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Grazing Behaviour of Slugs (Gastropoda: Arionidae, Agriolimacidae) on the Aboveground and Underground Organs of Potato Plants

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Abstract

The extent of damage caused by slugs depends on factors such as the slug species, the plant cultivar and the organ on which the slugs feed. Three experiments were performed in laboratory conditions on leaves and wounded and unwounded potato tubers of three potato cultivars exposed to the slugs *A. vulgaris*, *A. rufus* and *D. reticulatum*. We calculated the rate and extent of plant damage caused by the species studied and identified differences in the susceptibility of potato cultivars to slug grazing and the effect of mechanical injury to tubers on the grazing activity and the extent of damage.

Keywords *Arion rufus* · *Arion vulgaris* · *Deroceras reticulatum* · Leaves and tubers · Pest/invasive species · Potato cultivars

Introduction

Slugs are among the most common pests occurring in potato crops. Alongside winter oilseed rape and cereals, potato plants are heavily damaged by these pests, especially in the temperate climate zone (South 1992). *Deroceras reticulatum* (Müller) is the most common species found in potato crops as well as other agricultural plants. Substantial damage is also caused by other slugs of the genus *Deroceras (D. laeve* (Müller) and *D. panormitanum* (Lessona & Pollonera)) and by slugs of the genera *Tandonia* (*Tandonia budapestensis* (Hazy)) and *Milax (Milax gagates* (Draparnaud) and

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M. sowerbyi (Férussac)). Some potato crops are also affected by slugs of the genus *Arion*, such as *Arion vulgaris* (Moquin–Tandon), previously known in central and north-western Europe under the incorrect name *Arion lusitanicus* (Mabille) (Welter-Schultes 2012), *A. rufus* (Linnaeus), *A. distinctus* (Mabille) and *A. hortensis* (Férussac). Much less common species include *A. subfuscus* (Draparnaud), *A. circumscriptus* (Johnston), *A. silvaticus* (Lohmander) and *A. fasciatus* (Nilsson) (Gould 1965; Pinder 1974; Airey 1987; South 1992; Ester and Trul 2000; Meredith 2003; Howlett 2012).

Damage caused by slugs is particularly severe in regularly irrigated small-scale potato crops. The high humidity of soil in such cultivations creates favourable conditions for the development of these pests and their grazing (Stephenson 1965; Meredith 2003). Slugs may feed on every organ of the potato, but the most severe damage is sustained by tubers (Port and Port 1986; Beer 1989; South 1992; Ester and Trul 2000; Meredith 2003). Damage to the aboveground parts of plants directly after the emergence and development of the first leaves significantly weakens the plant (Hunter et al. 1968). Substantial damage is also done to leaves and shoots in further plant development stages. Underground slugs sometimes feed on seed potatoes directly after planting and during sprouting; later, they attack new forming tubers. Damage leading to severe economic losses occurs in the final stage of tuber growth and maturation, shortly before harvest (Winfield et al. 1967; Pinder 1974; South 1992). Slugs make holes and tunnel out cavities in tubers, eating their flesh, which reduces the market value of the potatoes. Slugs often attack tubers which have been damaged by other pests, such as cutworm caterpillars (*Agrotis segetum*, *A. exclamationis*, *A. ipsilon*, Noctuidae) and wireworm larvae (*Ectinus aterrimus*, *Agriotes lineatus*, *A. obscurus*, *A. sputator*, Elateridae), which make small holes in the tuber skin (Alyokhin et al. 2012). These injuries make it much easier for slugs to feed on potato tubers. Another problem is damage sustained by tubers during transportation, storing and conservation. During potato harvesting, especially under humid conditions, slugs are transported in soil clods into storage facilities (Ester and Trul 2000). Research conducted by Beer (1989) in 1987–1988 showed that almost 70% of the stored tubers were affected by slugs. The greatest damage occurs in the first few weeks of storage (Bus and Ester 1996) and the tubers wounded during harvesting are damaged first (Ester and Trul 2000). It is believed that unwounded tubers are not damaged by some slug species, such as *D. reticulatum* (Pinder 1974; Johnston and Pearce 1994; Ester and Trul 2000). According to Airey (1987), the tuber skin of some potato cultivars contains alkaloids, which have a deterrent effect on *M. budapestensis*, *A. hortensis* and *D. reticulatum*. Ester and Trul (2000) have found that fresh corky tissue formed in wounded tubers can significantly reduce the damage inflicted by *D. reticulatum*, although it does not eliminate it altogether.

