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FEEDING RATE OF *DEROCERAS RETICULATUM* (O. F. MÜLLER, 1774) (GASTROPODA: PULMONATA: AGRIOLIMACIDAE) ON HERBS AND OILSEED RAPE

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ABSTRACT: Experiments on feeding rate of *Deroceras reticulatum* (O. F. Müller) and damage caused by this slug to oilseed rape and other plant species were carried out under laboratory conditions. No-choice tests were conducted on 20 plant species at the growth stage of 2–3 leaves. The percentage of plant damage was assessed in consecutive days of the slug feeding and the consumption index (C.I.) was calculated for each plant species and for slugs of known weight. The slug feeding rates varied significantly between the examined plant species. *Papaver argemone*, *Sisymbrium officinale* and *Erigeron canadensis* were the most sensitive to the slug feeding, *Geum urbanum*, *Seneico vulgaris*, *Epilobium palustre* and *Impatiens roylei* – the least so.

KEY WORDS: slug, *Deroceras reticulatum*, oilseed rape, herb plants, no-choice test, plant damage, consumption index

INTRODUCTION

In recent years slugs of the families Agriolimacidae and Arionidae have became serious, economically important pests of some plant species cultivated in Poland. The highest losses have been observed in oilseed rape crops, winter wheat and vegetables (KOZŁOWSKI & KOZŁOWSKA 2002, KOZŁOWSKI 2003). Several slug species frequently damage plants but the most dangerous pest is the grey field slug *Deroceras reticulatum* (O. F. Müller, 1774). This species is the most widespread slug in Poland, as well as in other parts of Central and also in Northern Europe. It has a high reproduction rate, develops quite fast and is considered to be a major slug pest of arable crops (MOENS & GLEN 2002). Autumn-sown crops are especially vulnerable and often attacked. The grey field slug damages germinating cereal seeds and grazes on emerging oilseed rape plants. Numerous methods of control of the slug populations have been developed, but neither agricultural practice nor chemical treatment are sufficiently effective. Moreover, application of molluscicides may be dangerous to beneficial organisms and agricultural environment (MOENS et al. 1992, KOZŁOWSKI 2003).

Making use of natural features of various cultivated and wild plant species may become a potential way of controlling plant damage caused by *D. reticulatum* and other slug species. Such methods consist in providing the slugs with alternative food sources, or applying plant extracts or other plant-derived substances to reduce palatability of cultivated plants (MOLGAARD 1986, COOK et al. 1996, 1997, CLARK et al. 1997, FRANK & FRIEDLI 1999, BARONE & FRANK 1999, KOZŁOWSKI et al. 2003, 2004). Information on palatability of various plants and their susceptibility to slug damage is essential for developing utilization of plants in slug control. In this paper we present the results of our studies on slug feeding on young plants of selected herb species and oilseed rape, and their susceptibility to damage caused by *D. reticulatum*.

MATERIAL AND METHODS

The survey was conducted under laboratory conditions on 19 herb species and oilseed rape cv. Kana. The no-choice tests were carried out at day temperature of 18°C, night 14°C, RH 90±2% and day length 15 h. Ten seeds of each plant species were sown into well ventilated plastic containers (size 22 × 18 × 13 cm) filled with 5-cm soil layer. One starving slug *D. reticulatum* was placed in each container at the plant growth stage of 2–3 leaves and height of 5–8 cm. The slugs were collected in the field several weeks prior to the tests and reared in separate containers. Directly before launching the experiments the slugs were starved for 48 hours. The mean weight of the slugs at the beginning of the tests was 0.458 g and ranged from 0.385 to 0.560 (SD 0.042). The containers were put into the growth chamber and the percentage of aboveground plant area damage was evaluated daily for each plant separately throughout the entire 14-day experimental period. The assessment was visual, according to a 5-degree scale: 0% – no damage, 25%, 50%, 75% and 100% damaged area. Ten plants of 20 species in 10 replications were examined. The data were submitted to variance analysis and Tukey's test at significance level of 0.05. Consumption index (C.I.) was calculated for each day of observation and for each experimental unit (container) according to the formula:

$$\text{C.I.} = \frac{P}{T \cdot W}\ 100\%,$$

where P – percentage of plant damage; W – initial weight of slugs in g; T – time of slug feeding in days. Trend analysis for the consumption index for all 20 examined plant species was conducted.

