Floral Herbivory of an Invasive Slug on a Native Weed

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Abstract

Honěk A., Martinková Z. (2014): **Floral herbivory of an invasive slug on a native weed**. Plant Protect. Sci., **50**: 151–156.

Effects of floral herbivory (grazing flowers) by slugs on production and quality of seeds of herbaceous plants have been rarely quantified. We studied consequences of grazing by an invasive slug *Arion lusitanicus* (Mabille) for inflorescences of dandelion (*Taraxacum officinale* Weber ex Wiggers). In May 2008, a grassy site in Prague-Ruzyně (Czech Republic) was densely populated by dandelion inflorescences. Of the 40% of the flowers grazed by the slug, 70% died before seed dispersal and seed was eaten from 10% of the closed mature inflorescences. Viability of seeds from inflorescences that survived slug grazing was not affected. In addition to seedling predation, grazing of flowers may be an important source of dandelion mortality at sites where this slug is abundant.

Keywords: *Arion lusitanicus*; *Taraxacum officinale*; flower; inflorescence; seed; viability; germination

Crops are attacked by a complex of enemies, including animal pests and weeds. The latter impair the growth of crop plants and interact with one another. Invasion of an area by a herbivore thus may endanger not only cultivated plants but also their weedy antagonists. An example of conflict between an alien and a long established species is that of the invasive slug *Arion lusitanicus* Mabille (Arionidae) and the common weed, dandelion *Taraxacum officinale* Weber ex Wiggers (Asteraceae).

Arion lusitanicus (= *Arion vulgaris* Moquin-Tandon) is a west European species probably originating from the north of the Iberian Peninsula (Quintero *et al*. 2005). It spread throughout Europe and became established in the Czech Republic in 1991 (Horsák & Dvořák 2003). *Arion lusitanicus* has one generation per year, and lays its eggs in late summer, which hatch partly autumn (Briner & Frank 1998; Kozlowski & Kozlowski 2000), partly early the following spring (Grimm 2001). Juveniles of this slug feed on a number of host plants (Kozlowski & Kozlowska 2000) and consumption increases with increase in size of the slug until late summer (Honek & Martinkova 2007). The slugs prefer dense grassy stands from where they disperse into surrounding agricultural crops (Frank 1998; Grimm & Paill 2001; Honek & Martinkova 2011). Their selective grazing can change the composition of species in natural plant stands (Keller *et al*. 1999; Frank 2003; Buschmann *et al*. 2005; Lanta 2007). Populations of *A. lusitanicus* exterminate dandelion seedlings (Honek *et al*. 2009) and weaken mature plants.

Dandelion is a common perennial herb which colonises disturbed habitats (Novák 1994) and may survive for a long time in permanent stands, particularly grassland. Because their prostrate leaf rosettes are less likely to be damaged by livestock grazing and cutting than the surrounding grass (Gaisler *et al*. 2006), dandelions may gradually dominate stands. Flowering occurs throughout the vegetative season but mostly during spring (von Hofsten 1954) when more than 90% of the flowers are produced (Honek *et al*. 2005), flowering continues for 2 days to 3 days (Beach 1939; Gray *et al*. 1973; Martinkova & Honek 2008), and flowers in good weather open after sunrise and close at sunset (Percival 1955; Jenniskens *et al*. 1984).

Floral herbivory is an important factor that decreases reproduction success of herbaceous plants

Supported by Ministry of Agriculture of the Czech Republic, Project No. MZE RO0414.