The susceptibility of different potato cultivars to slug damage is another important aspect to be addressed. Research has shown significant differences in the extent of damage caused by some slug species to various cultivars (Thomas 1947; Gould 1965; Winfield et al. 1967; Pinder 1974; Ester and Trul 2000). The reasons behind the varying susceptibility have not been fully investigated. Alkaloid content certainly affects slug activity and the extent of plant damage, due to the fact that it can inhibit slug grazing (Airey 1987). Another important factor is climatic conditions in the final stage of tuber growth. As reported by some authors, late potato cultivars which mature during wet autumns and are harvested late in the year (Runham and Hunter 1970; Warley 1970; South 1992) are most vulnerable to damage. Knowledge on differences in the

susceptibility of potato cultivars to various slug species and the reasons behind this variability may have important practical implications, being potentially useful in selecting cultivars to be grown in areas endangered by these pests. It is also crucial to assess the risk of damage to stored potato tubers caused by these slug species.

This paper describes laboratory experiments on damage caused by the slugs *A. vulgaris*, *A. rufus* and *D. reticulatum* to various organs of plants of three potato cultivars. *D. reticulatum* is a common species, especially in central Europe (Wiktor 2000). The slug is a dangerous pest on agricultural and horticultural crops (South 1992). It is up to 4.5 cm long. Its maximum age is 9–12 months, and it has one or two overlapping generations per year (Shirley et al. 1998). Each slug lays up to 700 eggs in clutches with 10–20 eggs per clutch. The peak densities of *D. reticulatum* occur from late summer to early autumn during the emergence of winter crops. *A. vulgaris* is the most important invasive slug species in Europe, whereas *A. rufus* is a native species in Western Europe and part of central and northern Europe (Wiktor 1973; Welter-Shultes 2012). They are up to 12 and 15 cm long, respectively. They live for about 1 year and have one generation per year. They are serious pests, damaging vegetables, agricultural crops and ornamental plants. On average, they lay 400 and 415 eggs, respectively, in clutches with 12–124 and 20–230 eggs per clutch, respectively (Kozłowski 2007, 2012). The peak densities of *A. vulgaris* occur from the middle of August to the second half of October, partly corresponding with the egg-laying period, whereas for *A. rufus*, the peak densities occur from late June or early July until early September (Kozłowski 2012).

We performed laboratory research on damage caused by the slugs *A. vulgaris*, *A. rufus* and *D. reticulatum* to various organs of three potato plant cultivars. Other authors' studies on damage to potato plants caused by slugs have not included the species *A. vulgaris* and *A. rufus* or currently grown potato cultivars. We carried out research on cultivars listed in the official register of crop cultivars in Poland, which have been commonly grown for several years. These cultivars are characterised by high fecundity and resistance to potato wart disease (*Synchytrium endobioticum* Schilb.) and potato cyst nematode (*Globodera rostochiensis* Woll.). Their resistance to slugs has not previously been investigated. The aim of the study was to investigate the degree of damage to potato leaves and tubers (injured mechanically and non-injured) and to assess the sensitivity of valuable cultivars to damage caused by *D. reticulatum* and other slugs.

Materials and Methods

Slugs and Plants Used in the Experiment

Young specimens of slugs were collected from horticultural crops in the vicinity of Poznań (*D. reticulatum* and *A. vulgaris*) and Nakielno (*A. rufus*) at the end of May 2016. Prior to the experiment, the slugs were kept in containers filled with humid soil at 16 °C and with a photoperiod of 12/12 h (day/night cycle). The slugs were fed on Chinese cabbage leaves, carrot roots and wheat bran with the addition of calcium carbonate. Food was changed twice a week. Prior to the experiment, the slugs were placed in water for 30 s to balance their hydration. The slugs were weighed after being starved for 24 h in containers filled with moist filter paper, and individuals with the most similar weight were selected within each species.

In the experiment, we used tubers of three potato cultivars from commercial cultivations, with sizes from 5.0 × 3.0 to 6.5 × 4.0 cm. Two mid-early cultivars (Vineta and Ditta) and one mid-late cultivar (Yelly) were used in the study. The tubers were harvested manually and checked for injuries. Undamaged tubers were kept at 6 °C. The experiments were conducted in a climate chamber, at 17 °C, RH 70% ± 3%, and with a photoperiod of 12/12 h (day/night cycle). We conducted three single-factor experiments on aboveground potato organs and three two-factor experiments with a 3 × 2 factorial design on potato tubers. The design structure of all experiments was completely randomised.

The experiments on the aerial organs of potato plants were carried out in plastic containers measuring 26 × 26 × 20 cm, where the RH was 85–90%. Tubers were planted in soil in the containers, three tubers of one cultivar per container, with five replications for each of the three cultivars: two mid-early (Vineta and Ditta) and one mid-late (Yelly). The containers had ventilation openings 3 cm in diameter covered with polyamide gauze. When the tubers sprouted and two leaves emerged on the main shoots, one slug was placed in each container. Each experiment was performed for a single species of slugs. The mean weights of the slugs were as follows: *D. reticulatum,* 0.86 g; *A. vulgaris*, 3.11 g; *A. rufus*, 3.42 g. In each experiment, damage to plants (leaves and shoots) was assessed for 15 days on a five–point scale: 0 (no damage), 25, 50, 75 and 100 (percentage of plant surface damaged). Three observations were made for each container every 2 days. The observations were made every morning between 8.00 and 10.00 h. The mean percentage of damage to plants was calculated and the data were statistically analysed. We performed a MANOVA multivariate analysis of variance and, for each experiment separately, a univariate ANOVA and Fisher test at the significance level $\alpha = 0.05$.

