Slugs in Conservation Tillage Corn and Soybeans in the Eastern Corn Belt[1]

Ronald B. Hammond[2], Terry Beck,[3] Judith A. Smith,[2] Roger Amos,[4] John Barker,[5] Robert Moore,[6] Howard Siegrist,[7] Dean Slates,[8] and Barry Ward[9]

Ohio Agricultural Research and Development Center and Ohio State University Extension, The Ohio State University, Wooster, OH 44691 USA

J. Entomol. Sci. 34(4):467-478 (October 1999)

Abstract Slug problems have increased in frequency as conservation tillage has become a more widely adapted practice for production of corn, *Zea mays* (L.), and soybean, *Glycine max* (L.) Merrill, in the Midwest. Because of the increasing concern about slug damage to these crops, we initiated studies to aid growers in management of this serious pest. Slug populations were sampled in conservation-tillage fields in seven counties in Ohio from 1994-1996 to determine the species that were present in field crops and to gain insights into their life histories and damage potential. Four slug species were collected in numbers sufficient to be considered of potential economic importance. The predominant species in population size and geographic range were *Deroceras reticulatum* (Müller), followed closely by *D. leave* (Müller). Both species were common in most fields. The third most numerous slug species was *Arion subfuscus* (Drapamaud). Although this species was found in fewer fields, it was often collected in very large numbers. The fourth slug. *A. fasciatus* (Nilsson), was found only in two counties. We observed juvenile *D. reticulatum* causing the most damage by their feeding in late-May and in June. Damage caused by the other species was not as evident, with the possible exception of *A. subfuscus* causing stand loss in soybeans.

Key Words Slugs, gray garden slug, marsh slug, conservation tillage, no-till, *Deroceras reticulatum, Deroceras laeve.*

Conservation tillage has gained in popularity and usage in many parts of the United States. Growers in the Midwest have been leaders in its adoption, with >8 million hectares currently under some form of conservation tillage (C.T.I.C. 1995). Conservation tillage, defined as those practices that leave more than 30% residue cover, gives growers numerous benefits, including reduced soil erosion, reduced labor costs, time savings, greater soil moisture levels, and improved soil quality.

[1]Received 15 October 1998; accepted for publication 23 March 1999.

[2]Department of Entomology, Ohio Agricultural Research & Development Center
The Ohio State University, Wooster, OH 44691.
[3]Wayne County Extension, 428 W. Liberty St., Wooster, OH 44691.
[4]Ashland County Extension, 804 US 250 E, Ashland, OH 44805.
[5]Knox County Extension, 1025 Harcourt Rd., PO Box 1268, Mt. Vernon, OH 43050.
[6]Fairfield County Extension, 831 College Ave., Suite D, Lancaster, OH 43130.
[7]Licking County Extension, 771 E Main St., Suite 103, Newark, OH 43055.
[8]Holmes County Extension, 165 N Washington St., Millersburg, OH 44654.
[9]Current Address: Marion County Extension, 1100 E Center, Marion, OH 43302.

Many researchers and growers thought that invertebrate pests would increase in occurrence and severity as conservation tillage practices were widely adopted (Gregory and Musick 1976). However, widespread pest problems have not occurred to any great extent (Stinner and House 1990, Hammond and Stinner 1999). One invertebrate pest that has increased in severity in conservation tillage field crops are slugs (Hammond 1996). Slugs belong to the Phylum Mollusca, Class Gastropoda, Order Stylommatophora, and were associated with field corn, *Zea mays* (L.), planted into plowed alfalfa, *Medicago sativa* L., as early as the late 1950s (Neiswander 1959). Cultivation was considered the best control method at that time. Barry (1969) later reported on damage by *Deroceras reticulatum* (Müller) in conservation-tilled field corn during 1968. In their review of invertebrate pests in reduced tillage systems, Gregory and Musick (1976) considered slugs the most serious non-insect problem. After the onset of soybean production using conservation tillage methods in the late 1970s, Hammond (1985) reported on the first association of slugs and no-till soybeans, *Glycine max* (L.) Merrill. Hammond and Stinner (1987) later observed that the largest population densities of slugs occurred in corn and soybean fields that had the greatest amounts of residue. They predicted that the incidence of slug problems in both crops would increase as the number of soybean hectares grown using conservation tillage methods increased. Byers and Calvin (1994) conducted research on slug injury and established economic injury levels for slugs feeding on field corn.

As the numbers of conservation tillage hectares have increased in the eastern Corn Belt, concern about slugs also has increased. During the early 1990s, those of us conducting research in conservation tillage systems saw evidence in Ohio that the slug problem had increased, both in terms of severity and geographic range, since the work conducted in the 1980s. Some growers in eastern Corn Belt states have questioned their ability to continue using conservation tillage because of slugs (Willson and Eisley 1992). We realized that our knowledge about slugs, including correct identification of species, assessment of damage potential, and an understanding of their biology was limited.

