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SLUG DAMAGE AND NUMBERS OF SLUGS IN OILSEED RAPE BORDERING ON GRASS STRIPS

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ABSTRACT

In 1995, slug damage and numbers of slugs were estimated in two grass strips and adjacent rape fields. Investigations began as soon as rape seedlings emerged and lasted for five weeks. Slug damage to rape plants 1 m from the grass strips was significantly higher than at greater distances from the strips. *Deroceras reticulatum* was the most abundant slug species recorded in both grass strips and adjacent rape fields. *Arion lusitanicus* and *Arion fasciatus* were much less abundant than *D. reticulatum*. In one field, *D. reticulatum* declined steadily with increasing distance from the grass strips and therefore appeared to have caused the majority of severe damage to rape plants close to the strips. This finding was surprising because until now severe slug damage in oilseed rape beside semi-natural habitats has been observed only where *A. lusitanicus* was abundant.

INTRODUCTION

To counteract the general trend of losses of natural habitats in the agricultural landscape (Greaves & Marshall, 1987; Tivy, 1993), different types of man-made habitats are established to enhance the biodiversity of animals and plants. One type of such semi-natural habitats are linear structures dominated by grasses, which are created within fields or at the edges of fields. Species diversity of ground beetles on arable land was increased by the creation of 4–5 m wide grassland strips (Pfiffner & Luka, 1996). May, Ewin, Mott, Pack & Russell (1994) recorded particularly high numbers of epigeal spiders and beetles in boundary strips dominated by grasses. Kromp & Steinlechner (1992) found rare species of spiders in grassy field margins and emphasized the general importance of grassy margins for nature conservation. Grassy field boundaries were shown to be important overwintering refuges for predatory carabids (Sotherton, 1985; Thomas, 1990). Some predatory carabid species invaded adjacent crop areas after overwintering in the boundaries, which led to increased beetle densities in the fields in spring of the next year (Jensen, Dyring, Kristensen, Nielsen & Rasmussen, 1989; Thomas, Wratten & Sotherton, 1991).

In contrast to arthropods, there is little published information on the effects of grass strips on slug numbers (Speiser & Niederhauser, 1997), and nothing is known about their damage in adjacent crops. However, previous research on the impact of slugs on damage to oilseed rape adjacent to sown wildflower strips, another type of semi-natural habitat, has shown that slugs caused severe damage up to 2 m from the strips (Frank & Friedli, 1997; Frank, 1998). These investigations further revealed that damage to rape grown beside wildflower strips could be prevented by broadcasting slug pellets. This paper concentrates on the extent of damage adjacent to grass strips in rape fields where no molluscicides were used. Due to the findings alongside wildflower strips, the present study of slug numbers and damage was carried out in crop areas 1, 3 and 5 m from the grass strips to compare the influence of slug feeding on rape in areas close to the strips where high damage was expected and in areas farther from the strips where it was not expected.

MATERIAL AND METHODS

Study areas

The investigation took place in autumn 1995 on a farm in Belp, south of Bern, Switzerland. The investigation started as soon as seedlings of oilseed rape (cv. 'Express' sown at a rate of 5 kg seed/ha) emerged, and lasted for five weeks, during the phase when young rape plants are most vulnerable to slug attack. Rape was direct-drilled into wheat stubble on 6 September 1995 on two fields with reduced chemical input ('integrated production') with wet gley soil. In each field, research was made in a crop area of 55 m length alongside a grass strip. In these study areas no molluscicides were applied. The cropped area in field F1 was 1.3 ha and in field F2 0.8 ha. The grass strips were 145 m (strip 1) and 110 m (strip 2) long and 1 m wide. Both grass strips have existed for more than ten years and were mown once a year at the end of July. The vegetation cover of both grass strips was dominated by the grasses *Agropyron repens, Arrhenatherum elatius, Dactylis glomerata, Festuca pratensis, Lolium multiflorum, L. perenne, Phleum pratense* and *Poa pratensis*. Herbs were fairly rare and almost no broad-leaved herbs occurred in the two grass strips studied.

Slug sampling

Numbers of slugs were estimated using bait stations containing wheat bran, cat food and water in a ratio of 1:1:5 by weight. Each bait station consisted of a petri dish (140 mm diameter) filled with 20–25 g bait. In each grass strip, eight petri dishes with bait were placed 1 m from the edge of the adjacent field. In the adjacent fields, eight bait stations were located at 1, 3 and 5 m from the grass strips. In each grass strip and within each distance from the strips, the bait stations were located 7 m apart. Slug numbers were recorded weekly on wet evenings. Petri dishes with bait were placed on the soil surface at dusk; four hours later, slugs on the dishes were counted and identified to species. After that, the petri dishes with baits were removed from the field.

