aged plants were *S. bicolor*, *S. alba*, and *V. faba* (5.0–6.0%). From the ninth day onwards, the most damaged plants were *Brassica rapa* and *B. napus* as well as *P. tanacetifolia*. On the ninth day, the levels of damage to *B. rapa*, *B. napus*, and *P. tanacetifolia* were 55.0%, 48.7%, and 42.0%, respectively. The damage to *V. faba*, *S. bicolor*, and *S. alba* was significantly less (7.0–10.0%). After 13 days, the most damaged plants were *B. napus* and *B. rapa* (70.0% and 72%, respectively). Damage to the *V. faba* and *S. alba* plants was significantly the smallest, amounting to 7.0% and 10.0%, respectively. Relatively little damage (approximately 20%) was observed for *Lupinus luteus* L., *S. bicolor*, and *C. intybus*. Observations of damage to plants caused by *D. reticulatum* were continued for 19 days. In that period, none of the studied plant species were 100% damaged.

Incremental slug damage to plants

In view of the differentiation in the incremental damage to the 16 plant species caused by the slugs, exploratory techniques were applied to analyse these multi-dimensional data. Cluster analysis was used to combine the plant species into clusters in such a way that their degree of similarity within a group was as high as possible, and the degree of similarity with species in other groups as low as possible. Comparison of the incremental damage to plants based on Euclidean distances made it possible to group them for each slug species (Figs 1, 2 and 3). For all three species of slugs, clusters were identified at a Euclidean distance of 57 units. In this way, four, five, and six clusters of plant species were obtained, respectively, for *A. vulgaris, A. rufus,* and *D. reticulatum*. Each cluster contains plant species for which similar levels of incremental damage were recorded.

For *A. vulgaris*, the following four clusters of plant species were identified: I – *B. napus, O. sativus, V. sativa, P. somniferum* (average total damage from 86% to 92%); II – *H. annuus, Lens esculenta* Mnch, *C. intybus* (from 72% to 79%); III – *L. luteus, B. rapa* var. *pekinensis, P. tanacetifolia, V. faba, S. bicolor* (from 47% to 57%); and IV – *P. sativum* subsp. *arvense, S. alba, P. sativum, S. bicolor* (from 31% to 44%).

For *A. rufus*, the following five clusters were identified: I – *H. annuus, V. sativa, C. intybus* (average total damage from 79% to 83%); II – *L. luteus, B. napus, G. max, B. rapa* var. *pekinensis* (from 68% to 72%); III – *L. esculenta, P. somniferum, P. tanacetifolia, O. sativus* (from 56% to 66%); IV – *P. sativum, S. alba* (from 48% to 51%); and V – *P. sativum* subsp. *arvense, S. bicolor, V. faba* (from 21% to 34%).

For *D. reticulatum*, the following six clusters were identified: I – *B. napus, B. rapa* var. *pekinensis* (average total damage from 59% to 61%); II – *P. sativum* subsp. *arvense, L. esculenta, P. tanacetifolia* (from 43% to 47%); III – *P. sativum, G. max, H. annuus, P. somniferum, V. sativa* (from 31% to 43%); IV – *C. intybus, O. sativus* (from 26% to 30%); V – *S. alba* (25%); and VI – *L. luteus, S. bicolor, V. faba* (from 7% to 18%).

Summary of analysis results

Based on the results of Fisher's procedure and of the cluster analysis, an attempt was made to make a summary classification of the 16 studied plant species. The summary classification considered each slug species separately, in terms of the degree of damage caused by slugs, or in other words – the susceptibility to slug grazing.

A. vulgaris caused the greatest damage to the plants *O. sativus, P. somniferum, B. napus*, and *V. sativa* (Table 5). The plants least damaged by that slug were *S. bicolor, P. sativum, P. sativum* subsp. *arvense*, and *S. alba*. The slug *A. rufus* most heavily damaged *C. intybus, H. annuus*, and *V. sativa* plants. The slug, *A. rufus,* caused the least damage significantly to the *S. bicolor, V. faba* and *P. sativum*

Table 5. Degrees of damage caused to selected plant species by *A. vulgaris, A. rufus*, and *D. reticulatum* defined for each slug separately

