molluscicidal active ingredient. The most frequently used active ingredients are metaldehyde and carbamates (methiocarb, thiodicarb etc.). Good results can be achieved with all kinds of active ingredients.
- Pellets loose efficacy when mould grows on them, or when they are covered with soil during heavy rain.
- Resistance of slugs against molluscicides has not been observed yet and is considered unlikely to evolve.

How to use

- Pellets should be distributed evenly on the soil surface. To achieve this, choose a formulation with even pellet size.
- If necessary, reapply when pellets are decayed (if allowed by national registration).
- Avoid contamination of harvested plant material with slug pellets.
- When slugs migrate into crops from an adjacent habitat (e.g. setaside, meadow, hedge), a border treatment may be sufficient.
- Apply pellets only when the crop is in a slug-sensitive growth stage and when slug damage is likely from the climatic conditions.
- For certain regions, climate-based models for forecasting slug activity have been developed, which allow more efficient use of molluscicides.

Where to use

- Slug pellets are effective under most conditions. Note: They may only be used in the crops for which they are registered in your country.
- In organic horticulture, the use of slug pellets containing metaldehyde or carbamates is forbidden or severely restricted (see page 5).



Novel method: iron phosphate

What you should know

- A number of iron compounds are molluscicidal. Iron(III) phosphate is among the least toxic for pets, wildlife and humans. It is formulated as slug pellets.
- Ingestion first leads to feeding inhibition, and later to death of slugs. There is no excess production of mucus in poisoned slugs.
- Iron phosphate is presently registered in several European countries, and registration is pending in other countries.
- There are indications that iron phosphate might be allowed for use in **organic production** in the future, but **presently this is not the case**.

How to use

- Apply pellets as described above (dosage and number of applications according to national registration).
- Usually a higher dose is required than for other slug pellets.

Where to use

- There is only limited experience with this product, but preliminary results suggest that iron phosphate is successful in most crops and against most slug species.

Novel method: nematodes



What you should know

- Nematodes (eelworms) of the species *Phasmarhabditis hermaphrodita*, together with their associated bacteria *Moraxella osloensis*, are widespread natural parasites of slugs. They are mass-cultured in fermenters and sold as biocontrol agents for slugs. *P. hermaphrodita* has not been found to attack animals other than slugs and snails, or crop plants.
- These nematodes actively seek slugs and parasitize them. This causes feeding inhibition within a few days, and death of the slug within 1–2 weeks.
- *P. hermaphrodita* achieves good control of field slugs, while results with other slugs (particularly roundback slugs) are more variable.
- Use of nematodes is more demanding than use of chemical molluscicides. If used properly, nematodes result in good control.
- At present, *P. hermaphrodita* is not sold in all European countries.

How to use

- Apply at sowing, or a few days before planting.
- Nematodes are best applied in wet weather conditions.
- Disperse nematodes in water and apply evenly to the whole area with a watering can or with standard spraying equipment; if soil is not fully moist, water into soil if possible.
- Keep soil moist for two weeks after application, if possible.
- Dosage: 300 000–500 000 nematodes/m² (depending on national registration requirements etc.). Lower doses and band applications have been successful in some experiments.
- Store nematodes in the refrigerator.
- Observe expiry date (several weeks after purchase).

Where to use

- Particularly for crops damaged underground, such as green asparagus.
- Best justified in high value crops or in organic horticulture.
- Good results were obtained in green asparagus, Brussels sprouts and salad vegetables (e.g. Chinese cabbage, radish, lettuce) in field trials at a practical scale.

Other methods: beer trap



What you should know

- Beer traps are well known among home gardeners. They seem successful, because their catch is easily visible. However, the smell of beer can attract slugs into fields. Therefore, beer traps should only be used within fenced fields.

How to use

- Insert beaker into soil, leaving a rim of 1 cm above the soil (if the beaker is dug in to ground level, it will also catch beneficial arthropods such as carabid beetles and spiders).
- Fill half with beer. Replace beer every two to three days.

Where to use

- In home gardens.

Other methods: ducks



What you should know

- Of all slug-eating birds, runner ducks are the most efficient to use for slug control. Runner ducks are a special breed of mallard ducks (*Anas platyrhynchos*).
- Runner ducks reduce slug populations considerably in the long run, but cannot be used for short-term slug control.
- Runner ducks also eat crops, if they are given the opportunity.
- Duck keeping requires daily attendance.
- Predators and birds of prey may kill runner ducks.