(Louda & Potvin 1995). Important herbivore species damaging generative and vegetative parts of flowers belong to insect orders of Coleoptera, Diptera, Lepidoptera, and Hymenoptera (Ehlers & Olesen 2003; Bienkowski 2010; Kosinski 2013; McCall *et al*. 2013; Toth *et al*. 2013). In contrast to well-studied insect herbivory, floral herbivors of other invertebrate taxa are less studied. Although floral herbivory of slugs is common, well known, and economically importantant (Capello & Ugolini 1979; Alford 1991; Sannino *et al*. 2006), its consequences for host plant reproduction raised little attention. This is because the attention is mainly paid to aesthetic damage which destroys economic value of the flowers and the interest in this phenomenon ends with damage which is difficult to prevent (Ester *et al*. 2003). Few studies in natural habitats (Muir 1997) indicated important effects of floral herbivory on plant population biology. Our concern for slug floral herbivory issued from a case study. *Arion lusitanicus* was occasionally observed at a grassy site where, unlike other slug species (Breadmore & Kirk 1998), it caused massive grazing on dandelion flowers and maturing capitula. In this paper we describe this new aspect of the interaction between *A. lusitanicus* and dandelion, and its consequences for the viability of dandelion seed.

MATERIAL AND METHODS

Slug grazing on dandelion flowers was recorded in an area of grassland with a dense growth of dandelions (Prague-Ruzyně, 50°05'08.156"N, 14°17'50.243"E, 340 m a.s.l.) over a period of several days from May 6–20, 2008. Average number of flowers produced in the spring flowering period (at this location April 14–May 24, 2008) at the experimental site was 98.5 per m^2 (Martinkova and Honek unpublished.). The percentage of flowers damaged was recorded on May 8 and 13 in a 15 × 15 m plot. Recorded were capitula on the last day of flowering, recognised by the withered appearance of the florets, which were not likely to open on the next day. The flowers were classified (Figure 1) as having no damage, little damage (less than 1/2 of the length of floret ligulae eaten), and considerable damage (more than 1/2 of the length of ligulae eaten). Consequences of slug feeding was established on May 9, by marking 25 heavily damaged and 25 intact inflorescences, at the last day of their flowering. Each was labelled by placing a wire ring around the base of the peduncle and a wooden label indicating the position of the plant. Inflorescences that survived to seed dispersal were recorded and their seed collected on May 19–23. Damage to maturing seeds was established on May 19 when numbers of capitula showing no damage, little damage (involucrum damaged, some of the seeds eaten), and considerable damage (seeds completely eaten) were recorded. Slug abundance was determined on May 25, by recording all the individuals present in twenty 0.25 m^2 plots randomly located in the area where inflorescence damage was recorded. Slugs were counted by careful checking of ground surface and herbaceous vegetation, at sunset after a mild rain. Live mass of slugs was determined on May 7 and May 28, with a precision of 0.01 g.

Effect of simulated damage was studied at a nearby grassland site (50°07'07.801"N, 14°18'22.273"E) where there were no slugs. Fifty inflorescences were marked on May 9, of which 25 were intact controls and 25 had their florets cut (on May 9) to 1/3 of their original length thus simulating considerable damage. Seeds produced by these inflorescences were collected at seed dispersal, on May 20–23.

Germination experiments established differences in the percentage and time to germination of seed from damaged and intact capitula. The seeds were stored in paper bags at 25°C and 40% relative hu-

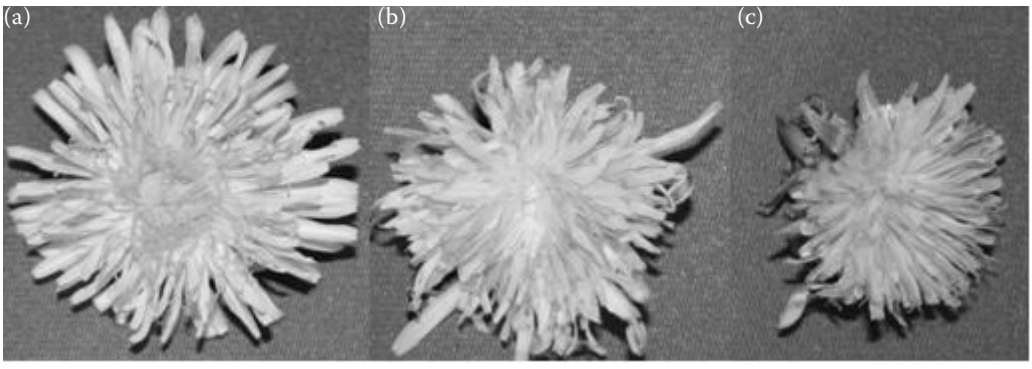

Figure 1. Damage to dandelion flowers: (a) no damage, (b) little damage, and (c) considerable damage (Photo J. Kohoutová)

