Species Spectrum of Flea Beetles (*Phyllotreta* spp., Coleoptera, Chrysomelidae) Attracted to Allyl Isothiocyanate-Baited Traps

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In field tests in Hungary, Slovenia and Bulgaria, in allyl isothiocyanate-baited traps significantly more beetles of *Phyllotreta cruciferae, Ph. vittula, Ph. undulata, Ph. nigripes, Ph. nodicornis, Ph. balcanica, Ph. atra, Ph. procera, Ph. ochripes, Ph. diademata* and *Psylliodes chrysocephalus* (Coleoptera, Chrysomelidae, Halticinae) were captured than in unbaited control traps. With the exception of *Ph. cruciferae*, this is the first report on significant field attraction by allyl isothiocyanate for these species. The species spectrum captured included six important agricultural pests. At all sites a great portion of the catch (ranging from ca 30 to 98%) was *Ph. cruciferae*, irrespective of the plant culture. The second most abundant species present at most sites was *Ph. vittula*. The present results are very promising from the point of view of applicability of allyl isothiocyanate in Europe as a bait in cabbage flea beetle traps for detection and monitoring.

Key words: Phyllotreta, Allyl Isothiocyanate, Trapping

Introduction

There are more than 250 flea beetle species (Coleoptera, Chrysomelidae, Halticinae) present in Hungary, Bulgaria and Slovenia (Kaszab, 1962; Gruev and Tomov, 1986; Brelih *et al.*, 2003). The economically most important flea beetle species belong to the genus *Phyllotreta*, and feed on several cruciferous cultures in Europe and also on other continents (Jourdheuil, 1966; Sáringer, 1998). Thus, attractant-baited traps would be very useful both in the detection of the occurrence of overwintering adults in early spring, or in monitoring their flight pattern and in giving estimates of the size of the local populations to aid the control of the beetles.

It has long been known that plant-derived isothiocyanates, as secondary metabolites arising from the decomposition of non-volatile glucosinolates, attract some species of flea beetles (Görnitz, 1956; Feeny *et al.*, 1970; Burgess and Wiens, 1980; Vincent and Stewart, 1984; Pivnick *et al.*, 1992; Smart and Blight, 2000). The objective of the present study was to investigate the range of *Phyllotreta* species responding to allyl isothiocyanate in Hungary, Slovenia and Bulgaria, so that the applicability of this attractant for plant protection purposes can be evaluated. This volatile compound has been described as one of the most potent attractants for certain flea beetles in other regions of the world (Görnitz, 1956; Feeny *et al.*, 1970; Vincent and Stewart, 1984; Pivnick *et al.*, 1992).

Materials and Methods

Traps

CSALOMON® VARL+ funnel traps (Plant Protection Institute, HAS, Budapest, Hungary) were used in most tests. These were originally developed for catching larger moths (Tóth *et al.*, 2000; Subchev *et al.*, 2004), but proved to be applicable also for capturing flea beetles (Tóth *et al.*, 2004). In some preliminary tests sticky delta CSALOMON® RAG traps were used (Szöcs, 1993; Tóth and Szöcs, 1993), while in most tests in 2004–2006 CSALOMON® KLP+ "hat" traps (Plant Protection Institute, HAS) were used (Tóth *et al.*, 2006). All types of traps were placed at soil level.

A small piece (1 cm × 1 cm) of household anti-moth strip (Chemotox®, Sara Lee, Temana Intl. Ltd, Slouth, UK; active ingredient 15% dichlorvos) was placed each catch container of the VARL+ and KLP+ traps as a killing agent for captured insects.