In the experiments with tubers of three potato cultivars (Vineta, Ditta and Yelly—factor A), we used undamaged (healthy) and mechanically injured tubers (factor B). The tubers were injured by removing a disc-shaped fragment of the skin tissue, 1.0 cm in diameter (one disc per tuber). The tubers were weighed and placed separately in containers (22 × 16 × 10 cm) in a 5-cm layer of humid soil covered with plastic mulch. The injured tubers were placed with the damaged side facing up. Subsequently, one slug was placed in each container. Three such experiments were conducted, one for each species of slug, with the following average body weights: *D. reticulatum,* 0.54 g; *A. vulgaris*, 2.83 g; *A. rufus*, 2.67 g. Ten replications of the experiment were performed for each AB combination. For the next 7 days, we assessed the location and number of injuries to tubers, the mass of the tubers and the weight of the slugs. MANOVA multivariate analysis of variance was used to interpret the results of the three two-factor experiments, and for each day of the experiment, we performed separate ANOVA analysis and Fisher tests at the significance level $\alpha = 0.05$. Linear regression analysis with consumed potato mass as response variable and weight change of slug as explanatory variable was performed. All calculations were made using STATISTICA v. 12 software.

Results

Damage to Leaves and Shoots

Slugs of the species *A. vulgaris* caused damage to the aboveground and underground plant organs. They first damaged the leaves and shoots, then tubers. From the third day

on, they fed on the flesh of Vineta tubers, and from the seventh day on the flesh of the other two cultivars. *A. rufus* and *D. reticulatum* damaged only the aboveground parts of plants. The rates of increase in damage to aboveground plant organs caused by *A. vulgaris*, *A. rufus* and *D. reticulatum* are shown in Figs. 1, 2 and 3.

The multivariate analysis of the damage to aboveground plant organs caused by *A. vulgaris* did not show significant differences between the cultivars ($p = 0.735$). Similarly, no significant differences were found in the successive days of observation (Fig. 1) ($p_i > 0.326$ for days $i = 1, 3 \ldots 15$). After 1 week, the damage inflicted to leaves and shoots of the three potato cultivars ranged from 21.7 to 23.3%. After 15 days, the most severely damaged parts were the aboveground organs of the cultivar Yelly (40%), and the least-damaged cultivar was Vineta (28.3%). However, the differences were not significant.

In the case of *A. rufus*, the most severe damage was also sustained by the aboveground organs of Yelly plants (Fig. 2). Multivariate MANOVA analysis showed significant differences in the extent of damage among the cultivars ($p = 0.002$). In the univariate analyses, significant differences between damage to different cultivars were observed on the first, third, ninth and fifteenth day of observation ($p_1 = 0.031$, $p_3 = 0.020$, $p_9 = 0.039$, $p_{15} = 0.015$ and $0.050 < p_i < 0.204$ for $i = 5, 7, 11, 13$). From the seventh day on, the cultivar which sustained the most severe damage was Yelly. After 15 days, damage to plants of this cultivar caused by *A. rufus* was 61.7%, compared with 58.3% for Vineta and 48.3% for Ditta.

In the case of *D. reticulatum*, the multivariate analysis did not show significant differences ($p = 0.561$). The ANOVA analyses showed significant differences only on the third day of the experiment (Fig. 3) ($p_3 = 0.035$, $p_5 > 0.050$, $p_i > 0.121$ for $i = 1, 7, 9 \ldots 15$). It is notable that the most severe damage was sustained by plants of cultivar

