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DIFFERENCES IN ACCEPTABILITY OF HERB PLANTS AND OILSEED RAPE FOR SLUGS (*A. LUSITANICUS*, *A. RUFUS* AND *D. RETICULATUM*) IN FOOD CHOICE TESTS

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Abstract: The following slug species, *Arion lusitanicus*, *Arion rufus*, and *Deroceras reticulatum* were included in laboratory-based multi-choice food tests consisting of 19 herb plants and oilseed rape. Rates of damage to plants at the growth stage of 2–4 leaves were estimated for each slug species and all tested herb plants using oilseed rape as a reference. The following indices were calculated: acceptability index (A.I.), palatability index (P.I.) and consumption index (C.I.). Based on the obtained results four groups of plants were designated: unacceptable, lowly acceptable, moderately acceptable and highly acceptable. *Brassica napus*, *Ocimum basilicum* and *Coriandrum sativum* were accepted by all three examined slugs while *Potentilla anserina* and *Chamaenerion angustifolium* were rejected. The acceptance degree for remaining plants varied according to slug species.

Key words: *Arion lusitanicus*, *Arion rufus*, *Deroceras reticulatum*, acceptability index, palatability index, consumption index, herb plants and oilseed rape

INTRODUCTION

Slugs (*Gastropoda*: *Pulmonata*: *Stylommatophora*) are polyphagous and feed on both animal and plant material. There are numerous species occurring throughout Europe and some are considered serious pests of arable crops (Martin and Kelly 1986; Glen *et al*. 1993; Mesh 1996; Frank 1998; Kozłowski 1999; Moens and Glen 2002). In Poland three slug species are recognized as notable pests, *Deroceras reticulatum* (O.F. Müller 1774), appearing commonly, *Arion lusitanicus* Mabille 1868 and *Arion rufus* (Linnaeus

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1758) in only some areas (Kozłowski 1999; Kozłowski and Kozłowska 2002). These species cause damage to vegetables, arable crops, orchards, and ornamental and herb plants. Besides these plants, the slugs graze on numerous weed species, wild growing herbs and animal material. That capability to feed on different food allows them to survive in agricultural environments during periods when arable crops are not available.

Application of molluscicidal bait pellets is, along with agricultural measures, the most popular slug control. The efficacy of these products is however often unsatisfactory (Henderson and Parker 1986; Bailey and Wedgewood 1991; Moens *et al*. 1992). Moreover, molluscicidal bait pellets can cause a threat to fauna, such as beneficial invertebrates and some vertebrates (Homeida and Cooke 1982; Purves and Bannon 1992). Therefore, a search for alternative control means for decreasing slug populations in arable crops successfully has become an important part of research projects. As slugs show preferences toward certain types of food that feature might be effectively applied in slug control. The slugs present high selectivity toward plant food despite a broad range of food they feed on (Grime *et al*. 1968; Duval 1971, 1973; Pallant 1972; Cates and Orians 1975; Jennings and Barkham 1975; Dirzo 1980; Whelan 1982; Rathcke 1985; Molgaard 1986; Cook *et al*. 1996, 1997; Clark *et al*. 1997; Briner and Frank 1998; Barone and Frank 1999; Frank and Friedli 1999; Keller *et al*. 1999; Kozłowski and Kozłowska 2000, 2003, 2004; Kozłowski and Kałuski 2004). Some plants are highly alluring for slugs while others completely unattractive. The content of compounds that might stimulate, inhibit or make grazing more difficult is the main reason of plants attractiveness. The choice of particular plant species might also be dependent upon the presence of nutritional ingredients (Port and Port 1986; Spaull and Eldon 1990), and more importantly on, activity of secondary metabolites (Webbe and Lambert 1983; Molgaard 1986; Hanley *et al*. 1995; Clark *et al*. 1997). Phagostimulant and antifeedant activities of plant substances might be applied to protect arable and other crops against slug damage. Arable crops and commonly occurring weeds as well as plants appearing less frequently in agricultural environment might be the source of these substances.

The objective of the presented data in this research paper was to select plant species that might be useful in reducing damage caused by the slugs to oilseed rape seedlings. Winter rape plants suffer heavy slug damage at seedling stage, and it is very difficult to protect them using available means (Kozłowski and Kozłowska 2002). Rate and size of damage on herb plants with oilseed rape as a reference were examined. The following indices were calculated: acceptability index (A.I.), palatability index (P.I.) and consumption index (C.I.), and based on them, a list of plants representing high attractiveness for slugs was provided.

