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Artificial barriers against arionid slug movement

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ABSTRACT

Arionid slugs can be serious pests on horticultural and agricultural crops. Using slug movement barriers is a potentially effective method to control slug damage. We evaluated the performance of waterglass (sodium silicate) and copper foil as barriers against *Arion vulgaris* movement both in a controlled experiment and in a semi-field validation under natural conditions. We used strawberry fruits as baits behind the barriers and monitored slug movement and damage to the strawberries. In the controlled experiment, copper foil barriers delayed but did not prevent passage, whereas waterglass barriers completely hindered slugs from passing. Barrier width (3, 4 or 6 cm) did not affect the passability of the barriers. In the semi-field validation, there was no difference in slug damage events between pots with and without copper foil barriers. Waterglass barriers applied to the pots reduced slug damage events by 50% compared with pots without a barrier. Using waterglass to hinder slug movement may prove to be a cost-effective method to control slug damage in horticulture without any adverse side effects on non-targeted organisms.

1. Introduction

Terrestrial gastropods can cause severe damage on horticultural and agricultural crops. Some species have recently emerged as serious pests, as they have been introduced into new environments (Cowie and Robinson, 2003). The Spanish slug (*Arion vulgaris* Moquin-Tandon 1855; previously, but incorrectly, referred to as *A. lusitanicus* in the literature, e.g. Quinteiro et al. (2005), (Zemanova et al., 2016)) is a highly invasive gastropod originating from forested habitats in south-western Europe. During the last 50 years it has been established in anthropogenic landscapes in many countries in northern Europe (Proschwitz 1997; Kozłowski 2007; Zemanova et al., 2016) where its introduction has resulted in production loss, both in agriculture and private gardens (Frank 1998; Kozlowski 2000). Conventional control methods include pesticides (Watkins et al., 1996; Laznik et al., 2011), biological treatment with nematodes (Grimm 2002), and, in garden settings, culling (Langlet 2008). Pesticides and nematodes, however, are not always effective and risk having adverse effects on native, non-target species (Laznik et al., 2011; Capinera 2018; Antzée-Hyllseth et al., 2020). Manual culling, on the other hand, may be perceived as a tedious task, with only a fraction of slugs present being visually observable at a given time (Nyqvist et al., 2020). Instead, movement barriers may prove efficient as a potential method to control slug damage if they can prevent slugs from performing movements for local dispersal (Grimm and Paill 2001; Knop et al., 2013), diel migrations between nocturnal feeding areas and diurnal sheltered habitats (Grimm et al., 2000), or adapting to shifting spatial and temporal patterns of resources.

A wide range of physical and chemical slug barrier types have been suggested and, with varying levels of scientific evidence of functionality, marketed to the gardening public. In laboratory experiments, barriers using hydrated lime and sulfur reduced feeding and leaf consumption by Florida leatherleaf slug (*Leidyula floridana*), whereas diatomaceous earth, fumed silica and wood ash did not prevent slug damage (Capinera 2018). Schüder et al. (2003) tested a range of barrier materials applied in 3 cm strips to prevent horizontal and vertical movement of brown field slug (*Deroceras panormitanum*). Urea formaldehyde and a garlic solution acted as semi-exclusive barriers both for vertical and horizontal movements (>65% exclusion), whereas a range of other materials only reduced vertical barrier passage to various degrees. An ethylene tetrafluoroethylene coating (ETFE, perhaps more suitable for laboratory experiments and gastropod terraria than in applications to prevent damages on crops) produces a low-friction surface that prevented horizontal passage by grey field slug *D. reticulatum* (Symondson 1993). For arionid slugs, a barrier of 3 cm wood ash and hydrated lime reduced passage over 2 days with more than 50% compared with controls (Laznik and Trdan 2016). The effect was likely caused by the resulting

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dry surface, suggesting that the barrier efficiency may be reduced should the surface become wet. When applied weekly and protected against rain, birch tar oil in combination with petroleum jelly, prevented passage by *Arion* slugs for months in a controlled field experiment (Lindqvist et al., 2010). Moreover, a medium-high voltage (10 V) electrical fence, has also been shown to constitute an effective barrier to arionid slug movement (Laznik et al., 2011).