Species of plants	*A. vulgaris*	*A. rufus*	*D. reticulatum*
Brassica napus	++[c]	+	++
B. rapa	x[b]	+	++
Cichorium intybus	+[d]	++	---
Glycine max	x	+	---
Helianthus annuus	+	++	---
Lens esculenta	+	---[e]	+
Lupinus luteus	x	+	xx
Ornithopus sativus	++	---	---
Papaver somniferum	++	---	---
Phacelia tanacetifolia	x	---	+
Pisum sativum	xx[a]	x	---
P. sativum subsp. *arvense*	xx	xx	+
Sinapis alba	xx	x	x
Sorghum bicolor	xx	xx	xx
Vicia faba	x	xx	xx
V. sativa	++	++	---

[a] least damaged; [b] lightly damage; [c] most heavily damaged; [d] heavily damaged; [e] average damaged

subsp. *arvense* plants. In the case of *D. reticulatum*, the greatest damage was observed on plants of *B. rapa* var. *pekinensis* and *B. napus*, while the plants lightly damaged by that slug included *S. bicolor*, *V. faba*, and *L. luteus*.

It should be noted, that certain plant species are less or more susceptible to grazing and damage from all of the three studied slug species. The least susceptible to damage by *A. vulgaris*, *A. rufus*, and *D. reticulatum* were the *S. bicolor* plants, while *S. alba* and *V. faba* were weakly susceptible. On the other hand, the plants that were most susceptible to damage by all of the studied slug species were *B. napus* and, to a somewhat less degree, *V. sativa*, *C. intybus*, and *H. annuus*.

Discussion

The phenomenon of different food preferences of slugs with respect to certain plants is well known. It has been reported in studies relating to herbaceous and wildflower plants. These plants show significant differences in terms of sensitivity to damage by slugs (Duval 1971; Cates and Orians 1975; Jennings and Barkham 1975; Dirzo 1980; Webbe and Lambert 1983; Molgaard 1986; Cook *et al*. 1996; Clark *et al*. 1997; Briner and Frank 1998; Frank 1998; Kozłowski and Kozłowska 2000, 2009). In the present work, we have described the results of laboratory experiments determining the extent of damage to 16 species of crop plants caused by the slugs *A. vulgaris*, *A. rufus*, and *D. reticulatum*. The studies involved leguminous and other plants, most of which are grown as small-area crops. Chinese cabbage *B. rapa* var. *pekinensis* and oilseed rape *B. napus* var. *oleifera* (a variety with a low content of glucosinolates) were used as the controls. They are plants which are heavily damaged by slugs (Moens and Glen 2002; Port and Ester 2002). The studies used young plants at the 3–5 true leaf stage. These young plants are known to be more sensitive to damage than mature plants (Byers and Bierlein 1982; Hanley *et al*. 1995).

Plants found to be heavily damaged by all of the studied slug species (*A. vulgaris, A. rufus*, and *D. reticulatum*) were *B. napus*, *C. intybus*, *H. annuus,* and *V. sativa*, while lightly damaged were *S. bicolor*, *S. alba*, and *V. faba*. The degree of damage to the remaining plants differed depending on the slug species. Plants of *L. luteus*, which were more heavily damaged by *A. rufus*, were only lightly damaged by *A. vulgaris* and *D. reticulatum*. On the other hand, plants of *P. sativum* subsp. *arvense*, which were more heavily damaged by *D. rerticulatum*, suffered only slight damage from *A. vulgaris* and *A. rufus* (Table 5). This confirms the fact, that the amount of slug damage done to crops depends not only on the number of slugs, but also on the species composition of the crop (Moens and Glen 2002; Glen and Moens 2002; Port and Ester 2002).