Evaluation of damage

Every day after slug numbers were estimated, slug damage on rape plants was evaluated using a defoliation index from zero to four: 0 = no damage; 1 = 1–25% defoliation; 2 = 26–50% defoliation; 3 = 51–75% defoliation; 4 = 76–100% defoliation. Slug damage was evaluated 1, 3 and 5 m from the grass strips on 5 plants at 10 randomly chosen places. By the fifth week of the investigation, rape had four to six true leaves. Means were calculated for each distance and week. On 23 March 1996, numbers of rape plants/m^2 were counted at twelve randomly chosen places at 1, 3 and 5 m from the grass strips.

Analyses

All data were transformed to square roots to stabilize the variance; the figures and tables present the actual data. ANOVA was used to evaluate whether or not there were significant differences in slug damage, numbers of plants/m^2 or numbers of slugs among the different distances on each date. Tukey's HSD-test was used to determine significant differences.

RESULTS

Slug damage

Slug damage in both fields was not significantly different at different distances from the grass strips in the first week after emergence of the rape seedlings (Fig. 1). However, from the second week onwards slug damage at 1 m increased distinctly and became significantly greater there than at 3 and 5 m from the strips in field F2. In field F1, slug damage was only significantly greater at 1 m than at the other distances from the fourth week onwards. After four weeks, severe defoliation was observed on rape plants 1 m from the grass strips, with mean defoliation scores of 2.86 in field F1 and 2.66 in field F2.

Numbers of rape plants/m^2 in spring 1996 exhibited a similar pattern to damage on young rape in autumn 1995. In field F1, mean number of plants/m^2 at 1 m from the grass strip (1.83) was lower than at the same distance in field F2 (6.67), corresponding with the extent of defoliation scores in these crop areas. Numbers of rape plants at 1 m from the grass strips were significantly lower than at the other distances (Table 1). In field F1 significantly more rape plants were observed at 5 m than at 3 m. In contrast, in field F2 numbers of rape plants at 3 and 5 m from the grass strip did not differ significantly. In both fields numbers of rape plants/m^2 and defoliation scores from 13 October 1995 on exhibited the same pattern of significant differences between all distances from the grass strips (Fig. 1, Table 1).

Numbers of slugs

Three slug species, *Deroceras reticulatum* (Müller), *Arion lusitanicus* (Mabille) and *Arion fasciatus* (Nilsson) were recorded on the bait stations. *D. reticulatum* and *A. lusitanicus* were almost exclusively adults, whereas only juvenile individuals of *A. fasciatus* were observed. Both grass strips and adjacent crop areas were dominated by *D. reticulatum* (Table 2).

In field F1, numbers of individuals of all slug species were never significantly different between the grass strip and the rape areas from the first to the fifth week of the investigation

Table 1. Numbers of rape plants/m^2 (Mean ± SE) at different distances from grass strips in spring 1996. Different letters indicate significant differences within each field (Tukey; $P < 0.05$).

Distance from grass strip	Field F1	Field F2
1m	1.83 ± 0.80 a	6.67 ± 2.14 a
3m	15.00 ± 2.76 b	31.50 ± 3.67 b
5m	29.33 ± 2.21 c	36.00 ± 4.10 b