Copper foil and waterglass (sodium silicate) are two readily available and relatively cheap and weather resistant potential barrier materials promoted in the popular garden literature (Brozinic 2020). Copper foil is believed to prevent slug passage by inducing an electrical current when coming in contact with the slug mucus, but previous results of its barrier efficiency are mixed (Laznik et al., 2011). Copper foil has been documented to slightly reduce the number of passing slugs (*D. panormitanum*) and snails (*Oxyloma pfeifferi*) (Schüder et al., 2003), and to delay, but not prevent, passage of *D. reticulatum* (Symondson 1993). Further, applied to the trunks of citrus trees, copper foil substantially reduced the number of citrus brown snails *Caucasotachea lencoranea* found in the treated trees (Kheirodin et al., 2012). Waterglass, a versatile material used in a wide range of applications in e.g. engineering and food conservation, can readily be applied to rough surfaces and potentially prevent passage because of its alkaline properties. We are not aware of any previous studies testing the performance of waterglass as a barrier to movement, but other alkaline materials have been shown to repel terrestrial gastropods (Capinera 2018). Here, we explore the effects of copper foil and waterglass barriers of different widths on slug passage in a controlled experiment using individual slugs in separate containers. Further, to validate the results from the experiments, we applied the two barrier types onto baited pots and assessed barrier efficiency in the field, where slug damage was recorded from pots placed in an urban forest edge in an area with high densities of *A. vulgaris*.

2. Materials and methods

2.1. Controlled experiments

We used 120 *A. vulgaris* individuals (mean body mass ± SD = 6.6 ± 3.1 g; collected from a nearby urban forest edge) divided equally between two experiments. We used plastic containers (length × width × height = 35 × 23 × 13 cm), with or without a barrier applied as a centerline on the floor, walls and roof of the container. The barrier divided the container into two equally sized spaces. The containers were placed outdoors (WGS 84: N59.32°, E14.11°) shielded from sunlight. The first experiment was carried out between 20 and 26 June 2020, using copper foil as barrier, and the second experiment between 16 and 21 July 2020, using waterglass (35–40% sodium silicate) applied as a thin layer onto paper masking tape fastened to the plastic. We used three containers of each barrier treatment: either no barrier or a barrier with 3, 4 or 6 cm width. Hence, twelve individual slugs were used each night in the experiment in separate containers. Both experiments were conducted for five consecutive nights, resulting in totally 60 trials for each barrier type, i.e., 15 trials with each treatment (i.e., no, 3, 4, or 6 cm barrier).

All twelve trials during a night started simultaneously at 19:30 (±1 h) with a slug and a piece of a strawberry fruit being placed on opposite sides of the barrier centerline, in the middle of each area demarcated by the barrier (in treatments without barrier, the slug and strawberry were placed in corresponding places). The containers were checked at 2, 4, 12 and 14 h after the start of the trial to record on which side of the barrier each slug was positioned. In control trials, the position was recorded in the same way as if there was a barrier in the center of the container. After 14 h (at 09:30 ± 1 h in the morning after), the trials were terminated and the strawberries were checked for bite marks from feeding slugs. Air temperature and moisture were measured 1 m above the ground before each data collection.

A slug that was observed to have passed the barrier at a certain time was assigned a 1 at that time and later times, and it was assigned 0 for the times before passage. To test the effect of copper foil presence (with no regards to barrier width) on passage success after 2 h, we used a logistic regression analysis with the binary dependent variable passage success. At 4 h and later, lack of variation in the control treatments prevented statistical analysis (practically all slugs had passed by this time in containers without a barrier). To test the effect of copper foil width on passage success (data from trials without a barrier were excluded), we used separate logistic regression analyses at 2, 4, 12 and 14 h. In all analyses, we included night as a factor to control for different passage conditions at different nights. The data from the experiment with waterglass barriers showed no variation, and thus they could not be analyzed statistically.

2.2. Semi-field validation

We validated the findings from the controlled experiment during five nights for each type of barrier (copper foil: 26, 29–30 June and 1–2 July 2020; waterglass: 23–27 July). We used plastic pots (length × width × height = 5.5 × 5.5 × 5.5 cm) filled to 50% with sand and baited with a strawberry fruit placed on the sand. At 19:45 (±1 h) each night, we placed ten pots with a 3 cm barrier and ten without the barrier as controls in a suburban forest edge (WGS 84: N59.34°, E14.08°) with observed high density of *A. vulgaris* (pers. obs. Johan Watz). The 20 pots were randomly distributed in a c. 10 × 10 m area. After 14 h, we collected the pots, and bite marks (a damage event) from large slugs (likely predominantly *A. vulgaris*) were recorded. During the semi-field validation, we observed many *A. vulgaris* (both outside and inside the pots) and a few *Limax maximus* in the area. Air temperature and moisture were measured at the start and end of each round of validation 1 m above the ground.