Baits

Allyl isothiocyanate was purchased from Sigma-Aldrich Kft. (Budapest, Hungary) and was > 95% pure as stated by the supplier. For making up the baits 100 mg amounts were administered onto a 1 cm piece of dental roll (Celluron®, Paul Hartmann, Heidenheim, Germany), which was placed into a tight polyethylene bag (ca. 1.0 cm × 1.5 cm) made of 0.02 mm thick polyethylene foil (PE bag). The dispensers were heat-sealed and attached to 8 cm × 1 cm plastic handles for easy manipulation when assembling the traps. In later experiments 100 mg of allyl isothiocyanate were administered into 0.7 ml polyethylene vials with lid (No. 730, Kartell Co., Milano, Italy) (PE vials). These vials were used with closed lids (so that allyl isothiocyanate penetrated through the walls only) in the field tests. Baits were wrapped singly in pieces of aluminum foil and stored at –65 °C until use. In the field, old baits were replaced with new ones at 2–3 weeks intervals.

Field tests

The tests were conducted at several sites in Hungary (26 experiments), Slovenia (2 experiments) and Bulgaria (1 experiment). The traps were arranged as blocks so that each block contained one trap baited with allyl isothiocyanate and one unbaited control trap. Traps within blocks were separated by 8–10 m, and blocks were sited at least 20–30 m apart. Technical details of single experiments are available from the authors archives on request.

Capture data were transformed to $(x + 0.5)^{1/2}$ and analyzed by Student *t* test or one-sample *t* test (in case unbaited traps captured zero), as appropriate. All statistical procedures were conducted using the software packages StatView® v4.01 and SuperANOVA® v1.11 (Abacus Concepts, Inc., Berkeley, CA, USA).

Results and Discussion

Ph. cruciferae Goeze

At most experimental sites our traps baited with allyl isothiocyanate caught large numbers of *Ph. cruciferae*. Catches in baited traps were always significantly higher than in unbaited ones. Since our results clearly confirmed earlier reports on the activity of this compound for this species (Görnitz, 1956; Feeny *et al.*, 1970; Burgess and Wiens, 1980; Vincent and Stewart, 1984; Pivnick *et al.*, 1992), no detailed catch figures are given in this paper. *Ph. cruciferae* is one of the most important pest flea beetles in Hungary, Bulgaria and Slovenia (Kaszab, 1962). It causes damage on several cultured cruciferous plants such as cabbage, rape varieties, white mustard, kohlrabi, kale, cauliflower and broccoli (Sáringer, 1990; Vig, 1992; Balázs *et al.*, 1998; Spilák *et al.*, 1998; Vörös and Garamvölgyi, 1998). In Bulgaria, the species was also found on *Reseda* spp. and the ornamental plant *Alyssum* (Gruev and Tomov, 1986). The species is also able to propagate several plant pathogens (Markham and Smith, 1949; Dillard *et al.*, 1998; Stobbs *et al.*, 1998).

Ph. vittula Redtb.

In our experiments the second most frequently captured species was *Ph. vittula*. Traps with allyl isothiocyanate caught significantly more than unbaited ones at many of the test sites, suggesting strong attraction by this compound (Fig. 1). We are not aware of any previous reports in the literature on the attraction of allyl isothiocyanate for this species. *Ph. vittula*, unlike other pest cabbage flea beetles, causes damage not only on Cruciferae, but also on monocotyledonous plants such as maize, barley, winter wheat and millet (Nagy and Deseö, 1969; Vig, 1996, 1998; Szeöke, 1997). It is a well-known vector of brome mosaic virus (Ryden, 1989).

Ph. undulata Kutsch.

This species was caught in sizeable numbers at three sites, traps with allyl isothiocyanate in all cases catching significantly more than unbaited traps (Fig. 2A). There were some previous reports on traps baited with allyl isothiocyanate catching