MATERIALS AND METHODS

Plants and slugs

The survey was conducted on 20 plant species (Table 1) and three slug species (*A. lusitanicus*, *A. rufus* and *D. reticulatum*). The seeds of 19 herb species were provided from the seed collection maintained at the Research Institute of Medicinal Plants in Poznań and oilseed rape (*Brassica napus* L. var. *oleifera* L.) cv. Kana from a commercial distributor. In a greenhouse the seeds were planted into 9 containers (800 mm x 500 mm x 200 mm) filled with soil and separated into 40 micro-plots (experimental units). Semitransparent, plastic containers were closed tight however, there were two air holes covered with cheesecloth. Planting was performed in accordance with an arrangement of treatments in experimental units in nested block design (Fig. 1). Ten seeds of each plant species were planted in each container, for five seeds on 2 micro-plots (250 mm x 40 mm). Due to different germination rate and plant development diversity timing of planting was coordinated so the growth stages of all plants at the beginning of the test were similar.

Block 1

Sub-block 1										Sub-block 2									
11	14	17	15	18	10	7	6	3	1	16	9	20	7	18	5	13	3	14	1
16	19	12	20	13	9	8	5	4	2	10	17	8	19	6	11	4	15	2	12

Block 2

Sub-block 1										Sub-block 2									
1	3	5	7	9	10	8	6	4	2	1	5	9	13	17	15	19	11	4	8
11	13	15	17	19	20	18	16	14	12	6	2	14	10	18	16	12	20	7	3

Block 3

Sub-block 1										Sub-block 2									
19	13	12	7	1	2	8	9	15	14	11	18	1	2	4	12	6	3	13	7
18	17	11	6	5	3	4	16	10	20	10	5	14	9	17	15	19	16	8	20

Fig. 1. Scheme of allocated treatments (1, 2, …, 20) to experimental units arranged in nested blocks

Few weeks prior to the experiment the individuals representing three slug species included in the research project were collected from the fields and placed in separate containers equipped with a ventilation system and filled with 5-cm soil layer. Three times a week the slugs were fed with the following food: wheat bran, leaves of Chinese cabbage, roots of carrot, powdered milk and calcium carbonate. Slug rearing was conducted in a growth chamber at daily temperature of 19°C, night 16°C, RH 93% (±3%) and day length 15 h. Before beginning of the experiment the slugs starved for 48 hours. Mean weights of slugs were for *A. lusitanicus* 2.3 g, *A. rufus* 2.7 g and *D. reticulatum* 0.7 g.

Experiments

Multi-choice food tests were performed in a growth chamber at daily temperature of 19°C, night 16°C, RH 93% (±3%) and day length 15 h. Upon plants reached the growth stage of 2–4 leaves and 5–8 cm, 10 slugs of one species covered with plastic box with holes were placed in a centre of each container. Visual evaluation of eaten food was done daily using 5-grade scale (0% – no damage; 25%, 50%, 75% and 100% of consumed plant area). For each slug species the assessment included 30 plants representing each from 20 tested plant species.

The nested block design consisted of three blocks and each of them of two sub-blocks with 20 micro-plots (Fig. 1). Summarizing, there were 6 replications for

19 treatments (herb plants) and one standard treatment (oilseed rape) thus there were 97 degree of freedom for experimental error. Based on observations conducted on 5 plants on each micro-plot a percentage of consumed plant area was calculated as the mean from 5 observations.

Analysis of data

The collected results from each micro-plot were subjected to analysis of variance and the Tukey's multiple comparison test at the 0.05 significance level. The damage rate of plants, acceptability index (A.I.), palatability index (P.I.) and consumption index (C.I.) were estimated for each plant species. Kozłowska and Kozłowski (2002) gave the definitions for these indices in earlier paper. The indices were calculated based on data recorded on 4th day of slug feeding in accordance with compatibility index (Kozłowska and Kozłowski 2004).

Acceptability index (A.I.) is a quotient of a consumed leaf area of examined plant (presented in percentage) to a mean consumed leaf area of all tested plants. Acceptability index values are placed in the range from 0 to 20 where 0 means lack of acceptability and 1 stands for an average acceptability for examined treatments. Values over 1 describe acceptability higher than the average.

Palatability index (P.I.) is a quotient of a mean consumed leaf area of examined plant to a mean consumed leaf area of a control plant (standard plant, *B. napus*).

Consumption index (C.I.) refers to a daily mean of consumed leaf area of examined plant.

To group plant species into certain categories illustrating food preferences of *A. lusitanicus*, *A. rufus* and *D. reticulatum*, ranks were applied. The rank sum was calculated for each slug and plant species. Four groups of food preferences were defined: 1 – unacceptable (rank sum not higher than 15), 2 – hardly acceptable (rank sum from 16 to 30), 3 – moderately acceptable (rank sum from 31 to 45) and 4 – highly acceptable (rank sum from 46 to 60).