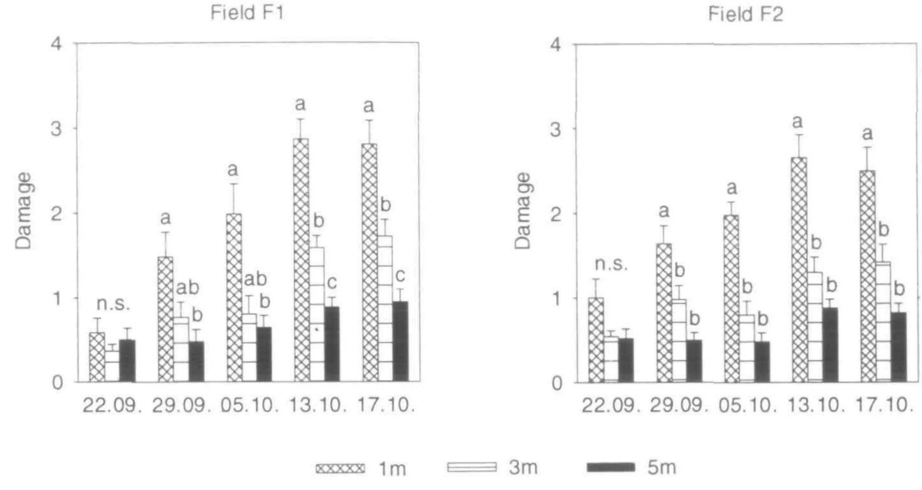

Figure 1. Slug damage score (Mean ± SE) in rape fields at different distances from grass strips. Different letters indicate significant differences within each date (Tukey; $P < 0.05$). n.s. = not significant.

Table 2. Numbers of slugs (Mean ± SE) per petri dish in grass strips and in adjacent rape areas. Data from wk 1–5 are pooled (n = 40). Different letters within each row indicate significant differences within each site (Tukey; $P < 0.05$). n.s. = not significant.

Site	*Deroceras reticulatum*	*Arion lusitanicus*	*Arion fasciatus*
Field F1			
strip	0.67 ± 0.13 a	0.37 ± 0.06 ab	0.10 ± 0.06 b
1m	0.35 ± 0.10 a	0.10 ± 0.05 b	0.12 ± 0.08 b
3m	0.37 ± 0.11 a	0.07 ± 0.04 b	0.12 ± 0.05 ab
5m	0.32 ± 0.11 a	0.02 ± 0.02 b	0.00 ± 0.00 b
Field F2			
strip	2.90 ± 0.32 a	0.07 ± 0.04 b	0.00 ± 0.00 b
1m	1.52 ± 0.22 a	0.05 ± 0.03 b	0.07 ± 0.04 b
3m	0.60 ± 0.13 a	0.05 ± 0.03 b	0.05 ± 0.03 b
5m	0.07 ± 0.04 n.s.	0.00 ± 0.00 n.s.	0.00 ± 0.00 n.s.

(Fig. 2). However, by pooling the numbers of individuals over all five weeks for each species, it was found out that *A. lusitanicus* declined smoothly with increasing distance from the grass strip, whereas *D. reticulatum* was evenly distributed over the whole crop area (Table 2). In contrast to the other species, *A. fasciatus* was discovered only from the third week on.

In field F2, *D. reticulatum* showed a different distribution pattern from those of *A. lusitanicus* and *A. fasciatus*. *D. reticulatum* was most abundant in the grass strip and decreased clearly from 1 to 5 m into the nearby rape area during the whole five-week period (Fig. 2). Thus, the distribution pattern of *D. reticulatum* corresponded well with the extent of damage in the rape. Pooled numbers of *D. reticulatum* revealed a distinct decline from the grass strip into the rape area (Table 2). Except for the field area 5 m from grass strip 2, *D. reticulatum* was always significantly more abundant in the strip and in the crop area than *A. lusitanicus* and *A. fasciatus*. *A. fasciatus* was only discovered from the fourth week onwards.

DISCUSSION

Slug damage and slug numbers

Generally, rape is considered to be the crop most vulnerable to slug attack in Germany (Mesch, 1996) and Switzerland (Högger, 1995). In the United Kingdom, slug damage in winter