Because of the increased incidence of slug problems, we began studies in 1994 to improve our understanding of slugs in conservation tillage field crops. Our objectives were numerous, because we were initiating slug research in the Midwest Corn Belt. This report presents information about identification of species and their occurrence, and population dynamics of slugs.

Materials and Methods

Field studies, 1994. Study sites in corn and soybean fields were located in Wayne Co., in northeast Ohio during the spring of 1994. We visited these fields in April and May to assess various sampling techniques and efficacy of molluscicides, although these studies are not reported herein. Initial sampling efforts (comparing attractant-type refuge traps using various attractants such as beer and sugar/yeast mixtures and *in situ* sampling beneath crop residue) collected more species than we anticipated, so we took them to the laboratory for correct identifications. The primary sources of information for identifications were Chichester and Getz (1973), Godan (1983), and South (1992). Types are stored at the Ohio Agricultural Research and Development Center, Wooster, OH.

Although we took numerous samples during April and May, we did not conduct a regular sampling program. However, by late June we initiated a more concerted examination of the life cycles of these slugs. We started monthly sampling in 3 fields in Wayne Co. that had relatively large slug populations. We placed 10 attractant-type refuge traps randomly in each field. A trap consisted of cutting a 10.5 cm hole in the soil with a hole cutter, and placing a plastic container, 10.5 cm diam × 7.5 cm deep, into the hole so that the container's lip was at soil level. The container was filled approximately 1/4 full with a strongly-flavored beer (compared with a "light" beer). An aluminum foil-covered roofing shingle (30 × 30 cm) was placed over the cup and hole; the residue underneath the shingle was undisturbed. The following morning, the numbers and species of the slugs underneath the shingle were recorded. Sampling continued into December. We collected enough numbers and species of slugs in these attractant-type refuge traps to enable us to determine a relative estimate of slugs present in fields and compare their occurrence among fields (Smith and Boswell 1970, South 1992). However, our sampling did not enable us to determine an accurate estimate of population density.

Field studies, 1995-1996. After receiving reports of large slug populations in nearby counties, we expanded sampling into six additional Ohio counties. These counties (Ashland, Fairfield, Holmes, Knox, Licking, and Richland) ranged from north central to east central Ohio, and all had a large percentage of hectares on which crops were produced in conservation tillage systems.

We sampled two fields with established slug populations in each county. An additional field was added to the sampling program in Wayne Co. We selected the fields based upon the practice of conservation tillage, a history of slug populations, and either a corn or soybean crop planted in 1995. Observations from the early 1990s indicated that the presence of a slug population did not depend on the crop being grown (R.B.H., unpubl. data); both corn and soybeans are injured when slugs reach a sufficiently large population size, although corn and soybean are damaged differently, based on the time of planting and stage of crop growth (Hammond 1996).

Beginning in late April/early May and continuing through June each year, we took weekly samples in each field. After June, samples were taken monthly. Collections were terminated when extremely cold or frozen soil prevented further sampling or stopped slug activity. In a few instances, we sampled a different, nearby field during the second year because the field originally used was taken out of crop production.

Results and Discussion

Species. Five different slug species were collected from these fields during the 3 years of sampling, although only four were in sufficient numbers to be considered potentially economically injurious. The slug species sampled most commonly in terms of population size and numbers of fields in which the slug occurred was *Deroceras reticulatum,* commonly known as the gray garden slug (E.S.A. 1997). It is arguably the most economically important slug in many parts of the world (South 1992) and is the most important slug species in Ohio in terms of reports of it damaging field crops. Our observations indicate that either adults or eggs were the predominant overwintering stages depending upon the environmental conditions. Most of the injury caused by this slug was associated with large populations of juvenile slugs that hatched in mid-to-late May and early June. Injury to both corn and soybeans was most evident on developing young plants.

The second most commonly collected slug species in terms of population density and geographical range was *D. laeve* (Müller), commonly referred to as the marsh slug (E.S.A. 1997). *Deroceras laeve* is the only endemic species (Chichester and Getz 1973) of the four principal slug species in Ohio. Injury most often occurs when these slugs feed on leaves, although the numbers of fields reported as being damaged by this species in Ohio are much fewer than numbers of fields damaged by *D. reticulatum.* Thus, we believe the damage potential of *D. laeve* is much less than the damage potential of *D. reticulatum* in the eastern Corn Belt.

Two other species of slugs were found in fewer fields and from a more limited geographic area. *Arion subfuscus* (Draparnaud) is referred to as the dusky slug throughout much of Europe where extensive slug research has been conducted. *Arion fasciatus* (Nilsson) is commonly referred to as the banded slug in the northeast U.S. These are not, however, approved E.S.A. common names. The most numerous of these two slugs was *A. subfuscus.* Although we did not find it in as many fields as we found the two *Deroceras* species, *A. subfuscus* was very abundant in a few fields (e.g., 1 field had >50 slugs per trap during a 24-h period). The damage potential of this slug is unclear. Literature suggests that *A. subfuscus* is mostly a woodland species and fungivorous (Chichester and Getz 1969, 1973) and not a significant defoliator (Foster 1977). Our empirical observations supported Foster's (1977) findings; we found less defoliation caused by this species in fields where it was present. However, we observed soybean fields in which large stand reductions occurred, damage believed to be caused by *A. subfuscus.* This potential for causing stand loss warrants further investigation.