RESULTS

After first day of *D. reticulatum* feeding the most damaged plants were *Sisymbrium officinale* (Table 1). The percentage of damage was 38.5%. *Erigeron canadensis* and the remaining species were damaged significantly less (*E. canadensis* 14.5%). There were no indications of grazing on the following five plant species: *Anethum graveolens*, *Echinochloa crus-galli*, *Hieracium pilosella*, *Imapatiens roylei* and *Rosmarinus officina-*

Table 1. Rate of damage to different plant species by *Deroceras reticulatum* in no-choice tests and results of Tukey's test at 0.05

Plant species	Day of feeding											
	1 day		2 day		4 day		6 day		10 day		14 day	
Anethum graveolens L.	0.0	c	6.5	cd	14.5	bcd	24.5	bcde	39.5	cde	52.5	cde
Artemisia absinthium L.	7.0	bc	10.0	bcd	16.5	bcd	23.0	bcde	34.0	def	61.5	bcd
Brassica napus L. var. *oleifera* L.	4.0	bc	9.0	cd	11.0	cd	17.5	de	29.5	defg	50.5	cdef
Echinochloa crus-galli (L.) Beauv.	0.0	c	4.0	d	7.5	d	9.5	e	16.0	efg	19.0	ghi
Epilobium palustre L.	1.0	bc	1.5	d	2.0	d	3.0	e	6.5	fg	11.5	i
Erigeron canadensis L	14.5	b	21.5	bc	33.5	b	45.0	abc	63.0	abc	75.0	abc
Galeopsis tetrahit L.	5.5	bc	9.5	bcd	11.5	cd	16.0	de	31.5	def	68.5	abcd
Galium aparine L.	3.0	bc	5.5	cd	16.0	bcd	23.5	bcde	49.5	cd	64.5	bcd
Geum urbanum L.	0.5	bc	0.5	d	2.0	d	2.0	e	2.5	g	3.0	i
Hieracium pilosella L.	0.0	c	0.0	d	1.5	d	5.5	e	16.0	efg	24.0	efghi
Impatiens roylei Walp.	0.0	c	0.5	d	0.5	d	1.5	e	2.5	g	20.5	ghi
Papaver argemone L.	5.0	bc	11.0	bcd	30.0	bc	49.0	ab	82.5	a	96.5	a
Plantago media L.	10.5	bc	26.0	b	35.0	b	39.0	bcd	55.0	bcd	65.0	bcd
Polygonum persicaria L.	4.5	bc	8.5	cd	15.5	bcd	21.5	cde	30.5	def	48.5	cdefg
Rosmarinus officinalis L.	0.0	c	1.5	d	4.5	d	5.5	e	16.5	efg	23.0	efghi
Senecio vulgaris L.	1.5	bc	1.5	d	2.0	d	2.5	e	2.5	g	11.0	i
Sisymbrium officinale (L.) Scop.	38.5	a	49.5	a	62.0	a	66.0	a	79.5	ab	89.0	ab
Solidago canadensis L.	1.5	bc	2.0	d	3.0	d	3.0	e	9.5	fg	12.5	hi
Urtica urens L.	1.0	bc	4.5	d	8.5	d	18.5	cde	31.0	def	42.5	defgh
Viola arvensis Murr.	1.5	bc	3.0	d	5.5	d	8.5	e	15.0	efg	20.5	ghi

a,b,… – values followed by the same letter within columns do not differ statistically in Tukey's test

lis. After two days of slug grazing, the percentage of damage to *S. officinale* increased to 49.5%. *E. canadensis* was damaged moderately (21.5%), like *Plantago media* (26.0%). *H. pilosella* remained untouched. *S. officinale* was significantly the most damaged after four days of slug feeding (62.0%). Six days after the beginning of the tests this species was still damaged to the greatest extent (66.0%) however, also *Papaver argemone* and *E. canadensis* were considerably damaged (49.0% and 45.0%, respectively). In the subsequent days the susceptibility of the examined plant species to slug feeding was similar and the damage degree increased gradually. Finally, after 14 days of *D. reticulatum* grazing the most damaged plants were *P. argemone* (96.5%), *S. officinale* (89.0%), *E. canadensis* (75.0%) and *Galeopsis tetrahit* (68.5%). The species injured the least after the same period of time was *Geum urbanum* (3.0%). The damage to *Senecio vulgaris*, *Epilobium palustre* and *Solidago canadensis* was also low (11.0%, 11.5% and 12.5%, respectively).