How to use

- Let runner ducks graze on fields until immediately before emergence or planting of crops, and soon after harvest.
- Let ducks graze around fields surrounded by netting or around polytunnels and glasshouses. Where predators are frequent, use electric netting.
- Preferentially let ducks graze after each soil cultivation, at dawn and dusk, and during rain.
- Always provide access to water.
- During droughts and winter, feed ducks with vegetable wastes, maize etc. Do not feed too much; scatter food at a distance from housing, to train ducks to search entire area for food.

Where to use

- Feasibility of use depends on logistics (e.g. availability of housing).
- Runner ducks are mainly used by organic farmers, often with good results.

Other methods: slug fences



What you should know

- Slug fences can reduce immigration of slugs drastically, but are ineffective against the resident slug population.
- Efficacy is highest if small areas are fenced. However, costs per unit area are also highest in this case. Fencing larger areas reduces costs, but also efficacy.
- Slug fences are seldom efficient on their own, but may enhance the effect of other methods.
- There are different brands on the market. Some are mechanical barriers, others are painted with a deterrent (e.g. soft soap) or equipped with electrical contacts.
- Slug fences are mainly used in home gardens, but may be useful in commercial growing of certain high value crops (e.g. herbs).

How to use

- Insert fence a few cm into soil and ensure tight closure of fence (according to instructions).
- Combine with other control methods, to reduce their intensity or dosage.

Where to use

- Useful where crops border on setaside, meadows, hedges or other slug habitats.
- Besides home gardeners, this method is used by some organic farmers to protect high-value crops (e.g. plantlets, ornamentals).

Other methods: salt



What you should know

- Asparagus are tolerant of high concentrations of salt in the soil, while molluscs are sensitive to salt.
- Green asparagus crops are grown for about eight years in the same field and can be damaged by slugs.
- In the Netherlands, application of salt (NaCl) to the soil is recommended to control *Fusarium spp.* and *Phytophthora spp.*. This results in higher yields due to disease control and as a side effect, it also controls slugs.
- Soil salinity may affect subsequent crops.

How to use

- Apply dry salt to the rows.
- Dosage: two times 2000 kg/ha or four times 1000 kg/ha.
- The first application should be made when the first shoots break through the soil surface. Subsequent treatments should be applied at one-week intervals.
- For further information contact Albert Ester (address no 3; last page).

Where to use

- This method is **only suitable for asparagus**, because other crops do not tolerate high salt levels.
- Present experience is limited to the Netherlands.
- Use of salt is restricted in organic production, and may not be allowed in your country.

Other methods: hand collection



What you should know

- Hand collection is laborious and therefore only practicable on small areas.
- It is only economic under special conditions (e.g. high-value crops, urgently needed plantlets, cheap labour).

How to use

- Collect slugs regularly at dusk or dawn.
- Baiting with food or shelter improves success, but neither food nor shelter should be left in the field without collection.
- Populations of large slugs can be reduced by hand collection, but this method is almost ineffective against small slugs.
- Can be combined with nematodes for highest levels of control.

Where to use

- Use only in small areas, especially if protected with a slug fence, or isolated by roads, walls etc.
- This method is mainly used by home gardeners, and occasionally by organic farmers.

Further reading

General biology and impact of slugs

- «Slug & Snail Pests in Agriculture». Henderson, I.F., 1996. British Crop Protection Council, Farnham, 450 pp.
- «Terrestrial Slugs. Biology, Ecology, Control». South, A., 1992. Chapman & Hall, London, UK, 428 pp.
- «Slugs and Snails in World Agriculture». Henderson, I.F., 1989. British Crop Protection Council, Thornton Heath, 422 pp.
- «Pest Slugs and Snails, Biology and Control». Godan, D., 1983. Springer, Berlin, 445 pp.
- «Schadsschnecken und ihre Bekämpfung». Godan, D., 1979. Ulmer, Stuttgart, Germany, 467 pp.



Larva of staphylinid beetle eating slug.