RESULTS

Arion lusitanicus

On the first day of the experiment *A. lusitanicus* was feeding on eighteen plant species (Table 1). The most injured was *Calamintha vulgaris* (50.3%). The slugs did not graze on *Geranium pusillum* and *Polygonum aviculare*. After four days of feeding the most damaged plants were *C. vulgaris* (92.1%), *Ocimum basilicum* (89.2%), *Brassica napus* var. *oleifera* (81.7%), *Artemisia dracunculus* (80.8%) and *Coriandrum sativum* (76.7%). These plants were significantly more injured than ten other plant species. Slugs showed the least interest in grazing on *Potentilla anserina*, *P. aviculare*, (1.7% of injuries on each). After six days, plants of *C. vulgaris* and *O. basilicum* were destroyed in 100%, *A. dracunculus* and *Calendula officinalis* in 99%, while *Achillea millefolium*, *C. sativum*, *Matricaria chamomilla* and *Mentha piperita* more than 90%. Group of slightly injured plants included 5 species i.e. *P. anserina* (3.3%), *P. aviculare* and *Chamaenerion angustifolium*, damaged in 7.5 and 10% respectively, and *Borago officinalis* and *Impatiens balsamina*, in 21.7%. After 14 days of conducting the experiment, plants of thirteen species were damaged in 100%. Significantly less damaged were still plants of *P. anserina* (34.2%). Also plants of *C. angustifolium* showed relatively fewer injuries compared to other species (36.7%). Until the end of experiment the slugs were less interested in feeding on *P. anserina* and *C. angustifolium*. After 20 days of grazing the damage on these plants was 53.3% and 55.8%, respectively.

Table 1. Rate of damage on different plant species at growth stage of 2–4 leaves caused by *Arion lusitanicus*; results from multiple-choice food tests and results of Tukey's test at $\alpha = 0.05$

Plant species	Day of feeding				
	1	4	6	14	20
Achillea millefolium L.	29.2 abc	65.0 abc	95.0 a	100.0 a	100.0 a
Artemisia dracunculus L.	30.0 abc	80.8 a	99.2 a	100.0 a	100.0 a
Borago officinalis L.	5.0 bc	15.0 de	21.7 d	59.2 bc	81.7 ab
Brassica napus L. var. *oleifera* L.	48.3 ab	81.7 a	85.8 ab	100.0 a	100.0 a
Calamintha vulgaris (L.) Druce	50.3 a	92.1 a	100.0 a	100.0 a	100.0 a
Calendula officinalis L.	14.2 abc	74.2 ab	99.2 a	100.0 a	100.0 a
Chamaenerion angustifolium (L.) Scop.	3.3 c	5.0 e	10.0 d	36.7 c	55.8 cd
Coriandrum sativum L.	19.2 abc	76.7 a	95.0 a	100.0 a	100.0 a
Geranium pusillum L.	0.0 c	13.3 e	25.8 cd	54.2 bc	75.0 bcd
Helichrysum arenarium (L.) Moench	3.3 c	29.2 cde	79.2 ab	100.0 a	100.0 a
Impatiens balsamina L.	7.5 abc	15.8 de	21.7 d	58.3 bc	70.8 bcd
Leucanthemum vulgare Lam.	10.8 abc	29.2 cde	57.5 bc	100.0 a	100.0 a
Malva silvestris L.	5.0 bc	15.0 de	31.7 cd	71.7 ab	88.3 ab
Matricaria chamomilla L.	31.7 abc	55.8 abcd	90.8 a	100.0 a	100.0 a
Mentha piperita L.	7.5 abc	62.5 abc	90.8 a	100.0 a	100.0 a
Ocimum basilicum L.	20.8 abc	89.2 a	100.0 a	100.0 a	100.0 a
Polygonum aviculare L.	0.0 c	1.7 e	7.5 d	46.7 bc	78.3 abc
Potentilla anserine L.	0.8 c	1.7 e	3.3 d	34.2 c	53.3 d
Salvia officinalis L.	11.7 abc	33.3 bcde	77.5 ab	100.0 a	100.0 a
Satureja hortensis L.	25.8 abc	64.2 abc	88.3 ab	100.0 a	100.0 a

Values within each column, followed by the same letter are not significantly different

Comparison of calculated indices for 20 plant species revealed that the slug *A. lusitanicus* accepted the most *C. vulgaris* (A.I.=2.0) and *O. basilicum* (A.I.=2.0) (Table 2). Acceptability of these species was twofold higher than an average value of all examined treatments. Also the indices P.I. and C.I. reached the highest values for these plant species; P.I.=1.1 and C.I. >22. It means that their palatability is higher than palatability of oilseed rape plants and their consumption is on average over 20% of plant area daily. All three indices were also relatively high for *A. dracunculus* and *B. napus*. Their acceptability is higher than the average, palatability at the same level and daily consumption around 20%. Plants of *P. aviculare* and *P. anserina* were unaccepted and the index A.I. for them was equal 0. The index P.I. was also 0 and their daily consumption was on average 0.4% of plant area. Plants of *C. angustifolium* were slightly accepted by *A. lusitanicus* and the indices were as follows: A.I. and P.I. equal 0.1, and C.I.=1.3.