Based on the initial slug weight (Table 2) and other parameters the consumption index was calculated. Its variation reflects the consumption rate for 14 days of *D. reticulatum* feeding on 20 plant species. The C.I. value varied with the duration of the experiment. For example, for 2 days of grazing of the 0.5 g slug, the C.I. could be within the range of 0%–100% while over the 14 day period – from 0% to 14.3%. Taking into consideration the average weight of slugs (0.458 g) the C.I. for 14 days of feeding could exceed 15.6%.

The feeding rate of *D. reticulatum* differed significantly between the examined plant species. Figure 1 presents the feeding rate for five plant species and the corresponding C.I. values which were higher than 10%. These plants were the most sensitive to the slug grazing. *S. officinale* and *E. canadensis* were consumed intensively on the first day, then the consumption rate decreased and stayed at a high and stable level of 14.1% and 12.3%, respectively. In contrast, the feeding rate on *P. argemone* was low in the beginning (10.3%) and then increased reaching gradually 14.3%. The grazing on two other species, *P. media* and *A. absinthium*, declined progressively from 20% to 10%. Figure 2 shows the feeding rate for seven other plant species with consumption below 12% for the 14-day experimental period. The consumption of *G. tetrahit*, *P. persicaria*, *B. napus* and *A. graveolens* was rather constant at about 10%, however, it was higher than the average consumption rate. The consumption of *G. aparine* increased from 6% to 9.3%, that of *U. urens* – from 2.2% to 6.6%. The examined pest did not graze on *H. pilosella* within the first three days and then the consumption rate increased up to 4.1%. The

Table 2. Weight of *Deroceras reticulatum* in no-choice test (mean weight in g, minimum and maximum weight, S – standard deviation, V – variability coefficient in %) and consumption index C.I. after 2 and 14 days of slug feeding

Plant species	Mean	Minimum	Maximum	S	V	C.I.(2)	C.I.(14)
Anethum graveolens L.	0.411	0.390	0.430	0.015	3.7	7.8	9.1
Artemisia absinthium L.	0.434	0.395	0.470	0.023	5.2	11.6	10.1
Brassica napus L. var. *oleifera* L.	0.427	0.395	0.455	0.019	4.4	10.3	8.3
Echinochloa crus-galli (L.) Beauv.	0.513	0.480	0.550	0.024	4.6	3.8	2.7
Epilobium palustre L.	0.518	0.490	0.550	0.021	4.1	1.5	1.6
Erigeron canadensis L	0.438	0.410	0.460	0.015	3.3	25.0	12.3
Galeopsis tetrahit L.	0.484	0.450	0.510	0.019	3.9	9.9	10.1
Galium aparine L.	0.495	0.470	0.525	0.020	4.0	5.6	9.3
Geum urbanum L.	0.439	0.410	0.470	0.020	4.5	0.6	0.5
Hieracium pilosella L.	0.424	0.395	0.450	0.019	4.4	0.0	4.1
Impatiens roylei Walp.	0.531	0.490	0.560	0.023	4.2	0.5	2.8
Papaver argemone L.	0.482	0.460	0.505	0.014	2.9	11.4	14.3
Plantago media L.	0.504	0.480	0.535	0.017	3.4	26.0	9.3
Polygonum persicaria L.	0.405	0.385	0.430	0.017	4.3	10.5	8.6
Rosmarinus officinalis L.	0.457	0.430	0.480	0.016	3.5	1.6	3.6
Senecio vulgaris L.	0.446	0.425	0.465	0.013	2.8	1.7	1.8
Sisymbrium officinale (L.) Scop.	0.450	0.410	0.480	0.022	4.9	55.3	14.1
Solidago canadensis L.	0.432	0.395	0.455	0.017	4.0	2.3	2.1
Urtica urens L.	0.462	0.420	0.490	0.024	5.2	4.8	6.6
Viola arvensis Murr.	0.417	0.390	0.450	0.022	5.3	3.7	3.6