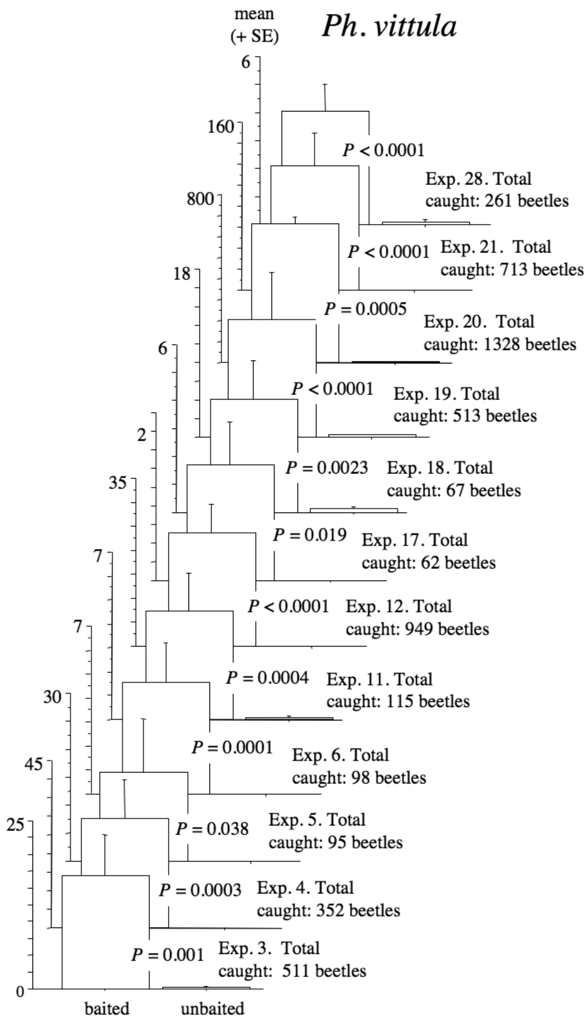

Fig. 1. Catches of *Phyllotreta vittula* in traps baited with allyl isothiocyanate and in unbaited traps. *P* values derive from Student *t* test (unpaired or one sample, as appropriate). *Y* axis shows mean catch/trap/inspection (+ SE).

Ph. undulata (Foster, 1984; Liblikas *et al.*, 2003), however, a direct comparison of baited vs. unbaited traps giving statistically significant differences is first reported here. Liblikas *et al.* (2003) claimed that other related isothio- and thiocyanates were more attractive to *Ph. undulata* than allyl isothiocyanate, however, since they did not perform statistical analyses on their data, it is hard to evaluate the results. *Ph. undulata* is among the most important pests of the group of striped cabbage flea beetles (Kaszab, 1962; Sáringer, 1990; Vig, 1992; Vörös and Garamvölgyi, 1998), and is a known vector of turnip yellow mosaic virus (Markham and Smith, 1949).

Ph. nigripes Fabr.

The species was caught in significantly higher numbers in baited than in unbaited traps at two sites (Fig. 2B). There are no previous reports on the attraction of this species by allyl isothiocyanate. *Ph. nigripes* is a frequent, serious pest of cabbage in Western Europe (Kaszab, 1962; Sáringer, 1990).

Ph. nodicornis Marsh., Ph. balcanica Heikert., Ph. atra Fabr.

These species were caught in sizeable numbers at one site each, by allyl isothiocyanate-baited traps capturing significantly more than unbaited ones (Figs. 2C–E). We found no earlier reference on the attraction of these spp. to allyl isothiocyanate in the literature. From these species *Ph. atra* is a very serious pest of cruciferous crops in Europe (Kaszab, 1962; Sáringer, 1990; Vig, 1992; Balázs *et al.*, 1998; Spilák *et al.*, 1998; Vörös and Garamvölgyi, 1998). The host plant of *Ph. balcanica*, which is a rare species in the region, is reported as *Sinapis*, *Rorippa* and *Diplotaxis* (Gruev and Tomov, 1986). *Ph. nodicornis* feeds on plants belonging to the genus *Rezeda* (Kaszab, 1962).

Ph. procera Redtb., Ph. ochripes Curt., Ph. diademata Foudb.