Arion fasciatus belongs to a complex of slugs that is comprised of three morphologically similar species: *A. fasciatus, A. circumscriptus* Johnston, and *A. silvaticus* Lohmander (Backeljau et al. 1996). Chichester and Getz (1973) reported that *A. fasciatus* is by far the most widely distributed and common of the three species; the other two species are relatively uncommon. Thus, for purposes of our work, we assume that all found are part of an *A. fasciatus* complex. This slug species was not common during the 3 yrs of our study; thus, we believe its damage potential is low in the Corn Belt. However, scientists in other states, viz. New York and Pennsylvania, consider this slug to be an important species in no-till field crops (Goh et al. 1988 Byers et al. 1985).

A fifth species, *Pallifera dorsalis* (Binney), was found in Wayne Co. during this study, but only 4 individuals were collected during the 3 yrs. This slug is morphologically unique because its mantle covers the entire body. It is also an endemic species (Chichester and Getz 1973) but is not considered a slug normally associated with field crops.

Slug populations. The mean numbers of slugs collected in traps from 1994-1996 for Wayne Co. are shown in Fig. 1. Slug densities during 1995-1996 for the remaining counties are shown in Figs. 2 to 4. Sampling in Wayne Co. began in 3 fields in July 1994 (the fourth field was not included in the sampling program until 1995). Slug population densities were high in all three fields in late summer and fall of 1994, with an increase in density beginning in August (Fig. 1). *Deroceras reticulatum* reached population peaks of >10 slugs per trap in Fields 1 and 2, and >20 per trap in Field 3 and was the predominant slug species in Fields 2 and 3. *Deroceras laeve* also was collected in the 3 fields, with >10 slugs per trap, and was the predominant species in Field 1, with nearly 20 slugs per trap at its population peak. *Arion subfuscus* was the third most frequently collected slug in Wayne Co., and we found it in all 3 fields. However, its population density was always <10 slugs per trap. *Arion fasciatus* was collected only in Field 1, and then, at low numbers.