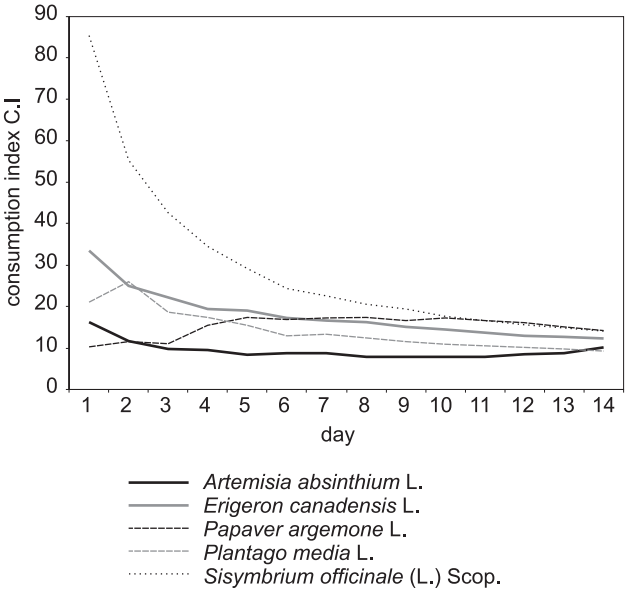

Fig. 1. Consumption rate of 5 plant species by *Deroceras reticulatum* throughout 14-day experimental period in no-choice tests presented as consumption index C.I.

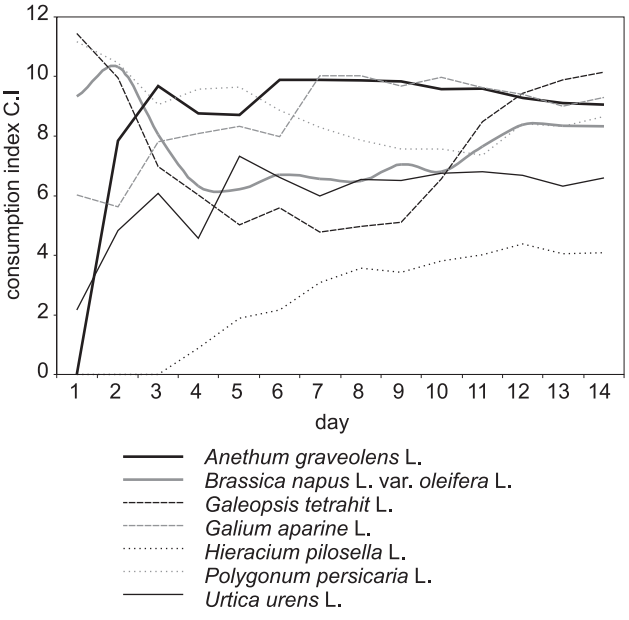

Fig. 2. Consumption rate of 7 plant species by *Deroceras reticulatum* throughout 14-day experimental period in no-choice tests presented as consumption index C.I.

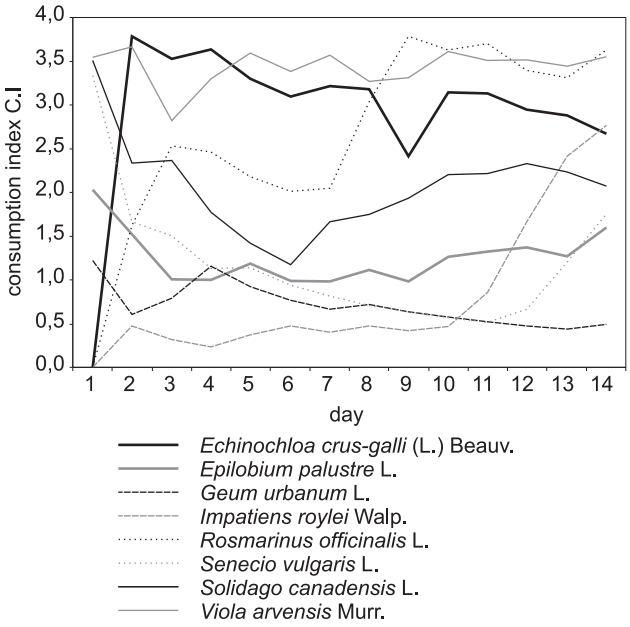

Fig. 3. Consumption rate of 8 plant species by *Deroceras reticulatum* throughout 14-day experimental period in no-choice tests presented as consumption index C.I.

remaining seven plant species were consumed at the rate either equal to or below 3.6% (Fig. 3).

Based on the results of the no-choice tests and the data analyses it can be concluded that out of the 20 tested plant species *P. argemone*, *S. officinale* and *E. canadensis* were the most sensitive to *D. reticulatum* feeding. Within this group *S. officinale* was eaten the most frequently, with the consumption rate starting at 55.5% and declining to 14%. The least susceptible species was *G. urbanum* with the constant consumption rate of 0.5%. *S. vulgaris*, *E. palustre* and *I. roylei* also showed a low susceptibility to the slug feeding. The damage to oilseed rape plants was moderate compared to herbs, and the consumption rate was constant, at 10%.