On the respective single test sites per species, significantly more beetles were recorded in baited vs. unbaited traps (which caught zero), indicating possible attraction by allyl isothiocyanate; however, overall numbers captured were that low that attraction needs further confirmation (Figs. 2F–H). From these spp. *Ph. diademata* is frequently collected at wet meadows and lives on *Nestia* and *Rorippa* (Kaszab, 1962), but has also been reported on Chinese cabbage (Gruev and Tomov, 1986). The host plants of *Ph. ochripes* include *Alliaria officinalis* Andrz. (Kaszab, 1962) and Chinese cabbage (Gruev and Tomov, 1986), while *Ph. procera* feeds mostly on *Rezeda* spp. (Kaszab, 1962).

Psylliodes chrysocephalus L.

Apart from *Phyllotreta* spp., specimens of the close relative *Ps. chrysocephalus* were regularly captured in significantly larger numbers in baited

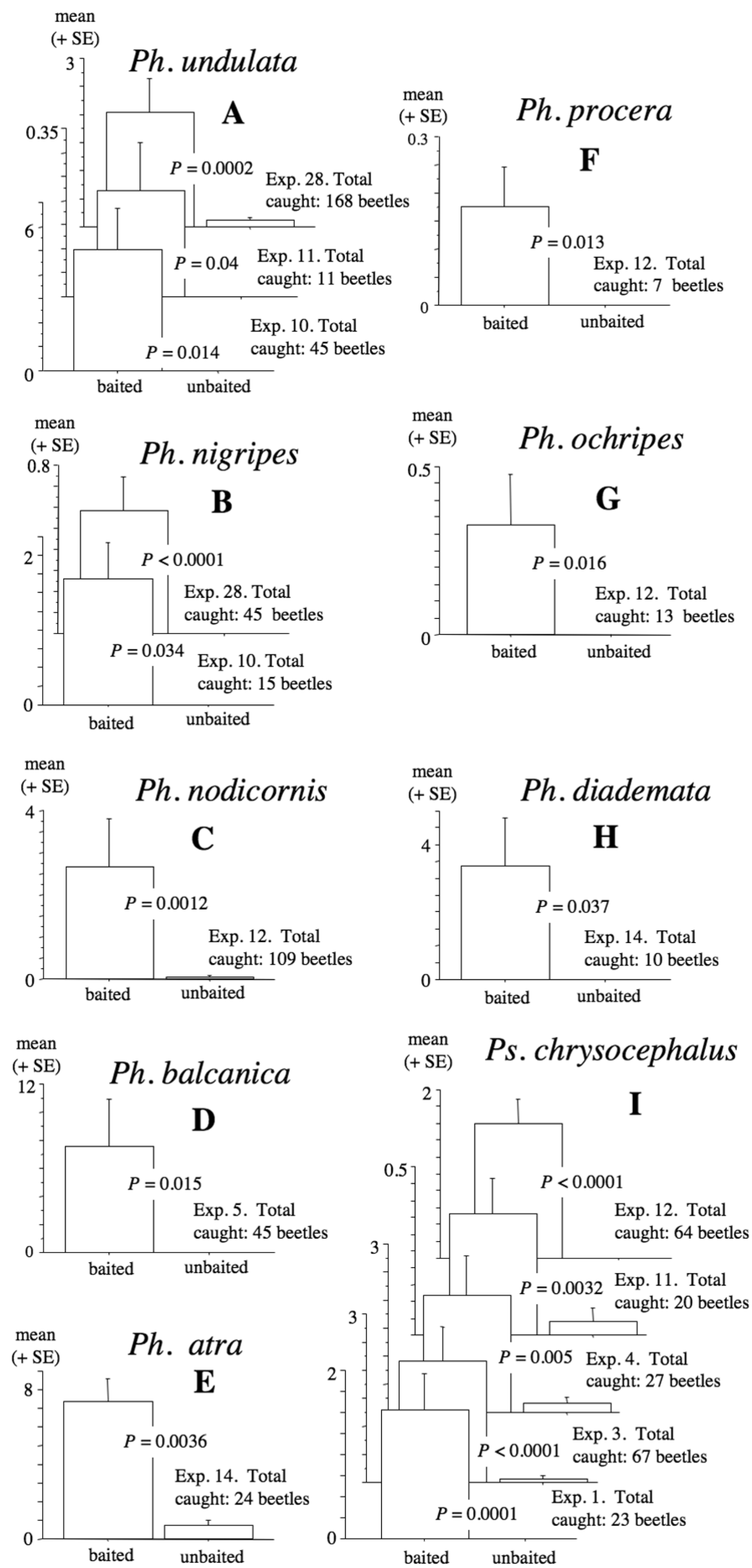

Fig. 2. Catches of *Phyllotreta* spp. and *Psylliodes chrysocephalus* in traps baited with allyl isothiocyanate and in unbaited traps. *P* values derive from Student *t* test (unpaired or one sample, as appropriate). *Y* axis shows mean catch/trap/inspection (+ SE).