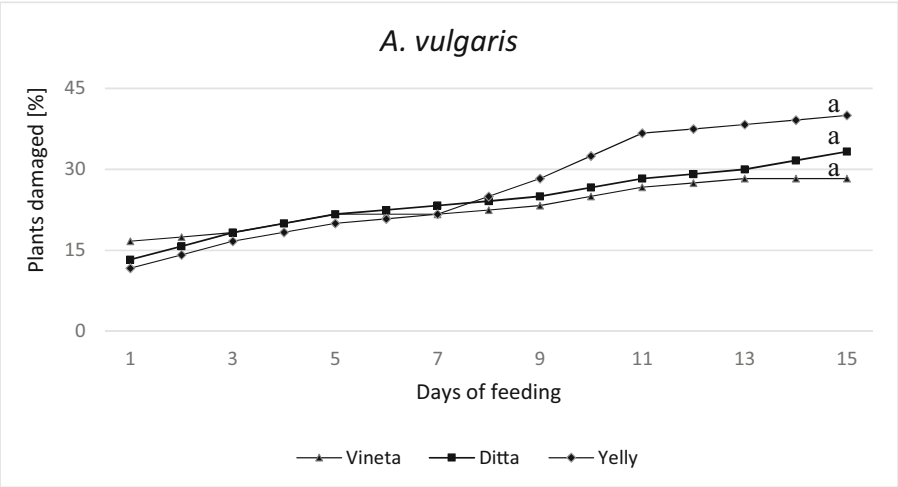

Fig. 1 The extent of damage to aboveground potato organs (%) caused by *Arion vulgaris* and Fisher test results at $\alpha = 0.05$ (series marked with the same letter do not differ significantly)

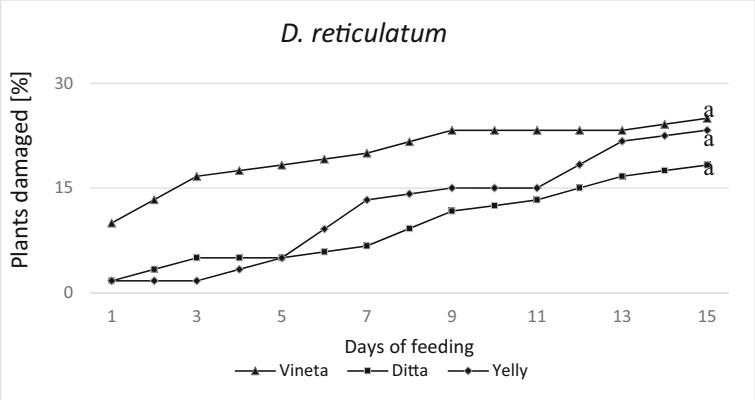

Fig. 2 The extent of damage to aboveground potato organs (%) caused by *Arion rufus* and Fisher test results at $\alpha = 0.05$ (series marked with the same letter do not differ significantly)

Vineta throughout the observation period. After 15 days of grazing by *D. reticulatum*, the extent of plant damage ranged from 18.3% for Ditta to 25% for Vineta.

Damage to Tubers

A. vulgaris, *A. rufus* and *D. reticulatum* fed on all of the artificially wounded tubers of the three potato cultivars at the injury sites (Fig. 4). In some artificially wounded tubers, slugs also attacked other parts of the tuber, causing new damage. *A. vulgaris* inflicted the most severe damage to potatoes of cultivar Yelly, preferring healthy (initially undamaged) tubers. The slug caused less damage to Ditta; however, it preferred artificially wounded tubers to healthy ones. *A. rufus* caused most damage to Vineta

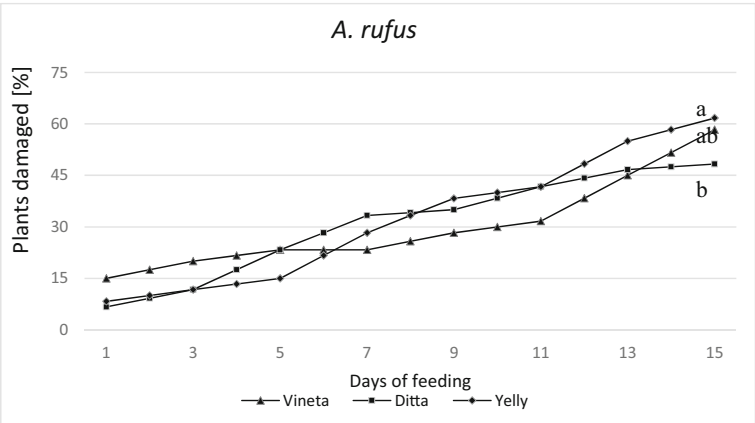

Fig. 3 The extent of damage to above-ground potato organs (%) caused by *Deroceras reticulatum* and Fisher test results at $\alpha = 0.05$ (series marked with the same letter do not differ significantly)

and Ditta, preferring healthy tubers. This species caused less damage to tubers of cultivar Yelly, especially healthy ones. *D. reticulatum* caused the most severe damage to the artificially wounded Yelly tubers. For this slug, we observed a marked difference between the extent of damage done to artificially wounded and healthy tubers, regardless of the cultivar, but no significant differences were found. *D. reticulatum* preferred previously injured tubers; more than a half of the healthy tubers were not attacked by the slug.

The Effect of Slug Grazing on the Weight of Tubers

The analysis of changes in the weight of slugs and tubers on the successive days of grazing showed significant positive correlation of these variables for *A. vulgaris* and *A. rufus* ($p < 0.0001$) (Figs. 5 and 6). No such correlation was found for *D. reticulatum* ($p = 0.219$) (Fig. 7).

