ABUNDANCE AND DIVERSITY OF ADULT CARABIDAE IN FOUR SOYBEAN CROPPING SYSTEMS IN VIRGINIA

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ABSTRACT

Carabidae (Coleoptera) were monitored from pitfall trap catches in four soybean cropping systems in Westmoreland Co., Virginia during the summer of 1982. *Harpalus pensylvanicus* DeGeer, *Poecilus chalcites* Say, *Amara* spp., and *Agonum octopunctatum* Fabricius were the most commonly encountered among the 39 species collected. These four species were more abundant in drill-planted and double-cropped soybean fields which were conservation tillage systems as compared to conventionally plowed fields. Significantly more species per field and more carabids per trap were found during June than in later summer months. The Shannon-Weaver diversity and Berger-Parker dominance indices showed no significant differences in species diversity among the cropping systems. The total number of carabids present in soybeans is more important in comparisons than either species number of species evenness.

Key Words: Carabidae, *Harpalus pensylvanicus, Poecilus chalcites, Amara* spp., *Agonum octopunctatum,* ground beetles, pitfall traps.

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INTRODUCTION

Carabidae represent an important component of the soil predators in the soybean agroecosystem. Several laboratory studies with carabids have been published (Best and Beetle 1977; Lesiewicz et al. 1982; McWorter et al. 1984); however, little is known of their pest suppression capabilities in the field. Ground beetle species have been observed in several agricultural crops, including soybeans (Rivard 1966; Deitz et al. 1976; Doane 1981; House and All 1981; Los and Allen 1982). House and All (1981) investigated the seasonal abundance of carabids in conventional and conservation tillage systems of soybeans in Georgia. Price and Shepard (1980) reviewed many of the reports on gound predators in soybeans, particularly in fields grown with reduced tillage and in narrow-row systems when produced double-cropped after wheat or barley and drill or broadcast planted.

This investigation was undertaken to study the carabid fauna inhabiting the four major soybean cropping systems practiced in Virginia: Full-season conventionally planted in wide rows, full-season drill-planted in narrow rows in plowed seedbed, no-till double-cropped following barley harvest, and no-till double-cropped after wheat. The objectives were to identify the carabid species associated with Virginia soybean agroecosystems, to determine dominant species and species diversity, and to determine their relative abundance throughout the season in each of the four cropping systems.

MATERIALS AND METHODS

Four soybean cropping systems were sampled monthly in Westmoreland County, VA, during 1982. Three fields, ranging from 2.8 to 15.2 ha, were monitored from each cropping regime. Full-season conventionally plowed fields were planted with 97 cm row spacing on 18 May (field designation C1), 19 May (C2), and 24 May (C3). Full-season drill-planted fields were planted in plowed seedbeds in 18 cm row spacings on 29 May (D1) and 30 May (D2, D3). The soybean fields no-till double-cropped after barley were planted with 61 cm row spacing on 5 June (B1, B2) and 12 June (B3). Fields no-till double-cropped after wheat harvest were planted with 61 cm row spacing on 26 June (W1, W2) and 28 June (W3). All fields were planted with the variety 'Essex' except for D1, D2, D3, and C1 which were of the variety 'Bay'. The soil type for each field was obtained from the Soil Conservation Service 1981 soil maps of Westmoreland County. No field received an insecticidal treatment during the growing season.

Ten pitfall traps were placed in each field using a stratified random design. Each trap consisted of a 947-ml plastic holding container placed in the soil flush with the soil surface. A 474-ml plastic catching container was placed in the larger cup. Plastic lids, ca 14 cm diam, were used as rain covers, placed ca 3 cm above the soil surface and anchored to the ground with four 40-penny nails. Holes were punched in the bottoms of the holding cups for drainage. The soil was firmly packed and smoothed around the edge of the trap. Ethylene glycol (auto antifreeze — 100 ml) was placed in each catching container at the beginning of each sampling period. Trap sites were marked with a 1.5 m wooden stake near the containers. Each marker had a brightly colored 0.3 m diam styrofoam disc stapled to its top. Traps were placed in the ground and left open for one week during late June, July, August, and September. Soybeans double-cropped after wheat were not sampled in June because they were still in the seedling stage. Plant developmental stage (Fehr and Caviness 1977) and plant height were recorded during each sampling period. Rainfall was monitored from the Warsaw weather data station 19.3 km from the fields. After the 7-d exposure in the field, pitfall trap contents were placed into 240 ml jars and returned to the laboratory for carabid identification.

The numbers of individuals of each carabid species per trap were recorded each sample date. Mean species numbers, mean total specimens, and relative abundance of the common species were analyzed with nested analyses of variance, using a log transformation. Comparisons were made among cropping regimes using Duncan's Multiple Range Test at the 0.05 level. Differences in species diversity were detected using the Shannon-Weaver diversity index [$H' = -\Sigma$ pi log pi] (Pielou 1966), and the Berger-Parker dominance index [d = Nmax/Ntotal] (Southwood 1978) was used for single-species dominance.