DISCUSSION

The consumption and damage rates for the examined herb species and oilseed rape plants (at growth stage of 2–3 leaves) varied significantly and were dependent on the plant species. The significant differences in the area damage of particular plant species were already apparent on the first day of *D. reticulatum* feeding and this tendency persisted throughout the entire experimental period of 14 days (Tables 1, 2). It indicates differences in palatability of the plants to the slugs. A broad range of palatability of plants has been recognised in earlier studies on *D. reticulatum* and other slug species food preferences (COOK et al. 1996, FRANK & FRIEDLI 1999, KELLER et al. 1999, KOZŁOWSKI & KOZŁOWSKA 2003, 2004, KOZŁOWSKI & KA-

ŁUSKI 2004). The results of earlier investigations on slug food preferences and feeding habits show that despite abundant variety of available food the slugs display strong preferences to some plant species. The behaviour is mainly based on the secondary compounds contained in the plant and on the pest chemoreception (WEBBE & LAMBERT 1983, MOLGAARD 1986, CLARK et al. 1997). For example, *Senecio vulgaris* contains alkaloids that inhibit grazing of some slug species (DIRZO 1980).

Twenty herb species included in the survey can be classified into two groups, i.e. plants more and less susceptible to *D. reticulatum* feeding compared to oilseed rape. *G. urbanum*, *S. vulgaris*, *E. palustre* and *I. roylei* were of particular interest because the slugs grazed on them unenthusiastically and the recorded damage was insignificant. It suggests that these plants might contain antifeedant or deterrent substances inhibiting *D. reticulatum* feeding. They thus may constitute potential means of slug control in oilseed rape by decreasing the crop palatability and damage rate. The effect of secondary plant substances on slug feeding rate has been observed in earlier studies on other plant species. It has been found that extracts from *Chelidonium maius, Epilobium hirsutum, Saponaria officinalis* and *Geranium sanguineum* reduce damage to oilseed rape seedlings caused by *D. reticulatum* (KOZŁOWSKI et al. 2003). Tests aimed at applying plant extracts to oilseed rape seedlings have also been carried out with other slug species. BARONE & FRANK (1999) in their laboratory tests with *Arion lusitanicus* Mabille demonstrated a deterring effect of extracts from *Saponaria officinalis* and *Valerianella locusta*. Similar results have been obtained while testing the extracts from *S. officinalis*, *E. hirsutum* and *Polygonum nodosum* (KOZŁOWSKI et al. 2004).

On of the important results of these studies is the very different feeding behaviour of *D. reticulatum* in relation to different plant species. Based on the analysis of the consumption index value (C.I.) on consecutive days of the tests, three categories of consumption rate patterns can be distinguished. The first refers to an intensive slug feeding on plants within the first days, which then gradually declines until reaching a certain level. The second includes a low consumption in the beginning followed by its increase until its stabilisation at a certain level. The third consists in grazing at a constant level. These three consumption rate patterns refer to three groups of plants representing different categories of susceptibility to slug feeding. Five plant species with the highest susceptibility to slug damage belong to the first group. The second group consists of seven species characterised by a moderate sensitivity to slug grazing and the last group, represented by eight species, includes those that are the least susceptible to slug damage. The differentiated consumption rate resulting from the slug feeding preferences might suggest that plants of particular groups show different properties. These properties initially determine the slug feeding behaviour and, consequently, the degree of damage. Information on different types of slug feeding may be very useful in developing new slug control methods. Plants which are less palatable to slugs might be utilized as an alternative method decreasing damage resulting from the pest grazing.

CONCLUSIONS

1. Susceptibility to slug feeding and damage caused by *D. reticulatum* varied greatly between the plant species.
2. Feeding behaviour of *D. reticulatum* varied significantly between the plant species.
3. Three consumption rate patterns could be distinguished.
4. Species the most damaged by *D. reticulatum* were *Papaver argemone*, *Sisymbrium officinale* and *Erigeron canadensis*.
5. The least damaged species were *Geum urbanum*, *Senecio vulgaris* and *Epilobium palustre*.
6. *Geum urbanum* could be applied in control of *D. reticulatum* feeding on oilseed rape seedlings.

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