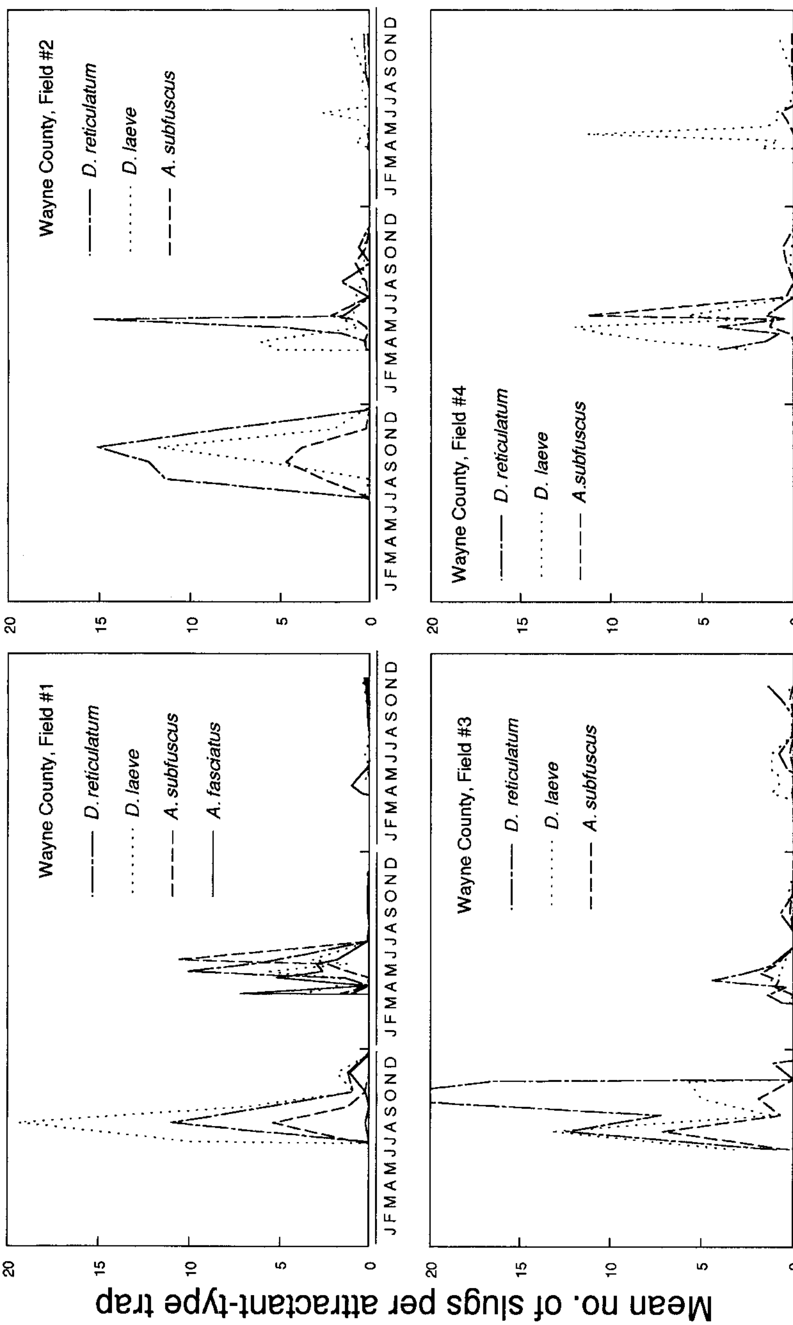

Fig. 1. Mean number of slug species in four crop fields in Wayne Co., OH, from 1994-1996.

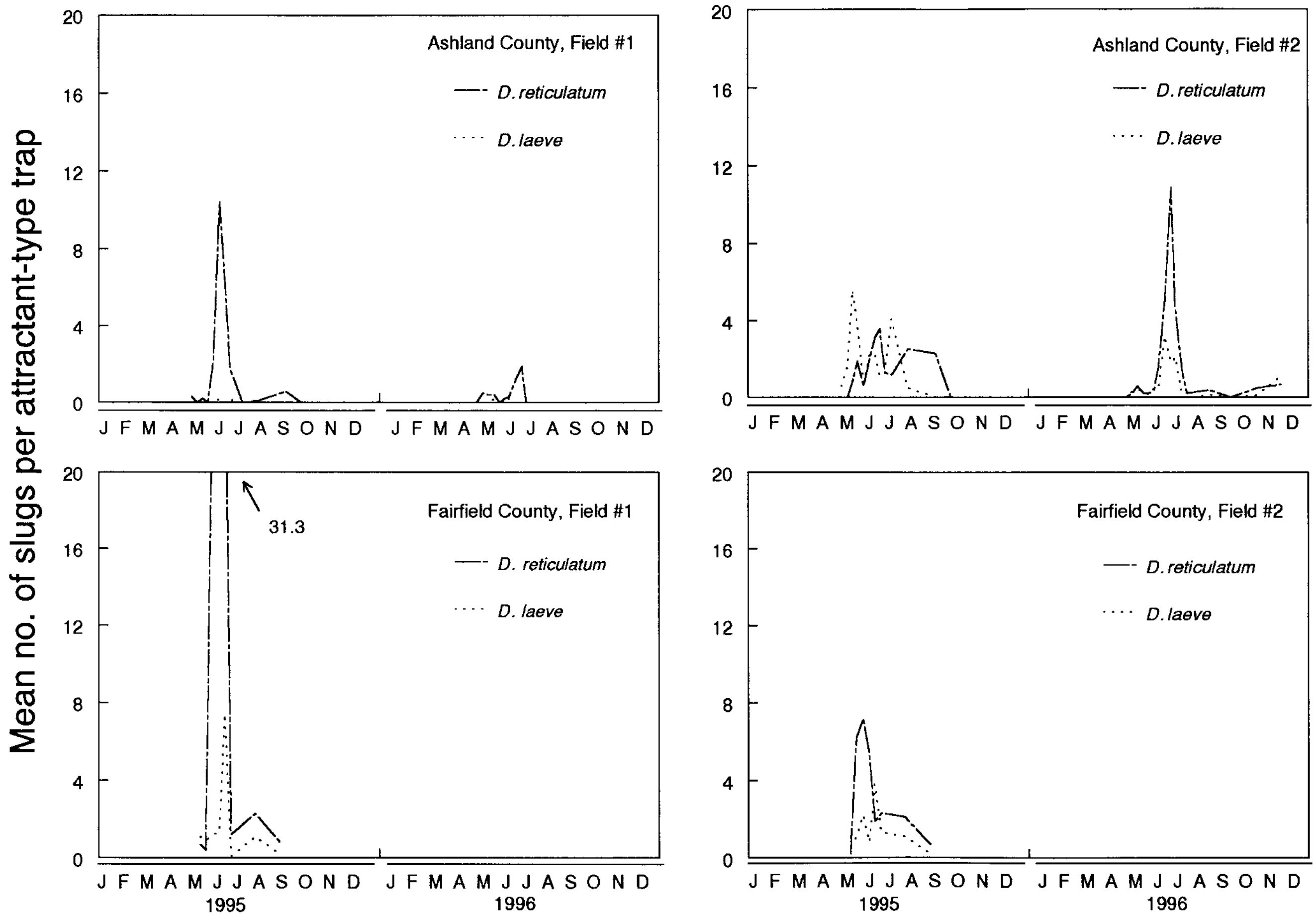

Fig. 2. Mean number of slug species in four crop fields in Ashland and Fairfield counties, OH, from 1995-1996.