Table 2. Acceptability index (A.I.), palatability index (P.I.) and consumption index (C.I.) of different plant species for *A. lusitanicus*, *A. rufus* and *D. reticulatum*

Plant species	*A. lusitanicus*			*A. rufus*			*D. reticulatum*		
	A.I.	P.I.	C.I.	A.I.	P.I.	C.I.	A.I.	P.I.	C.I.
Achillea millefolium L.	1.4	0.8	16.3	1.5	0.6	15.4	0.9	0.1	2.5
Artemisia dracunculus L.	1.8	1.0	20.2	1.3	0.5	12.9	0.1	0.0	0.2
Borago officinalis L.	0.3	0.2	3.8	0.6	0.2	5.6	0.5	0.1	1.5
Brassica napus L. var. *oleifera* L.	1.8	1.0	20.4	2.5	1.0	25.0	6.7	1.0	17.9
Calamintha vulgaris (L.) Druce	2.0	1.1	23.0	0.4	0.2	4.2	0.0	0.0	0.0
Calendula officinalis L.	1.6	0.9	18.5	1.1	0.5	11.3	0.6	0.1	1.7
Chamaenerion angustifolium (L.) Scop.	0.1	0.1	1.3	0.3	0.1	3.1	0.0	0.0	0.0
Coriandrum sativum L.	1.7	0.9	19.2	2.4	1.0	24.4	2.7	0.4	7.3
Geranium pusillum L.	0.3	0.2	3.3	0.5	0.2	4.8	0.2	0.0	0.6
Helichrysum arenarium (L.) Moench	0.6	0.4	7.3	0.2	0.1	2.1	2.5	0.4	6.7
Impatiens balsamina L.	0.4	0.2	4.0	0.5	0.2	5.2	0.0	0.0	0.0
Leucanthemum vulgare Lam.	0.6	0.4	7.3	0.2	0.1	2.1	0.0	0.0	0.0
Malva silvestris L.	0.3	0.2	3.8	1.0	0.4	9.6	0.6	0.1	1.7
Matricaria chamomilla L.	1.2	0.7	14.0	0.4	0.1	3.5	1.2	0.2	3.1
Mentha piperita L.	1.4	0.8	15.6	0.6	0.2	5.6	0.0	0.0	0.0
Ocimum basilicum L.	2.0	1.1	22.3	2.4	1.0	24.2	2.0	0.3	5.4
Polygonum aviculare L.	0.0	0.0	0.4	0.8	0.3	7.9	0.0	0.0	0.0
Potentilla anserine L.	0.0	0.0	0.4	0.0	0.0	0.2	0.0	0.0	0.0
Salvia officinalis L.	0.7	0.4	8.3	1.2	0.5	11.9	0.1	0.0	0.2
Satureja hortensis L.	1.4	0.8	16.0	2.3	0.9	22.9	1.9	0.3	5.0

Arion rufus

On the first day, the most injured plants were of *O. basilicum* (76.7%; Table 3). The most injured were plants of *O. basilicum* (76.7%). Plants of *B. napus* were damaged in 49.2%. The slugs did not feed on *P. anserina*, *Salvia officinalis*, *M. chamomilla* and *Helichrysum arenarium*. The remaining plant species were only slightly damaged (1–18%). After four days of grazing *B. napus* plants were consumed in 100% while *C. sativum*, *O. basilicum* and *Satureja hortensis* in 97.5, 96.7 and 91.7%, respectively. The least damaged plants were of *P. anserina*, 0.8%. Slight injuries were also observed on plants

Table 3. Rate of damage on different plant species at growth stage of 2–4 leaves caused by *Arion rufus*; results from multiple-choice food tests and results of Tukey's test at $\alpha = 0.05$