We calculated the proportion of pots containing a strawberry with a bite mark for the pots with and without the barrier, respectively. In one of the rounds of validation with waterglass, one pot with a barrier had fallen during the night and the strawberry was found lying on the forest floor (being eaten by an *A. vulgaris*). This pot was removed from the analysis, and the proportion from this night was thus based on 9 pots (instead of 10). The effect of the barrier on the proportion of pots with bite marks was tested with a paired *t*-test, using the two proportions (barrier vs. contol) from each night as replicates (pairs) to account for the dependent samples (i.e. condition affecting passage could vary among nights).

3. Results

In the first experiment (copper foil), slugs in trials without a barrier moved quickly to the opposite side containing the strawberry bait. The proportion of slugs that had passes at 2 h was (mean ± s.e.) 73 ± 12%. After 4 h and onwards, not a single slug had failed to cross the centerline (where the copper foil barrier was positioned in non-control treatments). Three slugs from trials with copper foil were never observed in the area with the strawberry bait, although there were bite marks on the strawberries. These slugs had obviously passed the barrier at least twice and were assigned to have passed between 12 and 14 h (i.e. when bite marks were produced). Copper foil delayed slugs from reaching the strawberry bait, but did not prevents passage. After 2 h, only 16 ± 9% of the slugs had passed, and after 4 h, 31 ± 7%. After 12 and 14 h, the majority of the slugs had passed (71 ± 7 and 91 ± 4%, respectively) (Table 1; Fig. 1a). The width of the copper foil barrier did not affect passage success at any time ($p > 0.05$; Table 1; Fig. 1a). In the second experiment (waterglass), 47 ± 13% slugs in containers without a barrier had passed the centerline to the side with the strawberry fruit after 2 h, 93 ± 7% after 4 h, and all slugs at 12 and 14 h. No slug succeeded in passing a waterglass barrier of any width at any time (Fig. 1b). Air temperature and relative humidity ranged from 13 to 27 °C and from 39 to 91% during the experiment (Table 2).

Table 1
Results from logistic regressions, with slug passage as the dependent variable at different times after experiment start.

Source of variation	Time (h)	β	s.e.	df	p
Copper foil presence	2	−3.16	0.85	1	<0.01
Night		0.64	0.29	1	0.03
Copper foil width	2	−0.17	0.37	1	0.64
Night		0.82	0.40	1	0.04
Copper foil width	4	−0.05	0.28	1	0.86
Night		0.57	0.26	1	0.03
Copper foil width	12	0.58	0.33	1	0.08
Night		0.73	0.30	1	0.01
Copper foil width	14	0.86	0.67	1	0.20
Night		0.66	0.47	1	0.16

Note: For times later than 2 h there was no variation in control treatments (no barrier) in the experiment with copper foil, and no statistical analyses for copper foil presence/absence could be conducted for 4, 12 or 14 h. In the experiment with waterglass, no slugs passed the barrier, and this lack of variation prevented statistical analyses of this barrier type.

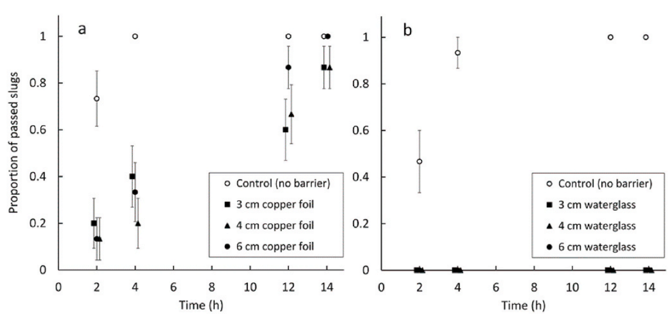

Fig. 1. Mean passage after 2, 4, 12 and 14 h past barriers to slug movement consisting of (a) copper foil and (b) waterglass of different widths. During five nights and for each barrier type, totally 60 slugs were tested individually in containers baited with a strawberry. Error bars indicate ±1 s.e.