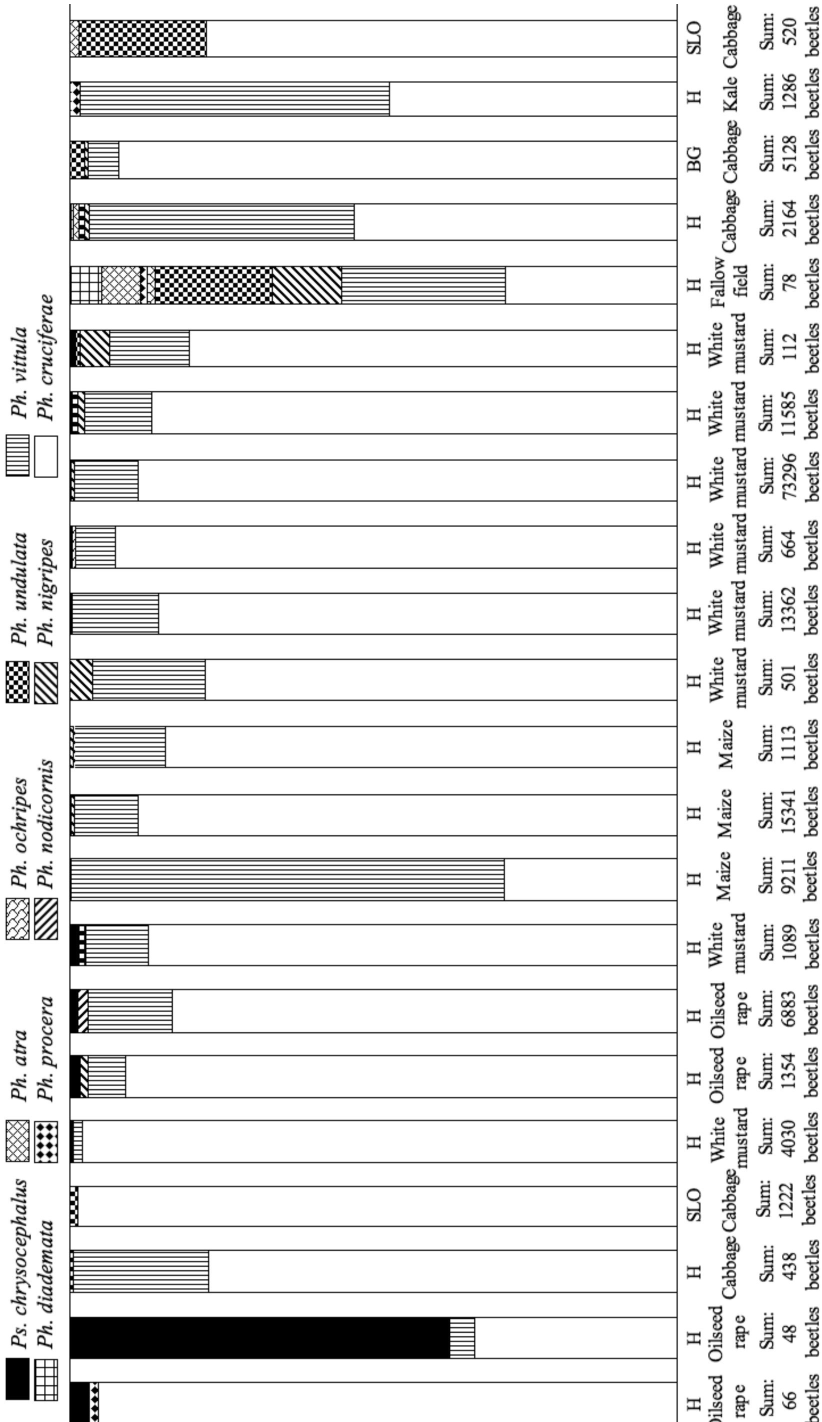

Fig. 3. Percentage distribution of *Phyllotreta* spp. and *Psylliodes chrysocephalus* in traps baited with allyl isothiocyanate at sites in Hungary (H), Slovenia (SLO) and Bulgaria (BG).

than in unbaited traps (Fig. 2I), indicating that allyl isothiocyanate may play some role in the chemical communication of this species too. It has been reported that several isothiocyanates evoked an electrophysiological response on the antennae of *Ps. chrysocephalus* (Blight *et al.,* 1989), however, to the best of our knowledge the present paper is the first report on the field activity of an isothiocyanate in this species. The close relative *Ps. punctulatus* Melsh. has been reported to be attracted to allyl isothiocyanate in North America (Vincent and Stewart, 1984). *Ps. chrysocephalus* is a serious pest of winter oilseed rape, oil rape, and mustard species (Sáringer, 1990; Vig, 2003).

Relative abundance of flea beetles in baited traps

Concerning the percentage distribution of the flea beetle spp. in allyl isothiocyanate-baited traps at the respective test sites, a great portion of the catch (ranging from ca 30 to 98%) was *Ph. cruciferae* (Fig. 3), irrespective of the plant culture. The second most abundant species present at most sites was *Ph. vittula*. This species showed an outstandingly high percentage at one of the sites in maize (Fig. 3). This may be the result of a local outbreak of *Ph. vittula* which is known to feed voluntarily on monocotyledonous plants also (Vig, 1996, 1998).