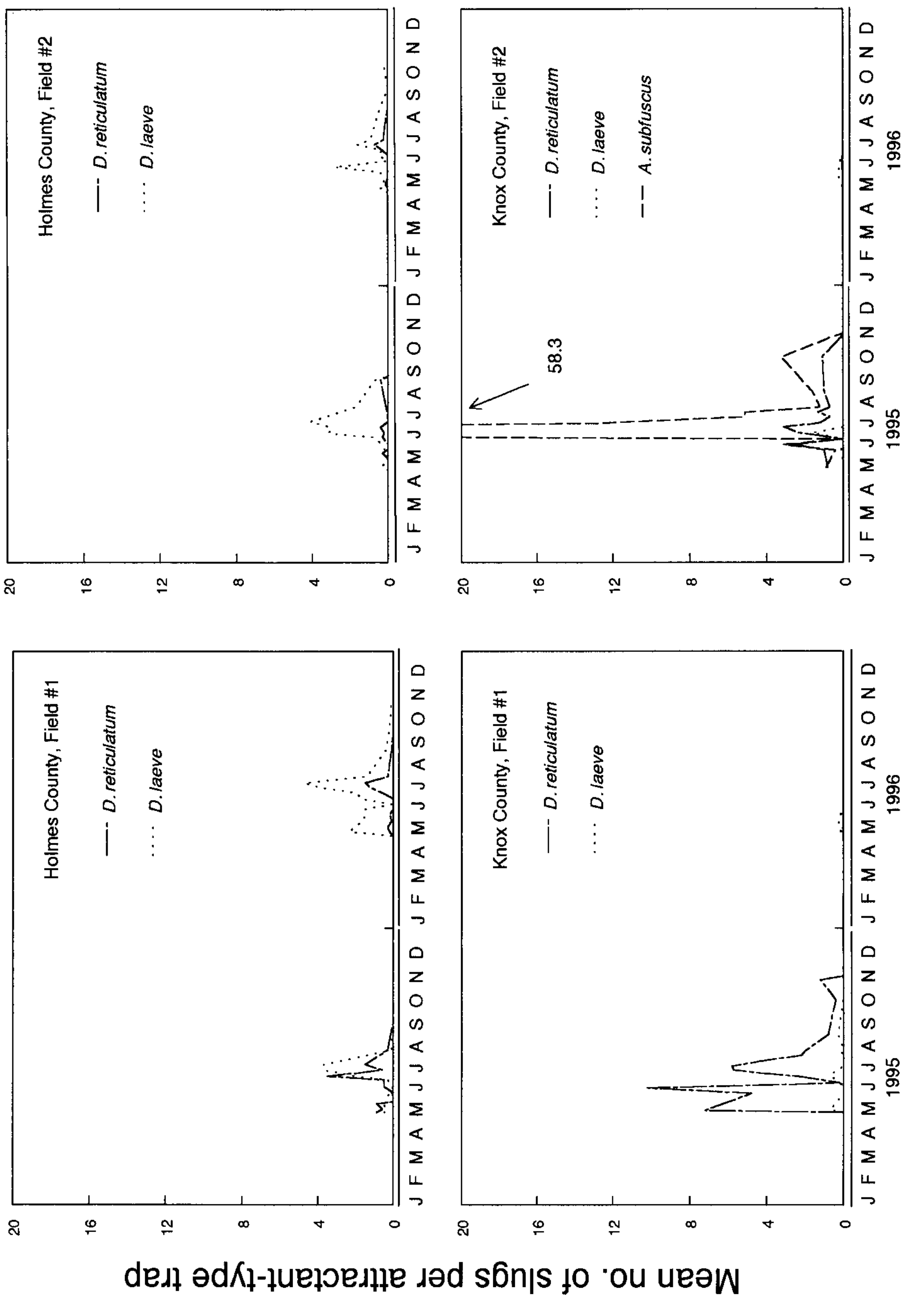

Fig. 3. Mean number of slug species in four crop fields in Holmes and Knox counties, OH, from 1995-1996.