In the semi-field validation of the copper foil barrier, (means ± s.e.) 22 ± 9% and 32 ± 9% of the pots with and without copper foil, respectively, had been visited by a large slug during the night as observed by marks on the strawberry (Fig. 2a; paired *t*-test, $t_4 = 1.12$, p = 0.16). In the validation of the waterglass barrier, the corresponding values were 16 ± 3% and 48 ± 10% (Fig. 2b; paired *t*-test, $t_4 = 3.01$, p = 0.02). Thus, copper foil had no statistically significant effect on damage events on the strawberries, whereas waterglass reduced them with more than half.

4. Discussion

Barriers to movement is a potentially efficient method to control slug damage. In this study, we tested the barrier effect of copper foil and waterglass on the movement of the invasive *A. vulgaris*. Waterglass prevented slug passage in a controlled arena setting and more than halved the recorded slug damage events in a field validation test. Copper foil, on the other hand, managed to delay but not prevent slug passage. After a night, no difference in slug passage over copper foil compared to unprotected controls was seen in the arena trials or in the semi-field validation.

Motivation for passage was likely a combination of exploratory movements and a directed movement towards the strawberry fruit, detected by olfaction (Cameron 2016). In the arena experiments, all slugs in containers without a barrier had passed the centerline (barrier position) at the end of the experiment and all but one slug did so in 4 h or less. These movements demonstrate the slugs' capability to explore their surroundings and peruse a food resource also in an unnatural plastic arena. In the validation tests, passage was more likely driven by a directed movement, aimed at the strawberry. Hence, this movement involved the likelihood of a slug first encountering olfactory cues from the strawberry or alternative foods, and then a choice whether or not to move towards it in a series of competing possible events. With other food sources available in a natural setting, an individual slug was probably less likely to attempt to pass the barrier, but on the other hand, more slugs were available to do so than in the controlled container experiment. The real number of slugs attempting to pass, as well as the number of passages prevented by the barrier, remain unknown.

The efficiency of the waterglass barrier can probably be attributed to its alkaline properties. This is supported by previous laboratory

Table 2
Air temperature and relative humidity measured 1 m above the ground before each data collection.

Experiment	Temperature (°C)/relative humidity (%)				
Copper foil					
Date	Start	2 h	4 h	12 h	14 h
20/06 2020	24/46	22/56	20/59	19/56	20/57
21/06	24/36	23/39	20/40	19/42	18/52
22/06	16/79	15/84	13/74	17/74	18/76
24/06	20/39	17/52	15/62	23/62	27/60
25/06	25/48	23/52	18/73	23/61	27/48
Water glass					
16/07 2020	21/63	18/73	14/88	17/76	20/62
17/07	20/57	17/74	16/79	17/79	18/78
18/07	21/62	18/76	16/84	18/68	19/69
19/07	19/62	16/76	15/80	15/67	16/63
20/07	17/69	13/87	11/89	13/64	16/55
Field validation					
Copper foil					
26/06 2020	28/42				25/59
29/06 2020	20/55				20/57
30/06 2020	18/68				16/65
01/07 2020	21/54				18/60
02/07 2020	18/80				20/41
Water glass					
23/07 2020	20/42				17/48
24/07 2020	21/51				17/51
25/07 2020	20/57				21/55
26/07 2020	18/75				18/73
27/07 2020	19/63				19/60

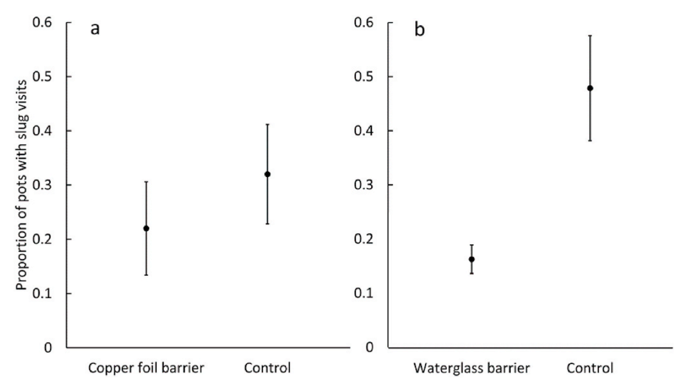

Fig. 2. Field validation of the performance of 3 cm barriers to slug movement. During five consecutive night, 10 pots with and 10 without the barrier was baited with a strawberry fruit and placed in an area with high densities of *Arion vulgaris*. The left panel (a) shows mean proportion of pots visited by slugs in the validation of copper foil and the right panel (b) the validation of waterglass. Error bars indicate ±1 s.e.

experiments where barriers made out of hydrated lime and sulfur, both alkaline materials, reduced feeding and leaf consumption by Florida leatherleaf slug (*Leidyula floridana*) with more than 50% (Capinera 2018). An important question is how long the waterglass can retain its repellant properties when applied as a barrier under different weather conditions.