Plant species	Day of feeding				
	1	4	6	14	20
Achillea millefolium L.	17.5 c	61.7 bc	75.8 abc	99.2 a	100.0 a
Artemisia dracunculus L.	1.7 c	51.7 cd	74.2 abc	100.0 a	100.0 a
Borago officinalis L.	8.3 c	22.5 defgh	42.5 defg	100.0 a	100.0 a
Brassica napus L. var. *oleifera* L.	49.2 b	100.0 a	100.0 a	100.0 a	100.0 a
Calamintha vulgaris (L.) Druce	4.2 c	16.7 efgh	25.8 fgh	59.3 c	95.0 a
Calendula officinalis L.	6.7 c	45.0 cdef	80.0 ab	100.0 a	100.0 a
Chamaenerion angustifolium (L.) Scop.	1.7 c	12.5 gh	30.0 efgh	86.7 ab	99.2 a
Coriandrum sativum L.	10.8 c	97.5 a	100.0 a	100.0 a	100.0 a
Geranium pusillum L.	2.5 c	19.2 efgh	25.0 fgh	80.8 abc	99.2 a
Helichrysum arenarium (L.) Moench	0.0 c	8.3 gh	65.8 bcd	100.0 a	100.0 a
Impatiens balsamina L.	5.8 c	20.8 defgh	33.3 efgh	97.5 ab	100.0 a
Leucanthemum vulgare Lam.	0.8 c	8.3 gh	16.7 gh	77.5 abc	100.0 a
Malva silvestris L.	1.7 c	38.5 cdefg	48.3 cdef	97.5 ab	100.0 a
Matricaria chamomilla L.	0.0 c	14.2 fgh	24.2 fgh	95.0 ab	95.8 a
Mentha piperita L.	7.5 c	22.5 defgh	24.2 fgh	71.7 bc	99.2 a
Ocimum basilicum L.	76.7 a	96.7 a	100.0 a	100.0 a	100.0 a
Polygonum aviculare L.	4.2 c	31.7 cdefgh	57.5 bcde	100.0 a	100.0 a
Potentilla anserine L.	0.0 c	0.8 h	8.3 h	22.5 d	49.2 b
Salvia officinalis L.	0.0 c	47.5 cde	81.7 ab	100.0 a	100.0 a
Satureja hortensis L.	16.7 c	91.7 ab	99.2 a	100.0 a	100.0 a

Values within each column, followed by the same letter are not significantly different

of *H. arenarium* and *Leucanthemum vulgare* (8.3%). After six days of slug feeding, the total plant damage (100%) besides oilseed rape plants was recorded on *C. sativum* and *O. basilicum*. Plants of *S. hortensis* showed 99.2% of injuries. Plants of *S. officinalis* and *C. officinalis* were also severely damaged (80%). The lowest injuries were recorded on *P. anserina* (8.3%). After 14 days, 10 plant species were damaged in 100% and 4 others more than 95.0%. Significantly less damaged were plants of *P. anserina* (22.5%). The remaining plants included in the experiment were consumed in 60–87%. At the end of the test, on 20th day, plants of all species were completely or almost entirely eaten except *P. anserina* that had only 49.2% of damaged area.

Based on the calculated indices of acceptability, palatability, and consumption one can conclude that within the group of 20 examined plant species the plants of *B. napus*, *O. basilicum*, *C. sativum* and *S. hortensis* were the most accepted by *A. rufus* (Table 2). Acceptability indices (A.I.) were for *S. hortensis* 2.3 and for *B. napus* 2.5. These values indicate that the acceptability of these plants was over twice higher comparing to the average acceptability of all tested plant species. Also palatability, and consumption indices were the highest for *B. napus*, *O. basilicum*, *C. sativum* and *S. hortensis* (P.I.=1.0 and C.I.>22.9, respectively). Mean daily consumption rate was approximately 23–25%. The group of unacceptable plants consisted of *P. anserina*, *L. vulgare* and *H. arenarium*. The indices calculated for *P. anserina* were the lowest (A.I.=0.0; P.I.=0.0; C.I.=0.2). Values of A.I., P.I. and C.I. were the same for *L. vulgare* and *H. arenarium*, 0.2, 0.1 and 2.1, respectively. *A. rufus* did not feed much on *C. angustifolium*, *M. chamomilla* and *C. vulgaris*, thus the indices for these species were very low.

Deroceras reticulatum

On the first day of observation, *D. reticulatum* was grazing on 11 plant species (Table 4) and plants of *B. napus* were significantly damaged in 23.3%. After 4 days of feeding, *B. napus* plants were already injured in 71.7%. Within the remaining 12 other species *C. sativum* and *H. arenarium* were the most damaged (29.2%, 26.7%, respectively).

Table 4. Rate of damage on different plant species at growth stage of 2–4 leaves caused by *Deroceras reticulatum*; results from multiple-choice food tests and results of Tukey's test at $\alpha = 0.05$