Other flea beetles occurred only in smaller percentages, at only one or at a few of the test sites. A remarkably high percentage of *Ps. chrysocephalus* was recorded at one of the sites (Fig. 3), probably reflecting exceptionally favourable conditions and a local outbreak of the species.

In conclusion, allyl isothiocyanate-baited traps captured in the present study 11 flea beetle species. Significant field attraction by allyl isothiocyanate was first proven in the present study for 10 of these spp. The captured species included six important agricultural pests. These results are very promising for the use of allyl isothiocyanate as a bait in detection and monitoring traps in Europe. Furthermore, preliminary results in Hungary indicate that the percentages of flea beetle species caught by allyl isothiocyanate-baited traps reflected well the percentage composition of flea beetle populations at the given site obtained by other sampling methods (P. Benedek and F. Bakcsa, unpublished data). Interestingly, *Ph. striolata* Fabr., another European flea beetle for which attractivity of allyl isothiocyanate was known (Görnitz, 1956; Feeny *et al.*, 1970; Vincent and Stewart, 1984; Pivnick *et al.*, 1992), was not caught in the present study in reliably high numbers.

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Balázs K., Nagy G., and Garamvölgyi I. (1998), Plant protection of field-grown cabbages (common white cabbage, savoy, red cabbage). Növényvédelem **34**, 79–86 (in Hungarian).

Blight M. M., Pickett J. A., Wadhams L. J., and Woodcock C. M. (1989), Antennal responses of *Ceutorhynchus assimilis* and *Psylliodes chrysocephala* to volatiles from oilseed rape. Aspects Appl. Biol. **23**, 329–334.