The multivariate analysis of the extent of damage to potato tubers of three cultivars (Vineta, Ditta and Yelly—factor A) wounded and unwounded (factor B) caused by *A. vulgaris* did not show any interactions ($p = 0.663$). What is more, no significant differences were found for factors A and B ($p = 0.268$ and $p = 0.868$, respectively). In the univariate analyses for the consecutive days of observation, significant differences in the tuber mass consumed were found for the three cultivars (Table 1). *A. vulgaris* slugs generally preferred to consume tubers of cultivars Vineta and Ditta, rather than Yelly

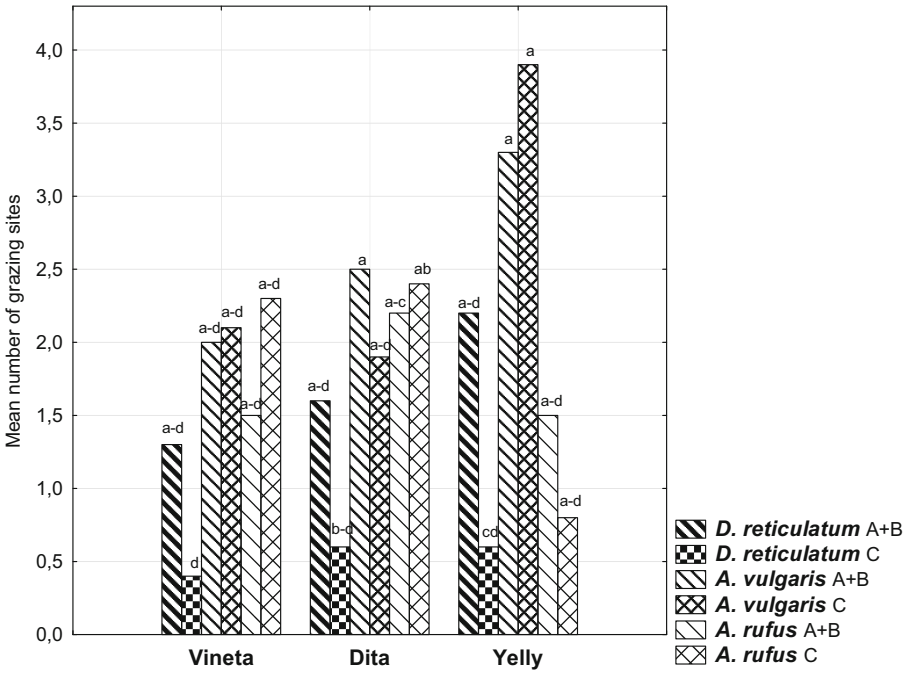

Fig. 4 Mean number of grazing sites on artificially wounded and unwounded tubers; A—artificially damaged tubers, grazing at wounded sites + B—artificially damaged tubers, grazing at unwounded sites; C—healthy, undamaged tubers, and results of nonparametric chi-square test—columns marked with at least one same letter do not differ significantly, $\alpha = 0.05$ (e.g., a–d denotes abcd)

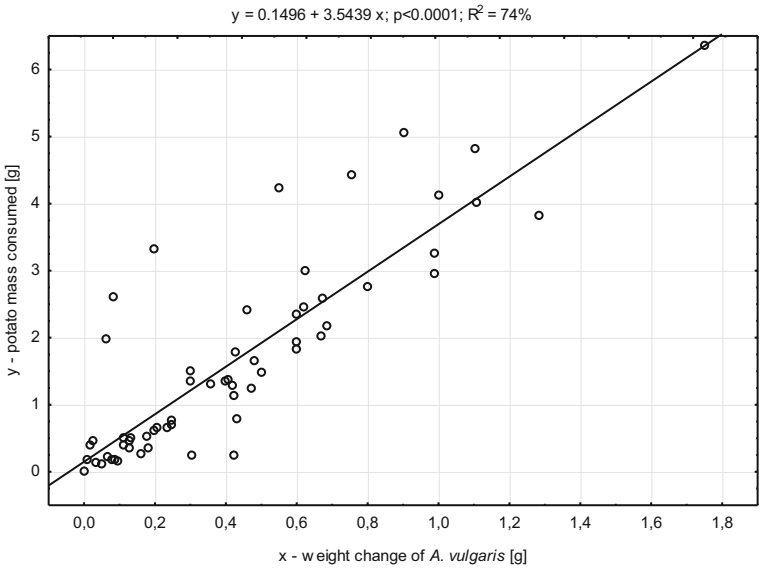

Fig. 5 Correlation diagram: *Arion vulgaris* body weight versus the mass of consumed tuber tissues of the three potato cultivars (in g)

(Table 1). For this slug, there were significant differences in the consumption of tubers depending on the cultivar, between the second and the last day. We observed that from the third day of grazing, the consumed mass of artificially damaged tissues of the Vineta tubers was significantly higher than the mass of uninjured tubers of that cultivar and significantly higher than the mass of unwounded and wounded tubers of cultivar Yelly.