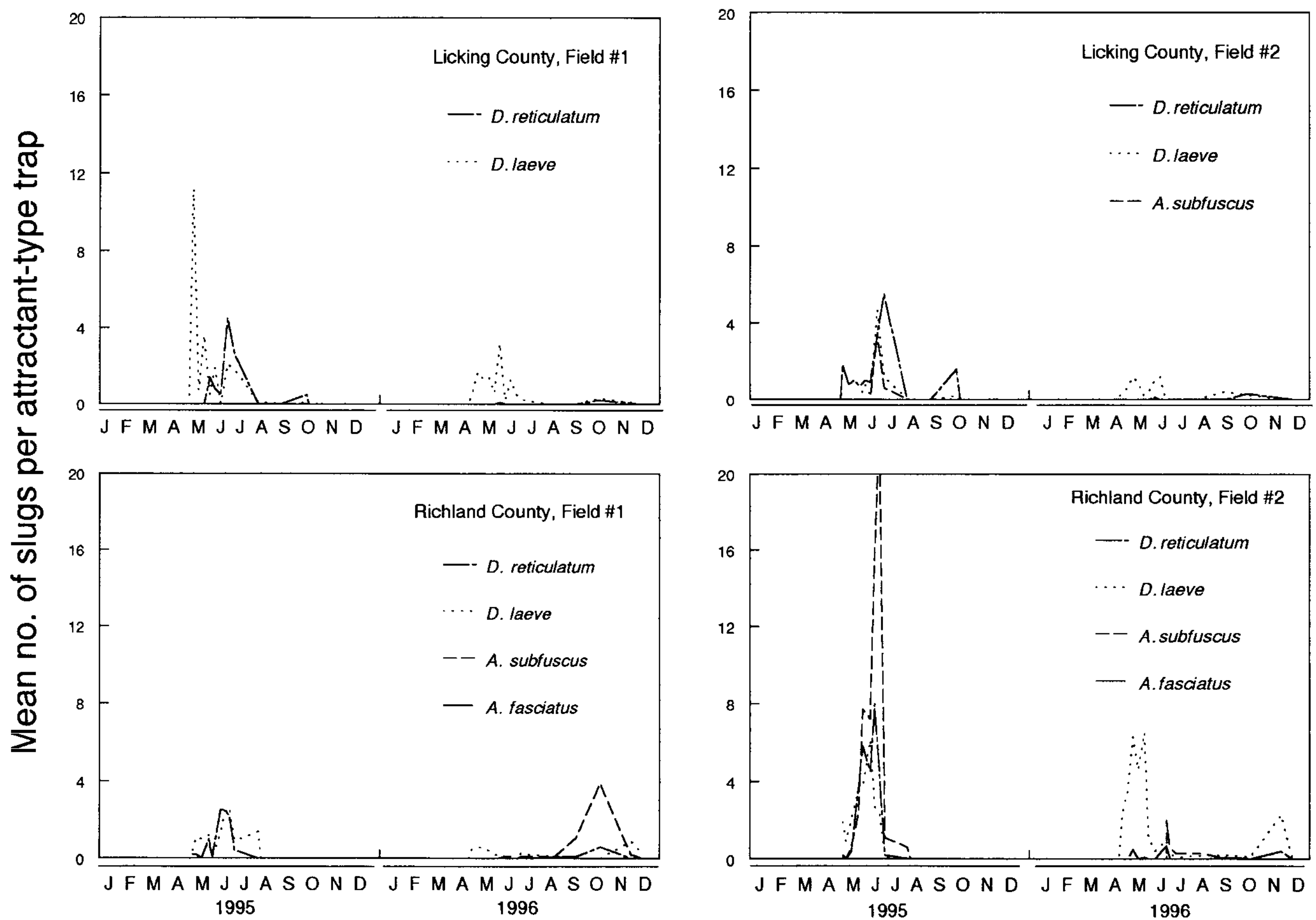

Fig. 4. Mean number of slug species in four crop fields in Licking and Richland counties, OH, from 1995-1996.

The large numbers of slugs in the fall of 1994 in Wayne Co. were followed by relatively large population densities in the spring of 1995 (Fig. 1). The same four species found in the fall of 1994 also were collected in the spring of 1995. The most numerous slug species in Fields 2 and 3 again was *D. reticulatum.* In Field 1, the slug population size was similar for *D. reticulatum* and *A. subfuscus,* whereas in Field 4, numbers were similar for *D. laeve* and *A. subfuscus.* As in the previous fall, *A. fasciatus* was only collected in Field 1.

The slug population densities in the fall of 1995 were extremely low, compared with densities in fall of 1994 and spring of 1995. Few slugs were collected from August through November, with peak numbers of <2 slugs per trap. These low population densities were unexpected, based upon the large densities that we observed earlier in the year. At that time, we did not know if the lower densities were the result of slugs being inactive or not present.

Slug population densities in the spring of 1996 were very low, suggesting that in all likelihood slugs had not been present in the fields the previous fall. The only exception was a population density of *D. laeve* in Field 4 with a peak of ≈10 slugs per trap on a single day. Sampling in the fall of 1996 indicated only a slight rise in population sizes compared with the population densities we observed the previous fall for *D. laeve.*

Similar observations of densities of slugs were made in the other counties (Figs. 2 to 4). Medium to large densities of slugs were recorded in the spring of 1995. *Deroceras reticulatum* was the predominant species in most fields, and *D. laeve* was the next most frequently collected species. These two slugs were the only species collected from most fields. However, in Field 2 in Knox Co. (Fig. 3) and Field 2 in Richland Co. (Fig. 4), *A. subfuscus* was the predominant species, with peaks >50 and >20 slugs per trap in the two counties, respectively. *Arion fasciatus* was not found in any of these other counties.