In the semi-field validation, waterglass barriers had substantially fewer recorded passage events than the control, but still some slugs managed to pass. These passages could have been caused by slugs being able to climb across the barrier on the pots by means of lifting the front of the foot, extending forward, descending and then contracting (i.e., "lope"; Cameron 2016). Perhaps slugs were also aided by surrounding vegetation in this activity. Moreover, for large slugs, it may be easier to pass over a vertical than horizontal barriers, as gravitational forces do not push slugs against the surface under them when climbing upwards or downwards. Indeed, barrier effects from several different materials have been observed to differ between horizontal and vertical application. For example, Schüder et al. (2003) tested a range of barrier materials applied in 3 cm strips to prevent horizontal and vertical movement of *D. panormitanum*, and several of these materials only reduced vertical barrier passage. Copper foil, however, only had an effect on horizontal movements in that study and did not reduce passage in vertical directions.

Copper foil only resulted in delayed passage of *A. vulgaris* in our study, indicating a reluctance to pass that was eventually overcome. This finding was corroborated by direct observations of slugs hesitating and turning at the copper barrier during the trials. This result is similar to those of a previous experiment on passage of *D. reticulatum* (Symondson, 1993) and indicates that copper foil does not constitute an efficient barrier to slug movement, at least not in temperate climates (Kheirodin et al., 2012).

Weather conditions may have affected the results in the semi-field validations. For example in the two separate semi-field tests of copper foil and waterglass, the mean number of visits to the pots in the control treatments (without barriers and identical between the validations) differed and was higher in the test of waterglass than that of copper foil (48 vs. 32%). Probably weather-related difference in overerall slug activity played a role in explaining this difference. It is also possible that weather conditions affected the performance of the barriers. To elucidate this potential effect, further experiments under different weather or irrigation conditions are warranted.

The complete prevention of slug passage across the waterglass barrier in the arena experiment is promising and merits further exploration. Renewed field experiments, perhaps increasing barrier size to prevent potential climbing should further explore the real-life barrier effectiveness of waterglass, preferably testing for potentially deterioting effects of weather events and tear of time on the material's barrier effect. Waterglass places itself together with birch oil (Lindqvist et al., 2010) and medium-high voltage electrical fencing (Laznik et al., 2011) as an experimentally highly efficient barrier solutions to protect horticultural crops from arionid slug damage.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.cropro.2020.105525.

Ethics approval

Not applicable.

Consent for publication

Not applicable.

Availability of data and material

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Code availability

Not applicable.

Authors' contributions

JW and DN conceived and designed the study. JW conducted the experiments. JW and DN analyzed the data. JW and DN wrote the manuscript.

References

Antzée-Hyllseth, H., Trandem, N., Torp, T., Haukeland, S., 2020. Prevalence and parasite load of nematodes and trematodes in an invasive slug and its susceptibility to a slug parasitic nematode compared to native gastropods. J. Invertebr. Pathol. 107372.

Brozinic, K., 2020. Bekämpa mördarsniglar – 12 metoder som fungerar! Allt om trädgård. Last visited on 26 August 2020. https://www.alltomtradgard.se/tradgard/skadedjur-vaxtsjukdomar/bekampa-mordarsniglar/.

Cameron, R., 2016. Slugs and Snails. The New Naturalist Library. HarperCollins Publishers, London, UK.

Capinera, J.L., 2018. Assessment of barrier materials to protect plants from Florida leatherleaf slug (Mollusca: Gastropoda: Veronicellidae). Fla. Entomol. 101, 373–381.

Cowie, R.H., Robinson, D.G., 2003. Pathways of introduction of nonindigenous land and freshwater snails and slugs. In: Ruiz, G.M., Carlton, J.T. (Eds.), Invasive Species: Vectors and Management Strategies. Island Press, Washington DC, USA, pp. 93–122.