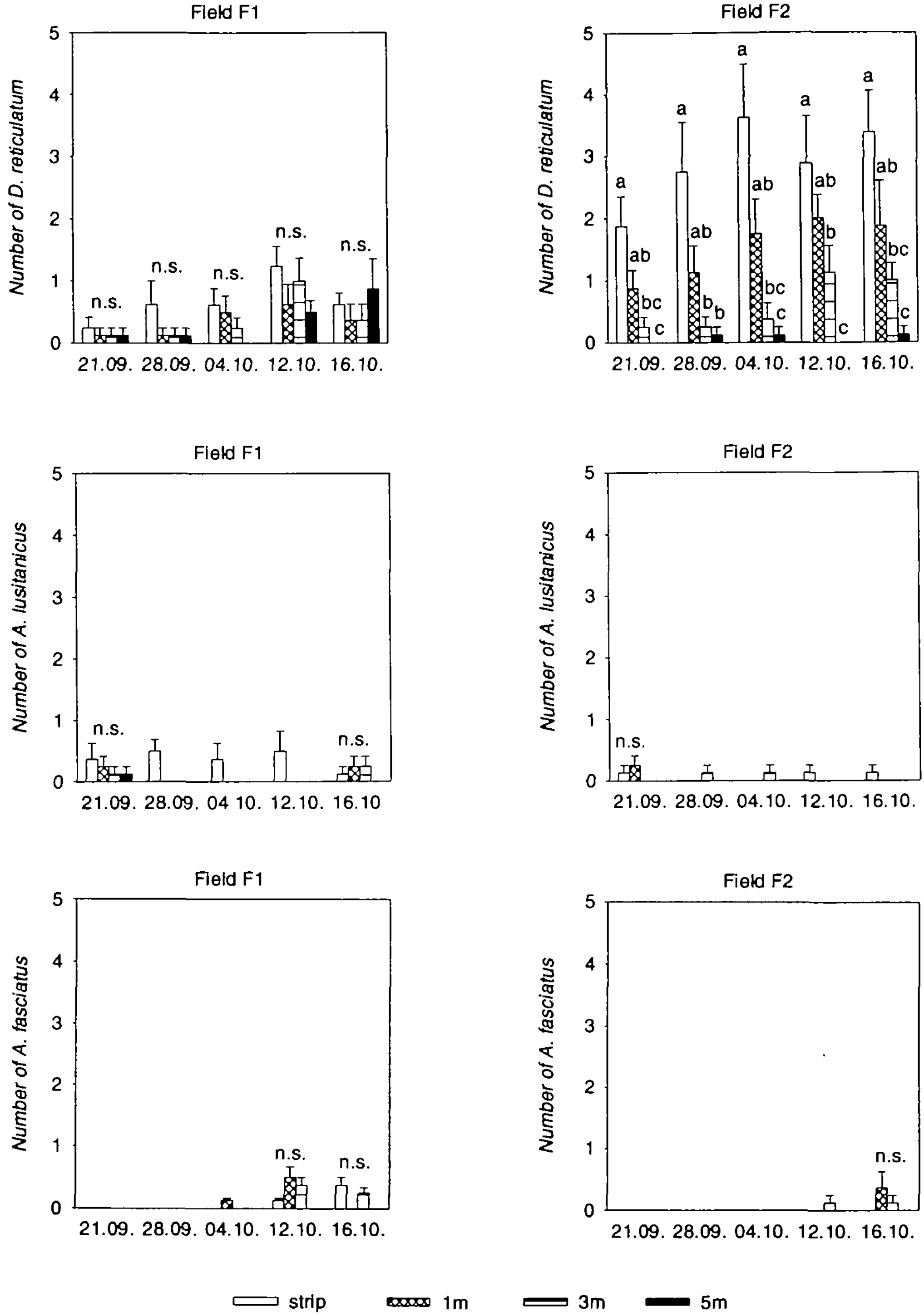

Figure 2. Numbers of slugs (Mean ± SE) in grass strips and in rape fields at different distances from strips. Different letters indicate significant differences within each date (Tukey; $P < 0.05$). n.s. = not significant.

wheat increased distinctly when rape was the previous crop (Glen *et al.*, 1993). Slug problems in rape may increase in the future because concentrations of glucosinolates, known to protect rape from slugs (Glen *et al.*, 1990; Giamoustaris and Mithen, 1995; Byrne & Jones, 1996), continue to decline in rape cultivars. Severe slug damage in oilseed rape fields without application of slug pellets has also been observed along wildflower strips, another type of linear semi-natural habitat (Frank, 1996; Högger, personal communication). Thus, severe problems with slugs in rape along semi-natural areas were not restricted to the fields investigated in this study.

Although slug damage was significantly higher at 1 m than at 3 and 5 m from the grass strips, in the first week of the research, rape seedlings emerged well without evidence of slugs causing damage before emergence. Later, when severe crop loss occurred, remains of rape stems were observed relatively often. These observations suggested that the main damage in both fields was caused by slug feeding on emerged seedlings and only a little damage was caused by destroying seeds and young seedlings below ground. This agrees with Moens, Couvreur & Cors (1992) who consider that epigeal feeding of slugs on early leaf stages is particularly harmful to rape.