The fields in the remaining counties also had low population densities of slugs during the fall of 1995. These low fall population densities resulted in relatively small number of slugs in the spring of 1996. Most of the spring densities were <4 slugs per trap. The only exceptions were large numbers of *D. reticulatum* in Field 2 in Ashland Co. (Fig. 2) and a population of *D. laeve* in Field 2, Richland Co. (Fig. 4). However, none of the fields had densities of slugs in the spring of a 1996 that equaled those densities observed in 1995. Sampling during the fall of 1996 indicated few slugs, with the exception of the 2 Richland Co. fields where slight increases in numbers in *A. subfuscus* in Field 1 and *D. laeve* in Field 2 were observed (Fig. 4).

The differences in the slug population size among years is compelling. Although slug population densities were relatively high in the fall of 1994 and spring of 1995, numbers in the fall of 1995 and spring of 1996 were greatly reduced. Because of the large numbers in the spring of 1995, we had anticipated greater numbers in the fall of 1995. Although many years of research are necessary to determine exact reasons for such year-to-year fluctuations in densities, we suggest that weather conditions during the summer months may have been responsible. The only complete weather data available when slugs were also monitored were from the spring of 1994 through the fall of 1996 from Wayne Co. (1994 spring slug population densities in Wayne Co. were relatively large [R.B.H., unpubl. data]). Fig. 5 shows both the precipitation and temperature deviations from normal from weather data collected at the Ohio Agricultural Research & Development Center, Wooster, OH, in central Wayne Co. during the months when slugs were active. During 1994, precipitation and temperature deviations from normal, long-time averages were relatively small and balanced, quite dif-

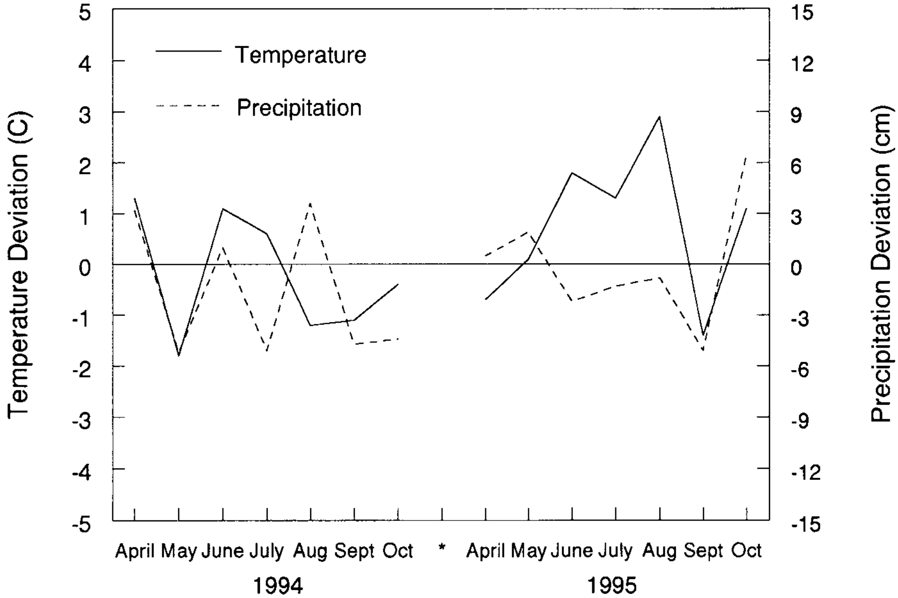

Fig. 5. Temperature and precipitation deviations from averages taken from near Wooster, OH, in Wayne Co. in 1994 and 1995.

ferent from the conditions in 1995. The weather conditions from May through August, 1995, were hot and dry.

We believe that slug populations fluctuate from year to year, partially because of summer weather conditions. We have observed low numbers of slugs during springs characterized by cool and wet weather believed to be favorable for slugs. On the other hand, we have observed large, economically-damaging numbers of slugs during springs that were relatively hot and dry. We believe that spring weather conditions are not as important to slug survival as weather conditions at other times of the year. We hypothesize that favorable summer weather allows slugs in the spring to survive into the fall and, subsequently, into the following spring.

As conservation tillage continues to gain acceptance in Ohio and other eastern Corn Belt states, we will need to monitor the changing slug situation. Our observations based on reports from growers and crop consultants suggest that the slug problem is increasing, albeit not an economic problem annually. Because of the differences in feeding habits and damage potential, growers should be aware of the species of slugs within their crop fields. Our findings suggest that there are yearly fluctuations in population size, requiring that a sampling program be initiated each spring in conservation-tilled fields, especially those with a history of slug problems. Whether slug population size in the fall can serve as a indicator of potential economic problems in the spring remains to be determined. However, we believe that sampling for slugs in the fall might be a potentially valuable predictive tool. Along with recent work on thresholds (Byers and Calvin 1994), efficacy of newer molluscicide formulations (Hammond 1997a, b), and timing of molluscicide applications (Hammond et al.