Plant species	Day of feeding				
	1	4	6	14	20
Achillea millefolium L.	0.0 b	10.0 bc	28.3 bcdef	62.5 bc	75.0 abc
Artemisia dracunculus L.	0.8 b	0.8 c	0.8 f	1.7 e	47.5 cde
Borago officinalis L.	2.5 b	5.8 bc	9.2 cdef	27.5 de	58.3 bcd
Brassica napus L. var. *oleifera* L.	23.3 a	71.7 a	90.0 a	100.0 a	100.0 a
Calamintha vulgaris (L.) Druce	0.0 b	0.0 c	1.7 ef	5.8 e	5.8 f
Calendula officinalis L.	2.5 b	6.7 bc	11.7 cdef	45.0 cd	65.0 abc
Chamaenerion angustifolium (L.) Scop.	0.0 b	0.0 c	2.5 ef	4.2 e	5.0 f
Coriandrum sativum L.	0.8 b	29.2 b	50.8 b	89.2 ab	99.2 a
Geranium pusillum L.	0.8 b	2.5 c	3.3 def	4.2 e	12.5 ef
Helichrysum arenarium (L.) Moench	5.0 b	26.7 b	40.0 bc	66.7 bc	86.7 ab
Impatiens balsamina L.	0.0 b	0.0 c	0.0 f	5.0 e	25.0 def
Leucanthemum vulgare Lam.	0.0 b	0.0 c	0.8 f	15.8 de	23.3 def
Malva silvestris L.	0.8 b	6.7 bc	10.0 cdef	16.7 de	20.8 def
Matricaria chamomilla L.	1.7 b	12.5 bc	33.3 bcde	70.0 abc	86.7 ab
Mentha piperita L.	0.0 b	0.0 c	0.0 f	4.2 e	11.7 ef
Ocimum basilicum L.	0.8 b	21.7 bc	35.0 bcd	63.3 bc	80.8 abc
Polygonum aviculare L.	0.0 b	0.0 c	0.0 f	6.7 e	90.8 ab
Potentilla anserina L.	0.0 b	0.0 c	0.0 f	0.8 e	0.8 f
Salvia officinalis L.	0.0 b	0.8 c	4.2 def	14.2 de	20.0 def
Satureja hortensis L.	0.8 b	20.0 bc	37.5 bc	85.8 ab	96.7 ab

Values within each column, followed by the same letter are not significantly different

On the 6th day of the experiment *B. napus* plants showed considerably the most injuries, 90.0%. Plants of *C. sativum* were damaged in 50.8% and of *H. arenarium* and *S. hortensis* in 40.0 and 37.5%, respectively. The slugs did not feed on the four species: *P. anserina*, *P. aviculare*, *I. balsamina* and *M. piperita*. Plants of *L. vulgare* and *A. dracunculus* were damaged the least (0.8%). After fourteen days, *B. napus* plants were completely destroyed (100%). Plants of *C. sativum* and *S. hortensis* were significantly damaged the most after fourteen days (89.2 and 85.8%, respectively). High injuries were recorded on *M. chamomilla* (70.0%), *H. arenarium* (66.7%), *O. basilicum* (63.3%) and *A. millefolium* (62.5%). The group of plants with slightest damage included 8 plant species. The injuries were from 0.8% for *P. anserina* to 6.7% for *P. aviculare*. Plants of *C. sativum* were damaged the most on 20th day (99.2%) and next *S. hortensis*, *P. aviculare*, *H. arenarium* and *M. chamomilla* (from 87.0 to 97.0%). Significantly less consumed were plants of *P. anserina* (0.8%), *C. angustifolium* (5.0%) and *C. vulgaris* (5.8%).

Based on the index data (Table 2) *B. napus*, *C. sativum*, *H. arenarium* and *O. basilicum* plants were the most accepted by *D. reticulatum*. The indices for *B. napus* indicated the highest values and acceptability of this plant was sevenfold higher than the average acceptability of all treatments. Four days after slug feeding on *B. napus* A.I. was 6.7 and C.I. equal to 17.9. The indices defined for *C. sativum* were A.I.=2.7, P.I.=0.4 and C.I.=7.3 and that species was the second most acceptable plant. Its acceptability was three times higher than the average, the palatability half the value of *B. napus* and mean daily consumption equal to 7.3%. *D. reticulatum* did not accept almost a half of examined plant species. The analyses of the indices showed that the least attractive plants were *M. piperita*, *I. balsamina*, *P. aviculare*, *C. vulgaris*, *P. anserina*, *C. angustifolium* and *L. vulgare*.