Figure 2. Young *A. lusitanicus* grazing a dandelion flower on May 6, 2008 (Photo J. Martinek)

midity until germination. A sample of 50 seeds was taken from each of the inflorescences, weighed to 0.01 mg, put in a Petri dish (9 cm diameter, 1 cm high) lined with filter paper (Filtrak®) moistened with 2 ml of tap water and kept (June 16) at 17°C and a 18 h light : 6 h dark photoperiod. Germinating seeds were counted daily until no germination occurred for 3 days.

For each sample of 50 seeds, time to germination of 50% of the seeds that germinated (T_{50}) was calculated using probit transformed data. Average seed mass, germination percentage, and T_{50} were calculated for each set of experimental capitula, (*i*) intact and (*ii*) grazed by slugs, (*iii*) control and (*iv*) artificially damaged. The data were tested for normality and homogeneity of variance and the differences between sets (*i*) and (*ii*), and sets (*iii*) and (*iv*) tested using *t*-test or, if the normality or homogeneity test failed, using Mann-Whitney Rank Sum Test. Percentage data were arcisn transformed. The calculations were made using SigmaStat® (Systat Software 2006).

RESULTS

Slugs eating dandelion flowers were first observed on May 6, 2008 (Figure 2) and then until the end of flowering in late May. Up to four slugs were recorded on one inflorescence eating floret ligules. Slugs were abundant (49.0 ± 8.16 slugs/m^2) and they were small (0.44 ± 0.031 g on May 7 increased to 0.85 ± 0.057 g on May 28). Grazing on flowers was limited to about 1 h between 18:30 (Central European Time) when the slugs climbed up into the inflorescences and 19:30 when the inflorescences closed at sunset. Slugs damaged more than one third of the flowers (Figure 3). In marked contrast to healthy capitula, which all produced seed, 18 of 25 (72%) damaged capitula died before seed dispersal because their peduncles dried out or decayed. Of the capitula that survived to the flowering stage ca. 10% (Figure 3) were damaged by slugs eating through their bracts and consuming the seeds (Figure 4). Simulating grazing by cutting floret ligulae proved to be less damaging than slug grazing. Only 3 of 25 (12%) artificially damaged inflorescences died while all the intact inflorescences produced seed.

In all aspects but one there was no effect of grazing on seed quality. Grazing did not affect seed weight

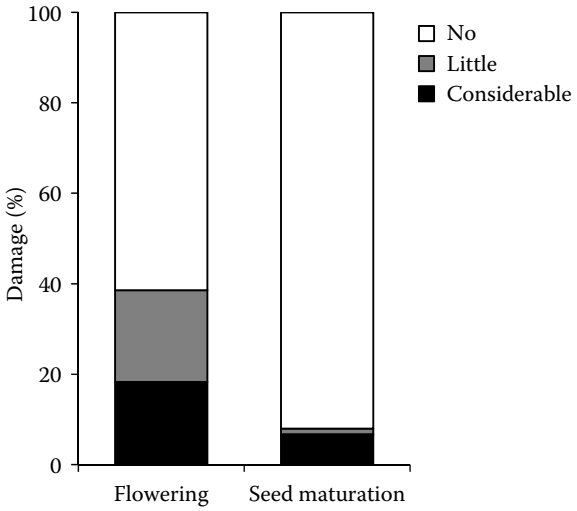

Figure 3. Percentage of capitula damaged during flowering (May 8 and May 13, 2008, *n* = 547) and seed maturation (May 19, 2008, *n* = 239). Classification of damage – see Figure 1)

Figure 4. A closed capitulum from which maturing seed was eaten by *A. lusitanicus*. On several occasions slugs were found in the cavity eaten into the capitulum (Photo J. Kohoutová)