A clear preference of *A. vulgaris* for certain species of plants was shown by Briner and Frank (1998) in studies of 78 species of wildflower plants sown on strips at the edge of rape fields. As in our study, they found that oilseed rape *B. napus* is a preferred plant for that slug. Other preferred plants reported by those authors included *Papaver rhoeas* L., *Sinapis arvensis* L., *Capsella bursa-pastoris* L. (Med.), and *Lamium purpureum* L. A preference of *A. vulgaris* prefers the plants *C. intybus*, *P. rhoeas* and *S. arvensis*. This preference is somewhat greater than for rape plants. These preferences of *A. vulgaris* were identified in previous studies conducted on 95 species of herbaceous plants (Kozłowski and Kozłowska 2009). On the other hand, the plants *S. alba*, *P. tanacetifolia*, and *P. sativum* subsp. *arvense* were poorly accepted by that slug (Kozłowski 2005). Frank (1998), in studies of the effect of *A. vulgaris* and *D. reticulatum* on the growth of seven wildflower plant species, found that density of *P. rhoeas* (field poppy) was significantly reduced by *A. vulgaris*, while numbers of plants of *S. alba* remained unaffected by both slug species. In our studies, *S. alba* was also the plant which was more lightly damaged by all of the slug species. The information cited above and the results of the present study, indicate that *A. vulgaris* have a strong preference for the plants *B. napus*, *P. rhoeas*, *P. somniferum*, and *C. intybus*, while plants damaged to a lesser degree by that slug are *S. alba*, *P. sativum*, and *P. sativum* subsp. *arvense*. Another plant heavily damaged by that slug is *O. sativus*, and another lightly damaged plant is *S. bicolor*. The data presented here on the extent of damage to the studied species of plants caused by *A. rufus* and *D. reticulatum* (Tables 3, 4 and 5), have not been previously reported.

The study shows that the susceptibility of plants to slug grazing, measured by the degree of damage suffered by the plants, differs significantly for particular species of slugs. This confirms previous data indicating that slugs choose the plants whose taste they find most acceptable, leading to selective grazing (Hanley *et al*. 1995; Cook *et al*. 1996; Frank and Friedli 1999). The choice of food is affected by the physical structure of the leaves (Dirzo 1980), the content of nutrients (Port and Port 1986; Spaull and Eldon 1990), and the quantity and quality of secondary plant metabolites. Of greatest significance are chemical compounds contained in plants such as glycosides, flavonoids, phenols, saponins, terpenes, tannins, which affect both the choice of plants and the grazing behaviour of the slugs. These chemical compounds play a large role in attracting the slugs or in the plants' defence mechanisms against these pests (Cates and Orians 1975; Webbe and Lambert 1983; Molgaard 1986; Hanley *et al*. 1995; Clark *et al*. 1997). It can be assumed, that the reason for the lower level of damage caused to *S. bicolor* (sorghum) by *A. vulgaris*, *A. rufus*, and *D. reticulatum* was the cyanogenic glycosides contained in that plant. As in the case of cyanogenic forms of *Trifolium repens* L., the cyanogenic glycosides caused a reduction in slug grazing and damage to plants (Dirzo 1980; Dirzo and Harper 1982a, b). A similar effect may have come from the tannins contained in plants of *V. faba* var. Bobas. According to some authors, these phenol derivatives often play a defensive role against various agricultural pests (Boesewinkel and Bouman 1995). The lower amount of damage to *S. alba* can probably be explained by the sinalbin glycoside present in that plant, which in *S. arvensis* may not be present or exists in too small a quantity to have an effect on slugs. In the case of *P. sativum*, the reduction in grazing by *A. vulgaris* and *A. rufus* may be due to the phenolic compound xylohydroquinone (Kohlmünzer 2000). Particular attention should be paid to plants of the genus *Lupinus*, particularly bitter

varieties of *L. angustifolius*, which contain quinolizidine alkaloids (QA) that bring about a significant reduction in slug grazing. These compounds constitute a potential system of defence for leguminous plants against herbivores (Aguiar and Wink 1999; Chevalier *et al*. 2000). We studied the alkaloids contained in the plants of *L. luteus*. The alkaloids may have contributed to the lower levels of damage caused to those plants by *A. vulgaris* and *D. reticulatum*.

The results obtained in this work provide certain indications concerning the degree of risk posed and amount of damage done, to leguminous and other small-area crop plants by the slugs *A. vulgaris*, *A. rufus*, and *D. reticulatum*. They do not explain, however, which specific plant substances affect the grazing behaviour of slugs and by what mechanism they operate. Studies will continue on different varieties of selected plant species, to investigate their defence mechanisms against slug grazing and their potential use in integrated plant protection programmes.

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