Comparison of acceptability of all examined plant species

Ranks based on acceptability index (A.I.), palatability index (P.I.) and consumption index (C.I.) allowed to classify plants separately for each slug species into four group of preferences (Table 5). Within 20 examined plant species the most acceptable plant species for the all three slug species were *Brassica napus* (*Brassicaceae*), *Ocimum basilicum* (*Lamiaceae)* and *Coriandrum sativum* (*Apiaceae*), and the most unacceptable plants were *Potentilla anserina* (*Rosaceae*) and *Chamaenerion angustifolium* (*Onagraceae*). In addition, *A. lusitanicus* greatly accepted *Calamintha vulgaris* (*Lamiaceae*), *Calendula officinalis* (*Asteraceae*) and *Artemisia dracunculus* (*Asteraceae*), *A. rufus* accepted *Achillea millefolium* (*Asteraceae*) and *Satureja hortensis* (*Lamiaceae*), while *D. reticulatum* accepted *S. hortensis* and *Helichrysum arenarium* (*Asteraceae*). Besides *P. anserina* and *C. angustifolium*, those plants that were rejected by all three slug species, *A. lusitanicus* showed no interest in *Geranium pusillum* (*Geraniaceae*) and *Polygonum aviculare* (*Polygonaceae*), *A. rufus* was not interested in feeding on *Leucanthemum vulgare* (*Asteraceae*), *Matricaria chamomilla* (*Asteraceae*) and *H. arenarium*, and finally *D. reticulatum* did not accept *P. aviculare*, *Mentha piperita* (*Lamiaceae*), *Impatiens balsamina* (*Balsaminaceae*), *C. vulgaris* and *L. vulgare*.

Table 5. Preferences of different herb plant species showed by *A. lusitanicus*, *A. rufus* and *D. reticulatum* presented according to scale where 1 means unacceptable plants

Plant species	*A. lusitanicus*	*A. rufus*	*D. reticulatum*
Achillea millefolium L.	3	4	3
Artemisia dracunculus L.	4	3	2
Borago officinalis L.	2	2	3
Brassica napus L. var. *oleifera* L.	4	4	4
Calamintha vulgaris (L.) Druce	4	2	1
Calendula officinalis L.	4	3	3
Chamaenerion angustifolium (L.) Scop.	1	1	1
Coriandrum sativum L.	4	4	4
Geranium pusillum L.	1	2	2
Helichrysum arenarium (L.) Moench	2	1	4
Impatiens balsamina L.	2	2	1
Leucanthemum vulgare Lam.	2	1	1
Malva silvestris L.	2	3	3
Matricaria chamomilla L.	3	1	3
Mentha piperita L.	3	2	1
Ocimum basilicum L.	4	4	4
Polygonum aviculare L.	1	3	1
Potentilla anserina L.	1	1	1
Salvia officinalis L.	2	3	2
Satureja hortensis L.	3	4	4

2 – hardly acceptable; 3 – moderately acceptable; 4 – highly acceptable

DISCUSSION

The number of plant species in the classified groups representing eating preferences varies. Each group consists of different plant species. Three plant species appeared to be highly accepted and two rejected by *A. lusitanicus*, *A. rufus* and *D. reticulatum*. The most attractive plants were *B. napus* and next *O. basilicum* and *C. sativum*. The plants of *P. anserina* and *C. angustifolium* belonged to the unattractive group. The results revealed that the slugs showed a strong tendency to eat plants from the families *Brassicaceae* and *Apiaceae* and hardly interest in plants from the families *Rosaceae*, *Onagraceae*, *Geraniaceae* and *Polygonaceae*. It cannot be ruled out that the strong acceptance of plants from the families *Brassicaceae* and *Apiaceae* may be influenced to a certain extent by the food (Chinese cabbage leaves and carrot roots) given to the slugs prior to the experiment. The slugs showed great differentiation in acceptability of particular plant species from the families *Asteraceae* and *Lamiaceae.* According to Molgaard (1986) plants from families *Rosaceae*, *Geraniaceae*, *Fagaceae*, *Ericaceae* and *Primulaceae* expose low acceptability for slugs and snails while plants from *Asteraceae*, *Lamiaceae*, *Apiaceae*, *Plantaginaceae*, *Polygonaceae* and *Ranunculaceae* might be well or hardly ever accepted depending on the plant species.

The results revealed that acceptance grade of examined plants differed for particular slug species. For instance, plants of *Helichrysum arenarium* were accepted by *A. rufus* and rejected by *D. reticulatum*. It shows different food preferences by particular slug species and suggests certain food specialization. Similar difference of acceptance was observed in previous survey conducted on eating preferences by different slug species and acceptability of arable crops and weeds (Dirzo 1980; Whelan 1982; Clark *et al*. 1997; Molgaard 1986; Briner and Frank 1998; Kozłowski and Kozłowska 2000, 2003, 2004; Kozłowski and Kałuski 2004).

It was proved that the slugs fed on oilseed rape (*B. napus*) the most eagerly. Other authors also observed that the slugs favour *B. napus* plants the most frequently (Frank 1998; Briner and Frank 1998). Low contents of glucosinolates, as used in present study, affect sensitivity of oilseed rape seedlings of modern cultivars to slug herbivory damage (Byrne and Jones 1996).