(grazed: 0.51 ± 0.025 mg, n = 7; intact: 0.53 ± 0.017 mg, n = 25; $P_{\text{Mann-Whitney}}$ = 0.553; U = 74.000) and T_{50} (grazed: 4.4 ± 0.16 days; intact: 4.7 ± 0.32 days; P_t = 0.344; t = –0.962), and insignificantly decreased percentage germination (grazed: 81.7 ± 12.99%; intact: 91.2 ± 1.75%; $P_{\text{Mann-Whitney}}$ = 0.783; U = 81.000). Simulated grazing did not affect seed weight (damaged: 0.43 ± 0.024 mg, n = 25; control: 0.46 ± 0.016 mg, n = 25; $P_{\text{Mann-Whitney}}$ = 0.741; U = 330.000) and T_{50} (damaged: 4.1 ± 0.15 days; intact: 3.8 ± 0.14 days; P_t = 0.129; t = –1.546), but the percentage germination of the seed of damaged inflorescences with cut florets (81.0 ± 2.97%) and intact control (94.1 ± 1.46%) differed significantly (P_t < 0.001; t = 4.204).

DISCUSSION

The grazing of vegetative parts of dandelion by slugs (Frank & Friedli 1999; Kozlowski & Kozlowska 2000; Kozlowski & Kaluski 2004) is well documented but the eating of flowers has largely escaped attention. In the British grassland (Breadmore & Kirk 1998), dandelion flowers were avoided although slugs, *Deroceras reticulatum* (Müller) and *Arion ater* (L.), were dominant floral herbivores. The reason of high floral herbivory in this study was possibly the coincidence in time of populations of palatable flowers and a plenty of *A. lusitanicus*. More than 50% of the slugs present at the experimental site of the present study aggregated in the flower heads during the one hour when they were available to the slugs. Most of the slugs thus appear to have been attracted to climb up to the flowers possibly by their smell, sugar content (Szabo 1984) or a relatively large size.

Slugs influence weed populations in several aspects – as seed, seedling, and mature plant consumers (Kozlowski & Kozlowska 2000; Honek *et al*. 2009) and vectors of seed dispersal (Calvino-Cancela & Rubido-Barrá 2012, Blattmann *et al*. 2013; Türke & Weisser 2013). The food preferred by slugs are seedlings (Fenner *et al*. 1999). At the experimental site slugs ate > 90% of the dandelion seedlings presented for consumption in baits, in spring and summer usually within 1–3 days of their presentation (Honek *et al*. 2013). *Arion lusitanicus* and, in the autumn, *Deroceras* spp. were the main consumers of these seedlings (Honek *et al*. 2009). However, grazing of flowers may also be an important cause of mortality. In our experiment it killed up to 50% of the seeds in the pre-dispersal stage. Grazing of flowers not only occurs in spring. In another experiment at an adjacent site, of the 42 inflorescences labelled in late August peduncles of 6 (14%) were eaten through, probably by slugs, and the capitula of 2 (5%) showed symptoms of grazing by *A. lusitanicus* (Honek and Martinkova unpublished). Slug grazing on dandelion flowers is probably limited by the poor synchrony between the daytime opening of flowers and nocturnal feeding activity of slugs. Dandelion flowers also remain closed on rainy days when *A. lusitanicus* are active. At our study site the slugs that climbed up to the dandelion inflorescence had only 1 h to graze the open flowers. This probably protected dandelion flowers from heavier predation.

The encounter between an invasive slug and an established plant species resulted in an antagonistic relationship that importantly decreased the fecundity of the plant. Dandelion is occasionally an important weed of lawns and pastures. Thus the invasion of *A. lusitanicus*, whose pest status is indisputable, may also have a positive effect, namely the biological control of a weed.

Acknowledgements. We thank Mrs. J. Kohoutová, Mrs. L. Kreslová, and Mrs. H. Uhlířová for excellent technical assistance

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Received for publication October 31, 2013
Accepted after corrections January 2, 2014

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