1996), knowledge of slug population dynamics should allow growers to produce field crops using conservation tillage without unnecessary concern for slug damage.

Acknowledgments

The authors wish to thank all cooperating growers for allowing us access into their fields for purposes of sampling slugs. This research was partially funded by the Ohio Pest Management and Survey Program based in the Extension Entomology Unit of the Department of Entomology, The Ohio State University, Columbus, OH. Salaries and research support were also provided by state and federal funds appropriated to the Ohio Agricultural Research & Development Center, The Ohio State University, Wooster, OH, and Ohio State University Extension, Columbus, OH. This report is Journal Article 137-97.

References Cited

Backeljau, T., B. Winnepenninckx, K. Jordaens, H. de Wolf, K. Breugelmans, C. Parejo and T. Rodriguez. 1996. Protein electrophoresis in arionid taxonomy, Pp. 21-28. *In* Slug and Snail Pests in Agriculture, BCPC Symposium Proceedings No. 66. British Crop Protection Council, Surrey, England.

Barry, B. D. 1969. Evaluation of chemicals for control of slugs on field corn in Ohio. J. Econ. Entomol. 62: 1277-1279.

Byers, R. A. and D. D. Calvin. 1994. Economic injury levels to field corn from slug (Stylomatophora: Agriolimacidae) feeding. J. Econ. Entomol. 87: 1345-1350.

Byers, R. A., W. C. Templeton, Jr., R. L. Mangan, D. L. Bierlein, W. F. Cambell, and H. J. Donley. 1985. Establishment of legumes in grass swards: effects of pesticides on slugs, insects, legume seedlings numbers, and forage quality. Grass Forage Sci. 40: 41-48.

Chichester, L. F. and L. L. Getz. 1969. The zoogeography and ecology of a arionid and limacid slugs introduced into Northeastern North America. Malacologia 7: 313-346.

1973. The terrestrial slugs of Northeastern North America. Sterkiana 51: 11-42.

Conservation Technology Information Center. 1995. Conservation impact. Conservation Tech. Info. Center 13: 1-6. West Lafayette, IN.

Entomological Society of America. 1997. Common names of insects and related organisms. Entomol. Soc. Am., Lanham, MD.

Foster, G. N. 1977. Problems in cucumber crops caused by slugs, cuckoo-spit insect, mushroom cecid, hairy fungus beetle and the house mouse. Plant Pathol. 26: 100-101.

Godan, D. 1983. Pest slugs and snails—biology and control (translated by S. Gruber) Springer-Verlag, Berlin, Germany.

Goh, K. S., R. L. Gibson and D. R. Specker. 1988. Banded slug. Field crops fact sheet, 102GFS795.20. Cornell Coop. Ext., Cornell Univ., Ithaca, NY.

Gregory, W. W. and G. J. Musick. 1976. Insect management in reduced tillage systems. Bull. Entomol. Soc. Am. 22: 302-304.

Hammond, R. B. 1985. Slugs as a new pest of soybeans. J. Kansas Entomol. Soc. 58: 364-366.

1996. Conservation tillage and slugs in the U.S. corn belt, Pp. 31-38. *In* Slug and Snail Pests in Agriculture, BCPC Symposium Proceedings No. 66. British Crop Prot. Counc., Surrey, England.

1997a. Gray garden slug control in field corn, 1995. Arthropod Management Tests: 1997. 22: 437.

1977b. Slug control in soybean, 1995. Arthropod Management Tests: 1997. 22: 438.

Hammond, R. B. and B. R. Stinner. 1987. Seedcorn maggots (Diptera: Anthomyiidae) and slugs in conservation tillage in Ohio. J. Econ. Entomol. 80: 680-684.

1999. Impact of tillage systems on pest management, pp. 693-712. *In* Handbook of Pest Management, J. R. Ruberson, ed. Marcel Dekker, Pub., New York, NY.

Hammond, R. B., J. A. Smith and T. Beck. 1996. Timing of molluscicide applications for reliable control in no-tillage field crops. J. Econ. Entomol. 89: 1028-1032.

Neiswander, C. R. 1959. Slugs can injure young corn. Ohio Agric. Res. Develop. Cent., Ohio State Univ. Res. Bull. May-June, P. 37.

Smith, F. F. and A. L. Boswell. 1970. New baits and attractants for slugs. J. Econ. Entomol. 63:1919-1922.

South, A. 1992. Terrestrial slugs: biology, ecology, and control. Chapman and Hall, London, England.

Stinner, B. R. and G. J. House. 1990. Arthropods and other invertebrates in conservation tillage agriculture. Annu. Rev. Entomol. 35: 299-318.

Wilson, H. R. and B. R. Eisley. 1992. Effects of tillage and prior crop on the incidence of five key pests on Ohio corn. J. Econ. Entomol. 85: 853-859.