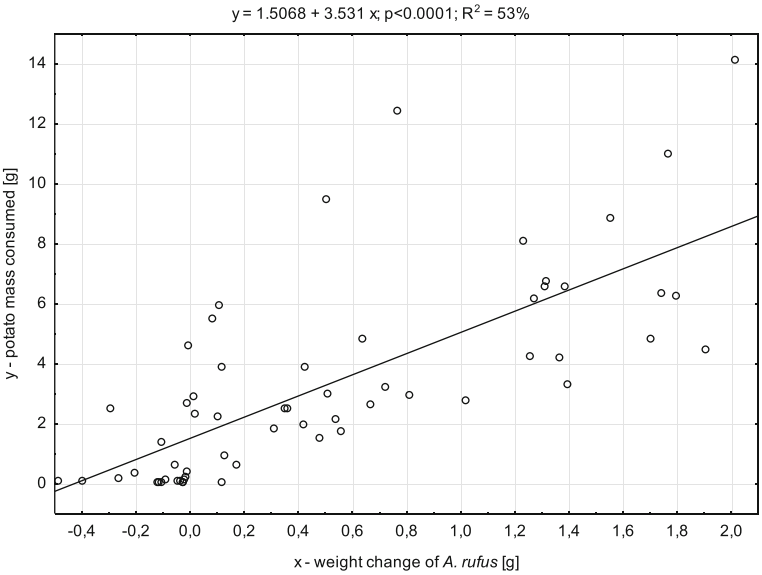

Fig. 6 Correlation diagram: *Arion rufus* body weight versus the mass of consumed tuber tissues of the three potato cultivars (in g)

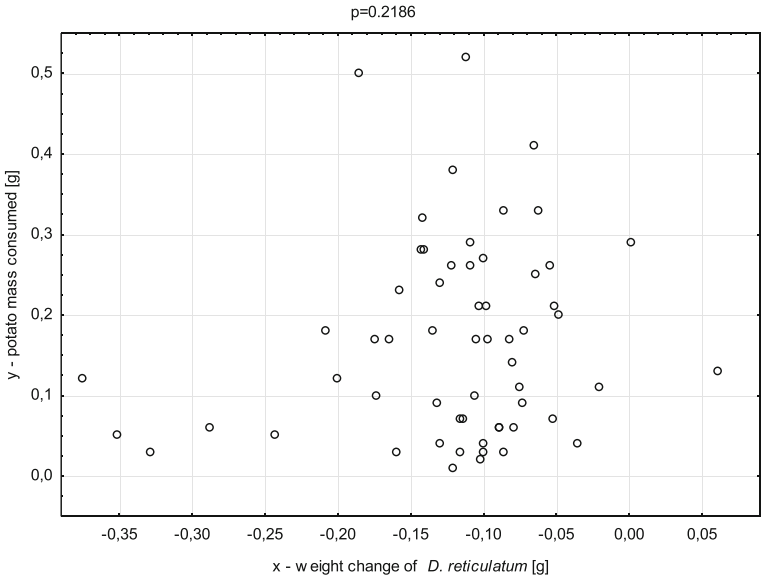

Fig. 7 Correlation diagram: *Deroceras reticulatum* body weight versus the mass of consumed tuber tissues of the three potato cultivars (in g)

In the case of *A. rufus*, similarly to the other slug species, no interactions ($p = 0.808$) or significant differences were observed either between the consumed quantity of damaged tubers and undamaged tubers ($p = 0.441$) or in the consumption of tubers of different cultivars ($p = 0.354$). The ANOVA (Table 2) showed considerable variation in the consumption of tubers of different potato cultivars, except on the seventh day of observation ($p = 0.051$). *A. rufus* preferred tubers of cultivar Vineta to Yelly (Table 2).

Table 1 Mean consumption of artificially damaged and undamaged potato tubers (in g) by *Arion vulgaris* and Fisher test results at $\alpha = 0.05$

Factor A: cultivar	Factor B: D/ND	Days of slugs' feeding						
		1	2	3	4	5	6	7
Vineta	D	0.529 b	1.233 c	1.813 c	2.306 c	2.578 c	2.749 c	2.848 c
	ND	0.281 ab	0.697 abc	0.916 ab	1.068 ab	1.162 ab	1.212 ab	1.320 ab
Ditta	D	0.379 ab	0.805 bc	1.193 bc	1.711 bc	1.886 bc	2.089 bc	2.204 bc
	ND	0.229 a	0.693 abc	1.221 bc	1.582 bc	1.745 bc	1.995 bc	2.050 bc
Yelly	D	0.126 a	0.158 a	0.231 a	0.328 a	0.400 a	0.488 a	0.540 a
	ND	0.224 a	0.392 ab	0.529 ab	0.741 ab	0.872 ab	0.943 ab	0.991 ab
Factor A	p_A	0.076	0.010	0.005	0.004	0.005	0.007	0.008
Factor B	p_B	0.222	0.454	0.458	0.308	0.288	0.294	0.294
Interaction A×B	p_{AB}	0.208	0.236	0.142	0.094	0.074	0.085	0.111