Brelih S., Döberl M., Drovenik B., and Pirnat A. (2003), Gradivo za favno hroscev (Coleptera) Slovenije/ Materialien zur Käferfauna (Coleoptera) Slowenien. 1. prispevek/1. Beitrag, Polyphaga: Chrysomeloidea (= Phytophaga): Chrysomelidae: Alticinae. Scopolia **50**, 1–279.

Burgess L. and Wiens J. E. (1980), Dispensing allyl isothiocyanate as an attractant for trapping crucifer-feeding flea beetles. Can. Entomol. **112**, 93–97.

Dillard H. R., Cobb A. C., and Lamboy J. S. (1998), Transmission of *Alternaria brassicola* to cabbage by flea beetles (*Phyllotreta cruciferae*). Plant Dis. **82**, 153–157.

Feeny P., Paauwe K. L., and Demong N. J. (1970), Flea beetles and mustard oils: host plant specificity of *Phyllotreta cruciferae* and *P. striolata* adults (Coleoptera: Chrysomelidae). Ann. Entomol. Soc. Am. **63**, 832–841.

Foster G. N. (1984), Monitoring and forecasting outbreaks of turnip flea beetles in the west of Scotland, 1978–1983. Proc. Crop Protection in Northern Britain, Dundee University, 19–22 March 1984, pp. 222–227.

Görnitz K. (1956), Weitere Untersuchungen über Insekten-Attractivstoffe aus Cruciferen. Nachrichtenbl. Dtsch. Pflanzenschutzdienst N. F. **10**, 137–147.

Gruev B. and Tomov V. (1986), Coleoptera, Chrysomelidae. Part II. Chrysomelinae, Galerucinae, Alticinae, Hispinae, Cassidinae. In: Fauna Bulgarica, Vol. 16 (Josifov M., ed.). Academie Scientiarium Bulgaricae, Sofia, p. 388 (in Bulgarian).

Jourdheuil P. (1966), Sous-famille des Halticinae. In: Entomologie appliquée ą l'agriculture, Vol. 1 (Balachowsky A. S., ed.). Masson et Cie Éditeurs, Paris, pp. 762–854.

Kaszab Z. (1962), Leaf beetles – Chrysomelidae. In: Magyarország Állatvilága Fauna Hungariae, Vol. IX/6 (Székessy V., ed.). Akadémiai Kiadó, Budapest, p. 416 (in Hungarian).

Liblikas I., Möttus E., Borg-Karlson A.-K., Kuusik S., Ojarand A., Kännaste A., and Tanilsoo J. (2003), Flea beetle (Coleoptera: Chrysomelidae) response to alkyl thiocyanates and alkyl isothiocyanates. Agron. Res. **1**, 175–184.

Markham R. and Smith K. M. (1949), Studies on the virus of turnip yellow mosaic. Parasitology **39**, 330–342.

Nagy B. and Deseö K. (1969), On damages caused by the flea beetle *Phyllotreta vittula* Redtb. (Coleopt., Halticinae). Növényvédelem **5**, 97–103 (in Hungarian).

Pivnick K. A., Lamb R. J., and Reed D. (1992), Response of flea beetles, *Phyllotreta* spp., to mustard oils and nitriles in field trapping experiments. J. Chem. Ecol. **18**, 863–873.

Ryden K. (1989), Brome mosaic virus, transmission and effect on yield in green house trials. J. Phytopathol. **124**, 256–258.

Sáringer G. (1990), Flea beetles. In: A növényvédelmi állattan kézikönyve (Jermy T. and Balázs K., eds.). Akadémiai Kiadó, Budapest, pp. 296–302 (in Hungarian).

Sáringer G. (1998), Flea beetles living on Cruciferae – *Phyllotreta* spp. In: A szántóföldi és kertészeti növények kártevöi (Jenser G., Mészáros Z., and Sáringer G., eds.). Mezögazda Kiadó, Budapest, pp. 212–214 (in Hungarian).

Smart L. E. and Blight M. M. (2000), Response of the pollen beetle, *Meligethes aeneus*, to traps baited with volatiles from oilseed rape, *Brassica napus*. J. Chem. Ecol. **26**, 1051–1064.