Frank, T., 1998. Slug damage and numbers of the slug pests, *Arion lusitanicus* and *Deroceras reticulatum*, in oilseed rape grown beside sown wildflower strips. Agric. Ecosyst. Environ. 67, 67–78.

Grimm, B., 2002. Effect of the nematode Phasmarhabditis hermaphrodita on young stages of the pest slug *Arion lusitanicus*. J. Molluscan Stud. 68, 25–28.

Grimm, B., Paill, W., 2001. Spatial distribution and home-range of the pest slug *Arion lusitanicus* (Mollusca: Pulmonata). Acta Oecol. 22, 219–227.

Grimm, B., Paill, W., Kaiser, H., 2000. Daily activity of the pest slug *Arion lusitanicus* Mabille. J. Molluscan Stud. 66, 125–130.

Kheirodin, A., Damav, M.R., Sarailoo, M.H., 2012. Mineral oil as a repellent in comparison with other control methods for citrus brown snail, *Caucasotachea lencoranea*. Afr. J. Agric. Res. 7, 5701–5707.

Knop, E., Rindlisbacher, N., Ryser, S., Grüebler, M.U., 2013. Locomotor activity of two sympatric slugs: implications for the invasion success of terrestrial invertebrates. Ecosphere 4, 1–8.

Kozlowski, J., 2000. Reproduction of *Arion lusitanicus* Mabille, 1868 (Gastropoda: Pulmonata: Arionidae) introduced in Poland. Folia Malacol. 8, 87–94.

Kozlowski, J., 2007. The distribution, biology, population dynamics and harmfulness of *Arion lusitanicus* Mabille, 1868 (Gastropoda: Pulmonata: Arionidae) in Poland. J. Plant Protect. Res. 47, 219–230.

Langlet, M., 2008. Vi testar snigelfällor. Koloniträdgården. Last visited on 26 August 2020. http://www.snigel.org/pdf/snigelartikel%20koloni.pdf.

Laznik, Z., Krizaj, D., Trdan, S., 2011. The effectiveness of electrified fencing using copper electrodes for slug (*Airon* spp.) control with direct electric current and voltage. Spanish J. Agric. Res. 9, 894–900.

Laznik, Ž., Trdan, S., 2016. Is a combination of different natural substances suitable for slug (*Arion* spp.) control? Spanish J. Agric. Res. 14, 20.

Lindqvist, I., Lindqvist, B., Tiilikkala, K., 2010. Birch tar oil is an effective mollusc repellent: field and laboratory experiments using *Arianta arbustorum* (Gastropoda: Helicidae) and *Arion lusitanicus* (Gastropoda: Arionidae). Agric. Food Sci. 19, 1–12.

Nyqvist, D., Hedenberg, F., Calles, O., Österling, M., von Proschwitz, T., Watz, J., 2020. Tracking the movement of PIT-tagged terrestrial slugs (*Arion vulgaris*) in forest and garden habitats using mobile antennas. J. Molluscan Stud. 86, 79–82.

Proschwitz, T. von, 1997. *Arion lusitanicus* Mabille *and A. rufus* (L.) in Sweden: a comparison of occurrence, spread and naturalization of two alien slug species. HELDIA 4, 137–138.
Quinteiro, J., Rodríguez-Castro, J., Castillejo, J., Iglesias-Piñeiro, J., Rey-Méndez, M., 2005. Phylogeny of slug species of the genus Arion: evidence of monophyly of Iberian endemics and of the existence of relict species in Pyrenean refuges. J. Zool. Syst. Evol. Res. 43, 139–148.
Schüder, I., Port, G., Bennison, J., 2003. Barriers, repellents and antifeedants for slug and snail control. Crop Protect. 22, 1033–1038.
Symondson, W.O., 1993. Chemical confinement of slugs: an alternative to electric fences. J. Molluscan Stud. 59, 259–261.
Watkins, R., Mosson, H., Gurney, J., Cowan, D., Edwards, J., 1996. Cinnamic acid derivatives: novel repellent seed dressings for the protection of wheat seed against damage by the field slug, Deroceras reticulatum. Crop Protect. 15, 77–83.
Zemanova, M.A., Knop, E., Heckel, G., 2016. Phylogeographic past and invasive presence of *Arion* pest slugs in Europe. Mol. Ecol. 25, 5747–5764.