D, artificially damaged tubers; ND, healthy, undamaged tubers

Values in columns marked with the same letter do not differ significantly

Table 2 Mean consumption of artificially damaged and undamaged potato tubers (in g) by *Arion rufus* and Fisher test results at $\alpha = 0.05$

Factor A: cultivar	Factor B: D/ND	Days of slugs' feeding						
		1	2	3	4	5	6	7
Vineta	D	0.797 c	2.750 c	3.752 b	4.599 b	5.050 b	5.535 c	5.639 c
	ND	0.555 bc	2.000 bc	2.432 ab	2.501 ab	2.610 ab	3.159 abc	3.642 ab
Ditta	D	0.474 abc	1.735 abc	2.441 ab	2.936 ab	2.981 ab	3.809 bc	3.850 ab
	ND	0.235 ab	0.992 ab	1.195 a	1.479 a	1.988 a	2.383 ab	2.614 a
Yelly	D	0.306 ab	0.768 ab	0.899 a	0.918 a	0.941 a	1.000 a	1.373 a
	ND	0.102 a	0.627 a	1.099 a	1.181 a	1.467 a	2.048 ab	2.723 ab
Factor A	p_A	0.011	0.003	0.012	0.013	0.016	0.018	0.051
Factor B	p_B	0.076	0.165	0.161	0.106	0.183	0.250	0.462
Interaction A×B	p_{AB}	0.990	0.762	0.457	0.335	0.250	0.198	0.250

D, artificially damaged tubers; ND, healthy, undamaged tubers

Values in columns marked with the same letter do not differ significantly

Throughout the observations, the consumed mass of artificially damaged tissues of the Vineta tubers was significantly higher than the mass of artificially damaged and healthy (unwounded) tubers of cultivar Yelly. From the second day of grazing, the consumed mass of artificially damaged tissues of the Vineta tubers was over four times as high as the mass of artificially damaged tubers of cultivar Yelly.

For *D. reticulatum*, the MANOVA analysis did not show interactions ($p = 0.115$), but revealed significant differences between the consumed mass of damaged and healthy tubers ($p = 0.041$). Moreover, there were no significant differences in the consumption of tubers of the cultivars studied ($p = 0.659$). The ANOVA analyses for each observation day confirmed significant differences between the consumed mass of artificially damaged tubers and healthy tubers. What is more, A × B interactions were found for each day, which indicates that damage to tubers had different effects on the extent of consumption in the three potato cultivars (Table 3). The consumed mass of artificially damaged tissues of cultivar Vineta tubers caused by *D. reticulatum* was significantly higher than in the case of artificially damaged and undamaged tubers of the other two cultivars (Table 3). Throughout the entire grazing period, the artificially injured tubers of cultivar Vineta sustained more damage from the slugs than the healthy tubers.

Discussion

The experiments on the effects of slug grazing on potato leaves and shoots demonstrated that the studied slug species had already caused damage to these plant organs in the first 24 h of grazing. Damage to the aboveground plant organs of three potato cultivars (Vineta, Ditta and Yelly) caused by *A. vulgaris* was comparable on all days of observation (15 days). Significant differences in the extent of damage to leaves and shoots of the three cultivars were found for *A. rufus* and *D. reticulatum* on certain days

Table 3 Mean consumption of artificially damaged and undamaged potato tubers (in g) by *Deroceras reticulatum* and Fisher test results at $\alpha = 0.05$

Factor A: cultivar	Factor B: D/ND	Days of slugs' feeding						
		1	2	3	4	5	6	7
Vineta	D	0.071 b	0.109 b	0.154 c	0.221 b	0.283 b	0.313 b	0.323 c
	ND	0.007 a	0.007 a	0.019 ab	0.065 a	0.087 a	0.118 a	0.139 ab
Ditta	D	0.032 a	0.051 a	0.077 b	0.119 a	0.153 a	0.163 a	0.178 ab
	ND	0.003 a	0.005 a	0.009 a	0.038 a	0.049 a	0.056 a	0.064 a
Yelly	D	0.011 a	0.027 a	0.064 ab	0.101 a	0.118 a	0.138 a	0.155 ab
	ND	0.020 a	0.039 a	0.053 ab	0.098 a	0.143 a	0.165 a	0.184 b
Factor A	p_A	0.084	0.200	0.186	0.102	0.087	0.039	0.034
Factor B	p_B	0.004	0.003	0.001	0.002	0.004	0.007	0.010
Interaction A×B	p_{AB}	0.010	0.012	0.039	0.048	0.018	0.029	0.037