Photo: Bernhard Speiser

Identification

Northern Europe

- «Cyberslug» (CD ROM). A. Cook, University of Ulster, Londonderry, Northern Ireland (order from: a.cook@ulst.ac.uk).
- «Land Snails of the British Isles». Wardhaugh, A.A., 1989. Shire natural history series: invertebrates no 45. Shire, UK, 24 pp.
- «A Field Guide to the Land Snails of Britain and North-West Europe». Kerney, M.P. and Cameron, R.A.D., 1979. Collins, London, 288 pp.

Western Europe

- «Guia de las babosas Ibericas». Castillejo, J., 1998. Academia Galega de Ciencias, Santiago, 154 pp.
- «De landslakken van Nederland». Gittenberger, E., Backhuys, W. and Ripken, T.E.J., 1984. Koninklijke Nederlandse Natuurhistorische Vereniging, Leiden, 184 pp.

Central & Eastern Europe

- «Die Landschnecken Nord- und Mitteleuropas». Kerney, M.P., Cameron, R.A.D. and Jungbluth, J.H., 1979. Paul Parey, Hamburg, Germany, 384 pp.
- «Weichtiere». Fechter, R. and Falkner, G., 1990. Mosaik Verlag, München, Germany, 287 pp.
- «Atlas der Mollusken der Schweiz und Liechtensteins». Turner, H. *et al.* 1998. CSCF, Neuchâtel, Switzerland, 527 pp.
- «Les limaces nuisibles aux cultures». Hommay, G., 1995. Revue Suisse d'Agriculture, 27, pp. 267-286.

Control

- «Schneckenbekämpfung ohne Gift». Graber, C. and Suter, H., 1989. Kosmos, Stuttgart, 71 pp.
- «Wenn Schnecken zur Plage werden». Sulzberger, R., 1996. BLV, München, Germany, 94 pp.
- «Biokulturen vor Schnecken schützen». Speiser, B. 2001. FiBL, Frick, 8 pp. (order from address no 6).
- «Schneckenregulierung: Eine Daueraufgabe». Speiser, B., 1999. Bio-land 2/99, pp. 26-27.
- «Proteger les cultures biologiques des limaces». Speiser, B. 1997. FiBL and srva, Frick, 8 pp. (order from address no 6).
- «Aaltjes lusten naaktslakken rauw». Van Rozen, K. and Ester, A., 2000. Groenten en Fruit/Vollegroentes, 10 November. pp 4-5.

- «Slakken, een bedreiging voor vele teelten». Ester, A. and Boogaard, M., 2000. Vakblad voor de Bloemisterij 44, pp 54-55.
- «Slakken bestrijden eist een geïntegreerde aanpak!» Ester, A., 1989. Groenten en Fruit, 44, pp 70-71.
- «Effect bodembedekkers op naaktslakken» Ester, A., 1995. Ekoland, 9, pp 10-11.
- «Slug Damage and Control of Field Slug (*Deroceras reticulatum* (Müller)) by Carvone in Stored Potatoes». Ester, A. and Trul R., 2000. Potato Research 43, 253-261 pp.
- «Slug-parasitic nematodes as biocontrol agents for slugs». Glen, D.M. and Wilson, M.J., 1997. Agro-Food-Industry Hi-Tech, March/April, pp. 23-27.
- «Can slug-parasitic nematodes protect your vegetable crops?» Glen, D., Hughes, L. and Wiltshire, C., 1999. Organic Farming, 62, pp.14-15.
- «The use of slug-parasitic nematodes and other techniques for control of slug and snail damage in horticultural crops». Glen, D.M. *et al.*, 2000. Brighton Crop Protection Conference – Pests and Diseases (2000) pp. 345-350.
- «Biological control of terrestrial molluscs». Port, G.R., Glen, D.M. and Symondson, W.O.C., 2000. In: Measures of Success in Biological Control (Eds. G. Gurr and S.D. Wratten), pp. 133-159. Kluwer Academic Publishers, The Netherlands.
- «Molluscicides». Speiser, B. In: Encyclopedia of Pest Management (Ed. D. Pimentel), Marcel Dekker, New York, in press.



Photo: Siegfried Keller (FAL Zürich-Reckenholz)

Carabid beetle eating slug eggs.

Impressum

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Project website:

<http://www.slugcontrol.iacr.ac.uk/>

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- 3 Applied Plant Research, P.O. Box 430, 8200 AK Lelystad, NL (<http://www.ppo.dlo.nl>)
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