Feeding experiments carried out in the laboratory with slugs from Belp showed that adult *A. lusitanicus* ate about half as many rape seedlings again as adult *D. reticulatum* (12.10 plants consumed/24 h and 7.76 respectively; Frank, unpublished). The numbers of slugs recorded at 1 m from the grass strips suggest, therefore, that *D. reticulatum* caused the majority of damage there, especially in field F2 where *D. reticulatum* was almost the only species present. Although *A. lusitanicus* was in some weeks restricted to the grass strips, this species was responsible for at least a small amount of damage at 1 m from the strip in field F1. Since only juveniles of *A. fasciatus* were observed, and even then only from the third or fourth week onwards in small numbers, it is obvious that this slug was not responsible for the damage caused at 1 m from the grass strips. In contrast to *A. fasciatus*, numbers of *D. reticulatum* and also *A. lusitanicus* in the rape areas often declined with increasing distance from the grass strips. A similar distribution pattern has also been observed for *A. lusitanicus* in rape fields grown beside wildflower strips in 1994 and 1995, indicating that this slug disperses from the strips into the nearby crop area (Frank, 1998). Although the available evidence indicates that *D. reticulatum* is largely sedentary within uniform fields of grass or cereals (South, 1965; Glen, Wiltshire & Butler, 1991), the distribution pattern of *D. reticulatum*, at least in field F2, suggests that this species dispersed from grass strip 2 into the adjacent rape area.

Although *A. lusitanicus* was abundant in several wildflower strips on the same farm at Belp in 1995, it was seldom recorded in the two grass strips studied. This is surprising because the grass strips were more than ten years old, whereas the wildflower strips were sown only in 1994 or 1995. Thus, in contrast to the grass strips, the wildflower strips were inhabited by many *A. lusitanicus* soon after they were established. The following features of the studied grass strips, which contrasted with the wildflower strips at Belp, may have been the reason for the near absence of *A. lusitanicus* from the grass strips: the soil surface of the grass strips was covered by a particularly dense layer of grass tussocks which possibly could not be penetrated by big adult *A. lusitanicus* to reach moist crevices in the soil in which to shelter during the day. Moreover *A. lusitanicus* could hardly find shelter below broad leaves because the vegetation was dominated by grasses. In every year, the grass strips were mown at the end of July, during the egg laying period of *A. lusitanicus*, so that its eggs on the ground probably suffered from desiccation. Since grasses are particularly unpalatable to *A. lusitanicus* (Briner, 1997), it found few palatable herbs in the grass strips. All these features of the grass strips were not unfavourable to *D. reticulatum*, which is more associated with a life below ground than *A. lusitanicus*. *D. reticulatum* spends the day in the soil and usually lays its eggs there (Graber & Suter, 1989) and is therefore much less influenced by the vegetational structure and the mowing regime than *A. lusitanicus*. South (1965) observed that the eggs of *D. reticulatum* were positively associated with the distribution of *Dactylis glomerata*, one of the dominant grasses in the grass strips studied. *D. reticulatum* is known to eat leaf material of grasses and dicotyledons (Pallant, 1972) and therefore found more suitable feeding conditions in the grass strips than *A. lusitanicus*. Nevertheless *D. reticulatum* apparently invaded the crop area to feed on the rape seedlings which, therefore, appeared to be more palatable than the plants in the grass strips.

Until now, severe damage in oilseed rape bordering on semi-natural habitats has been observed only where *A. lusitanicus* was abundant (Frank, 1998; Högger, personal communication). Although *A. lusitanicus* has been observed to be abundant in grass strips elsewhere (Speiser & Niederhauser, 1997), the present study revealed that high damage to rape crops beside semi-natural habitats can also be caused primarily by *D. reticulatum*.

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REFERENCES

BRINER, T. 1997. *Investigations on the reproduction and the feeding behaviour of the slug* Arion lusitanicus (Mabille). Master's Thesis, University of Bern, Switzerland.

BYRNE, J. & JONES, P. 1996. Responses to glucosinolate content in oilseed rape varieties by crop pest (*Deroceras reticulatum*) and non-pest slug species (*Limax pseudoflavus*). *Annals of Applied Biology*, **128**: 78-79.

FRANK, T. 1996. Sown wildflower strips in arable land in relation to slug density and slug damage in rape and wheat. *Slug and Snail Pests in Agriculture.* (I.F. Henderson, ed.), British Crop Protection Council Monograph, **66**: 289-296.

FRANK, T. 1998. Slug damage and numbers of the slug pests, *Arion lusitanicus* and *Deroceras reticulatum*, in oilseed rape grown beside sown wildflower strips. *Agriculture, Ecosystems & Environment*, **67**: 67–78.