D, artificially damaged tubers; ND, healthy, undamaged tubers

Values in columns marked with the same letter do not differ significantly

of observation. On these days, *A. rufus* caused more damage to Yelly plants, and *D. reticulatum* to Vineta plants. It should be noted that, despite the lack of significant differences, the extent of damage to the aboveground organs of the studied potato cultivars changed daily in the case of both *A. vulgaris* and *A. rufus*. We observed that after 2 weeks of feeding on the aboveground organs of the Yelly plants, the damage caused by *A. rufus* was over 60%, and the damage caused by *A. vulgaris* was 40%. Such extensive damage may considerably inhibit the growth and development of plants and lead to decreased potato yield. Literature data on the extent of damage to aboveground plant organs caused by slugs is fragmentary. Ester and Trul (2000) have suggested that the susceptibility of various potato cultivars to leaf and tuber damage may be comparable, but the assumption has not been thoroughly researched. Most studies on slug damage to potato crops have focused on assessing the extent of damage to tubers (Port and Port 1986; Beer 1989; South 1992; Ester and Trul 2000; Meredith 2003). Our research has demonstrated that *A. vulgaris*, *A. rufus* and *D. reticulatum* caused more damage to tubers of cultivar Vineta than to those of Ditta and Yelly. Similar results were obtained for damage to aboveground organs of these cultivars caused by *D. reticulatum*. Slugs of the species *A. vulgaris* and *A. rufus* caused most severe damage to the aboveground parts of Yelly plants. However, with regard to tubers, they preferred Vineta. We observed that in artificially damaged tubers, the slug species studied caused damage to both wounded and unwounded sites. *A. vulgaris* and *A. rufus* were equally attracted to tubers which had not been artificially wounded. By contrast, *D. reticulatum* damaged less than half of the healthy tubers. This shows that this species is more likely to damage wounded sites of tubers, which are not covered by the skin. This is confirmed by the results of comparison between the mass of artificially injured and uninjured tubers of the three potato cultivars after *D. reticulatum* grazing. We found no correlation between the consumed mass of tubers and *D. reticulatum* body weight. However, such a relationship was found for *A. vulgaris* and *A. rufus*. The

present results concerning *D. reticulatum* are not in line with the findings of other authors, who have reported that *D. reticulatum* does not damage unwounded potato tubers and should be considered a pest causing secondary tuber damage (Pinder 1974; Johnston and Pearce 1994; Ester and Trul 2000). In the authors' view, such behaviour was caused by the presence of deterrents in the skin of the tubers used in the experiments, which discouraged slugs from grazing. Airey (1987), who observed such a reaction of slugs, claimed that some slug species do not damage potato tubers due to alkaloids found in the skin tissues. Thus, the slugs feed on tubers of such cultivars only at the sites of mechanical injuries.

The results of the present study pertaining to the consumption of tubers exposed to *A. vulgaris*, *A. rufus* and *D. reticulatum* grazing have shown differences in the susceptibility of cultivars Vineta, Ditta and Yelly to damage caused by these slugs. Differences in susceptibility of potato tubers of various cultivars have been previously reported by other authors. It has been found, for instance, that the tubers of cultivars Majestic and Pentland Falcon sustained much less damage caused by *D. reticulatum*, *A. hortensis*, *A. fasciatus* and *M. budapestensis* compared with Maris Piper and King Edward (Gould 1965; Winfield et al. 1967; Pinder 1974). According to some studies, early and mid-early potato cultivars are less susceptible to slug damage due to the fact they are harvested before full maturation of the tubers, i.e. in the development stages when damage caused by slugs is less severe (South 1992). Mechanical injuries to tubers facilitate slug grazing and significantly increase the extent of damage to tubers done by *D. reticulatum* (South 1992). The same has been demonstrated in our research for *A. vulgaris* and *A. rufus*. It is known that injuries to tubers also increase the risk of damage caused by other pests and diseases, especially bacterial ones (Runham and Hunter 1970). It follows that efforts to reduce mechanical damage to tubers during maturation, harvest, sorting and storage are extremely important, as such damage increases the risk of attack by slugs and other pests.

Due to changes in plant production, global warming and the rapid spread of native and alien slug species in the last 50 years, potato crops have been increasingly exposed to the danger caused by these pests. The situation calls for the creation of a strategy for protecting potato crops against slugs. An important element of this strategy is research to investigate the mechanisms of damage to potato tubers caused by various slug species and to assess the susceptibility of different cultivars to grazing. The results of our study complement the existing data on the damage to aboveground and underground potato organs caused by the three species of slug *A. vulgaris*, *A. rufus* and *D. reticulatum*. They also confirm previous findings on differences in the susceptibility of potato cultivars to slug grazing. Further research on the subject should be conducted to investigate the mechanisms determining the susceptibility of potato cultivars to slugs and possibilities of using the data in integrated plant protection strategies.

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