Spilák K., Garamvölgyi I., and Balázs K. (1998), Plant protection of cauliflower and broccoli. Növényvédelem **34**, 137–142 (in Hungarian).

Stobbs L. W., Cerkauskas R. F., Lowery T., and VanDriel L. (1998), Occurrence of turnip yellow mosaic virus on oriental cruciferous vegetables in southern Ontario, Canada. Plant Dis. **82**, 351.

Subchev M., Toshova T., Tóth M., Voigt E., Mikulás J., and Francke W. (2004), Catches of vine bud moth *Theresimima ampellophaga* (Lep., Zygaenidae: Procridinae) males in pheromone traps: effect of the purity and age of baits, design, colour and height of the raps, and daily sexual activity of males. Z. Angew. Entomol. **128**, 44–50.

Szeöke K. (1997), Damages of *Phyllotreta vittula* on spring barley and maize. Növényvédelem **33**, 33–34 (in Hungarian).

Szöcs G. (1993), Pheromone traps on the Hungarian market. Növényvédelem **29**, 191–193 (in Hungarian).

Tóth M. and Szöcs G. (1993), One and a half decade of pheromone studies at the Plant Protection Institute, HAS. Növényvédelem **29**, 101–109 (in Hungarian).

Tóth M., Imrei Z., and Szöcs G. (2000), Non-sticky, nonsaturable, high capacity novel pheromone trap designs for the western corn rootworm (*Diabrotica virgifera virgifera*, Coleoptera: Chrysomeldiae) and the cotton bollworm [*Helicoverpa (Heliothis) armigera,* Lepidoptera: Noctuidae]. Integr. Term. Kert. Szántóf. Kult. **21**, 44–49 (in Hungarian).

Tóth M., Csonka É., Bakcsa F., and Benedek P. (2004), Comparison of performance of trap designs baited with allyl isothiocyanate for the capture of flea beetles (*Phyllotreta* spp.) (Coleoptera, Chrysomelidae). Növényvédelem **40**, 125–130 (in Hungarian).

Tóth M., Csonka É., Szarukán I., Vörás G., Furlan L., Imrei Z., and Vuts J. (2006), The KLP+ ("hat") trap, a non-sticky, attractant baited trap of novel design for catching the western corn rootworm (*Diabrotica v. virgifera*) and cabbage flea beetles (*Phyllotreta* spp.) (Coleoptera: Chrysomelidae). Int. J. Hortic. Sci. **12**, 57–62.

Vig K. (1992), Relationships of frequently found *Phyllotreta* species to their hostplants. Savaria, a Vas Megyei Múzeumok Értesítöje **20**, 281–294 (in Hungarian).

Vig K. (1996), Host plant selection by *Phyllotreta vittula* (Redtenbacher, 1849). Proceedings of the Fourth International Symposium on the Chrysomelidae, Proceedings of XX I. C.E., Firenze, Museo Regionale di Scienze Naturali, Torino, pp. 233–251.

Vig K. (1998), Data on the biology of *Phyllotreta vittula* (Redtenbacher, 1849) (Coleoptera: Chrysomelidae: Alticinae). Med. Fac. Landbouww. Univ. Gent **63**, 357–363.

Vig K. (2003), Data on the biology of cabbage stem flea beetle, *Psylliodes chrysocephalus* (Linnaeus, 1758) (Coleoptera, Chrysomelidae, Alticinae). Comm. Appl. Biol. Sci., Ghent University **6**, 231–237.

Vincent C. and Stewart R. K. (1984), Effect of allyl isothiocyanante on field behaviour of crucifer-feeding flea beetles (Coleoptera: Chrysomelidae). J. Chem. Ecol. **10**, 33–40.

Vörös G. and Garamvölgyi I. (1998), Plant protection of field-grown kohlrabi. Növényvédelem **34**, 193–200. (in Hungarian).

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