Selected plant species as highly acceptable and unacceptable by slugs might be potentially used as new means in oilseed rape control against slugs. That concerns mainly *C. sativum*, *O. basilicum*, *P. anserina* and *C. angustifolium*. There are also other plant species showing high potential in plant protection, however their assortment will depend upon slug species. According to numerous authors nutrient compounds, more precisely plant secondary metabolites specific for particular plant species, are the factors affecting acceptability of plants the most. These compounds are: saccharose, etheric oils, alkaloids, flavonoids, phenols, saponins, tannins and terpenes (Webbe and Lambert 1983; Molgaard 1986; Port and Port 1986; Spaull and Eldon 1990; Hanley *et al*. 1995; Clark *et al*. 1997). These substances decide on a choice of particular plant as food source and also slug feeding behaviour. Their activity might be successfully implemented as alternative methods of plant protection against slug feeding. They might provide attractive alternative food sources (Frank and Friedli 1999), or decrease palatability of cultivated plants if applied as deterrents or antifeedant (Barone and Frank 1999). For instance, *Veronica persica* G. planted in oilseed rape in the laboratory was shown to reduce damage of oilseed rape seedlings caused by *A. lusitanicus* feeding (Frank and Friedli 1999). Plants of *Taraxacum officinale* L. decreased grazing of *D. reticulatum* on oilseed rape in a field experiment (Frank and Barone 1999). It was also proved that extracts from *Saponaria officinalis* L. and *Valerianella lucusta* L. applied on oilseed rape seedlings decreased feeding of *A. lusitanicus* (Barone and Frank 1999). These examples indicate that possibilities to use natural attributes of plants in decreasing slug feeding my be very promising. Up till now numerous experiments have been conducted on palatability of different plant species for several slugs and snails. There is a wide range of plants that have been already tested though, there are still more species that are missing information about their sensitivity to slug feeding. Some of these might present qualities with special influence on some slug species.

The results presented in this paper also confirm the potential of using some plant species that when applied in arable crops might decrease damage caused by the slugs.

CONCLUSIONS

1. The palatability of tested species of plants to the slugs showed strong differentiation. A distinction was made between plants which were accepted (*B. napus, Oci-*

mum basilicum, Coriandrum sativum) and not accepted (*Potentilla anserina, Chamaenerion angustifolium*) by the slugs.
2. Not all plant species are accepted to the same extent by particular species of slugs. This is evidence of their different food preferences.
3. Future research should be done to assess the possibility of using plants which are accepted and not accepted by slugs to reduce slug feeding on seedlings of oilseed rape and other crops.

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POLISH SUMMARY

RÓŻNICE W AKCEPTACJI ROŚLIN ZIELARSKICH I RZEPAKU OLEISTEGO PRZEZ ŚLIMAKI (*A. LUSITANICUS, A. RUFUS* I *D. RETICULATUM)* W TESTACH Z WYBOREM

Do najważniejszych szkodliwych gatunków ślimaków w Polsce należą *Deroceras reticulatum*, a w niektórych rejonach kraju *Arion lusitanicus* i *Arion rufus*. Ślimaki te wyrządzają szkody w uprawach warzyw, roślin rolniczych, sadowniczych, zielarskich i ozdobnych. Najpowszechniejszą metodą ich zwalczania jest, obok zabiegów agrotechnicznych, stosowanie przynęcających granulowanych moluskocydów: metaldehydu i metiokarbu. Skuteczność tych środków jest często niezadowalająca, a ich stosowanie może być szkodliwe dla fauny pożytecznej i kręgowców. Z tych względów poszukuje się alternatywnych metod ograniczania liczebności i szkodliwości ślimaków. Jedną z nich jest możliwość wykorzystania zjawiska preferencji pokarmowych ślimaków i zróżnicowanej akceptacji poszczególnych gatunków roślin.

Celem przeprowadzonych badań było wyodrębnienie gatunków roślin o właściwościach przydatnych w ograniczaniu uszkodzeń siewek rzepaku oleistego przez ślimaki. W warunkach laboratoryjnych wykonano testy z wielokrotnym wyborem dla trzech gatunków ślimaków oraz dla 19 gatunków roślin zielarskich i rzepaku. Dla każdego gatunku ślimaka i poszczególnych gatunków roślin oceniono tempo uszkodzeń roślin w fazie 2–4 liści. W odniesieniu do roślin rzepaku wyznaczono wartości wskaźników: akceptowalności (A.I.), smakowitości (P.I.) i konsumpcji (C.I.) roślin zielarskich. Na podstawie uzyskanych wyników wyodrębniono rośliny akceptowane i nie akceptowane przez ślimaki. Wykazano, że roślinami akceptowanymi przez wszystkie badane gatunki ślimaków były: *Brassica napus, Ocimum basilicum* i *Coriandrum sativum*, natomiast do roślin nie akceptowanych należały: *Potentilla anserina* i *Chamaenerion angustifolium*. Stwierdzono również, że stopień akceptacji kilku gatunków roślin był różny dla poszczególnych gatunków ślimaków, co wynika z ich zróżnicowanych preferencji pokarmowych.