FRANK, T. & FRIEDLI, J. 1997. The effect of metaldehyde on slug damage in oilseed rape adjacent to sown wildflower strips. *Heldia*, **4**: 132-133.

GIAMOUSTARIS, A. & MITHEN, R. 1995. The effect of modifying the glucosinolate content of leaves of oilseed rape (*Brassica napus* ssp. *oleifera*) on its interaction with specialist and generalist pests. *Annals of Applied Biology*, **126**: 347-363.

GLEN, D.M., JONES, H. & FIELDSEND, J.K. 1990. Damage to oilseed rape seedlings by the field slug *Deroceras reticulatum* in relation to glucosinolate concentration. *Annals of Applied Biology*, **117**: 197-207.

GLEN, D.M., WILTSHIRE, C.W. & BUTLER, R.C. 1991. Slug population changes following molluscicide treatment in relation to distance from edge of treated area. *Crop Protection*, **10**: 408-412.

GLEN, D.M., SPAULL, A.M., MOWAT, D.J., GREEN, D.B. & JACKSON, A.W. 1993. Crop monitoring to assess the risk of slug damage to winter wheat in the United Kingdom. *Annals of Applied Biology*, **122**: 161-172.

GRABER, C. & SUTER, H. 1989. *Schneckenbekämpfung ohne Gift.* Stuttgart, Franckh.

GREAVES, M.P. & MARSHALL, E.J.P. 1987. Field margins: definitions and statistics. *Field margins*, (J.W. Way & P.W. Greig-Smith eds), British Crop Protection Council Monograph, **35**: 3-11.

HÖGGER, C. 1995. Schneckenschäden vermeiden, *Die Grüne*, **8**: 12-15.

JENSEN, T.S., DYRING, L., KRISTENSEN, B., NIELSEN, B.O. & RASMUSSEN, E.R. 1989. Spring dispersal and summer habitat distribution of *Agonum dorsale* (Coleoptera, Carabidae). *Pedobiologia*, **33**: 155-165.

KROMP, B. & STEINBERGER, K.H. 1992. Grassy field margins and arthropod diversity. A case study on ground beetles and spiders in eastern Austria (Coleoptera: Carabidae; Arachnida: Aranei, Opiliones). *Agriculture, Ecosystems & Environment*, **40**: 71-93.

MAY, M.J., EWIN, C., MOTT, J., PACK, R. & RUSSELL, C. 1994. Comparison of five different boundary strips—interim report of first two years' study. *Integrating Agriculture and Conservation* (N. Boatman, ed.), British Crop Protection Council Monograph, **58**: 259-264.

MESCH, H. 1996. Was hilft gegen Schnecken im Raps? *Top Agrar*, **8**: 52-53.

MOENS, R., COUVREUR, R. & CORS, F. 1992. Influence de la teneur en glucosinolates des variétés de colza d'hiver sur les dégâts de limaces. *Bulletin de Recherches Agronomiques Gembloux*, **27**: 289-307.

PALLANT, D. 1972. The food of the grey field slug, *Agriolimax reticulatus* (Müller), on grassland. *Journal of Animal Ecology*, **41**: 761-769.

PFIFFNER, L. & LUKA, H. 1996. Laufkäfer-Förderung durch Ausgleichsflächen. *Naturschutz und Landschaftsplanung*, **28**: 145-151.

SOTHERTON, N.W. 1985. The distribution and abundance of predatory Coleoptera overwintering in field boundaries. *Annals of Applied Biology*, **106**: 17-21.

SOUTH, A. 1965. Biology and ecology of *Agriolimax reticulatus* (Müll.) and other slugs: spatial distribution. *Journal of Animal Ecology*, **34**: 403-417.

SPEISER, B. & NIEDERHAUSER, D. 1997. Fördern extensive Wieslandstreifen Schneckenschäden? *Agrarforschung*, **4**: 179-180.

THOMAS, M.B. 1990. The role of man-made grassy habitats in enhancing carabid populations in arable land. In: *The role of ground beetles in ecological and environmental studies* (N.E. Stork, ed.), 77-85. Intercept, Hampshire.

THOMAS, M.B., WRATTEN, S.D. & SOTHERTON, N.W. 1991. Creation of 'island' habitats in farmland to manipulate populations of beneficial arthropods: predator densities and emigration. *Journal of Applied Ecology*, **20**: 906-917.

TIVY, J. 1993. *Landwirtschaft und Umwelt.* Spektrum, Heidelberg.