RESULTS AND DISCUSSION

A total of 3383 specimens representing 39 species were collected during the summer of 1982 (Table 1). Over 66% of the specimens were collected in June, although only 90 of the 120 traps were being utilized because the soybeans following wheat harvest were in the seedling stage. Significantly more species per field and more carabids per trap were found in this month (Table 2). Regular

Table 1. Incidence of carabids captured in pitfall traps in Westmoreland County, VA 1982 (in decreasing order of abundance).*

	No. collected each month sampled				
Species observed	June	July	Aug.	Sept.	Total
Harpalus pensylvanicus DeGeer	387	63	330	335	1115
Poecilus chalcites Say	740	119	26	13	898
Amara spp.†	798	6	9	12	825
Agonum octopunctatum Fabricius	187	17	0	0	204
Calathus opaculus Leconte	0	0	0	83	83
Calosoma alternans sayi Dejean	0	2	11	19	32
Anisodactylus sanctaecrucis Fabricius	28	2	1	0	31
Bradycellus sp.	18	5	1	0	24
Scarites subterraneus Fabricius	15	3	2	2	22
Galerita janus Fabricius	1	9	3	3	16
Bembidion rapidum (Leconte)	3	4	8	0	15
Clivina bipustulata (Fabricius)	14	0	0	1	15
Agonoderus comma (Fabricius)	17	0	0	2	19
Harpalus caliginosus (Fabricius)	1	4	7	0	12
Aspidoglossa subangulata (Chaud.)	8	3	0	0	11
Calosoma externum Say	0	2	3	4	9
Chlaenius platyderus Chaudoir	3	3	3	0	9
Calosoma calida Fabricius	1	2	3	0	6
Harpalus erythropus Dejean	2	1	1	1	5
Chlaenius tomentosus (Say)	4	0	0	0	4
Colliuris pennsylvanica L.	0	2	2	0	4
Clivina impressifrons Leconte	3	0	0	0	3
Evarthrus furtivus Leconte	1	0	2	0	3
Agonum punctiforme (Say)	1	0	0	1	2
Discoderus parallelus (Haldeman)	0	1	0	1	2
Dyschirius globulosus Say	1	1	0	0	2
Bembidion affine Say	1	0	0	0	1
Carabus limbatus Say	1	0	0	0	1
Carabus sylvosus Say	1	0	0	0	1
Chlaenius emarginatus Say	0	0	0	1	1
Chlaenius tricolor Dejean	0	0	0	1	1
Cratacanthus dubius (Beauvois)	1	0	0	0	1
Dicaelus elongatus Bonelli	0	0	0	1	1
Harpalus herbivagus Say	1	0	0	0	1
Lebia analis Dejean	1	0	0	0	1
Poecilus lucublandus Say	1	0	0	0	1
Scaphinotus unicolor (Fabricius)	0	0	0	1	1
Synuchus impunctatus Say	1	0	0	0	1
Total	2241	249	412	481	3383

* A total of 90 pitfall traps monitored after a 7-d field exposure in June, and 120 traps in July, August, and September.

† Includes *A. impuncticollis* Say and *A. cupreolata* Putz.

Table 2. Numbers of carabid species per field and numbers of carabids per trap during four sampling periods in Westmoreland County, VA, 1982.

Month	No. fields	No. species per field*	No. Carabids per trap*
June	9	10.4 a	25.5 a
July	12	5.8 b	2.1 c
Aug.	12	4.7 b	3.5 b
Sept.	12	4.2 b	4.1 b

* Column means followed by the same letter are not significantly different, Duncan's Multiple Range Test ($P \leq 0.05$).

rainfall during the early part of June created moist soil conditions. This probably accounted for the abundance of the predators during this sampling period. Carabids are highly susceptible to dry conditions and will increase their ground surface activity during moist periods (Kirk 1971, 1975). Heavy rainfall during the July sampling period flooded numerous pitfall traps and subsequently decreased total catches. August and September rainfall did not interfere with the trapping.

Another explanation for the high June catch was the abundance of four species which made up 77% of the sample, *Poecilus (= Pterostichus) chalcites* Say, *Amara impuncticollis* Say, *A. cupreolata* Putzeys, and *Agonum octopunctatum* Fabricius presumably overwinter as adults, are abundant and breed in the late spring, and oviposit from July to September (Kirk 1975; Doane 1981).

Seasonal Abundance

From 16 to 29 species were collected each month. *Harpalus pensylvanicus* DeGeer, *P. chalcites, Amara* spp., *Anisodactylus sanctaecrucis* Fabricius, *Scarites subterraneus* Fabricius, and *Galerita janus* Fabricius were present each month (Table 1). Five species comprised 90% of the totals sample. These were, in order of decreasing abundance, *H. pensylvanicus, P. chalcites, Amara impuncticollis, A. cupreolata,* and *Agonum octopunctatum.* With the exception of the *H. pensylvanicus,* these species exhibited a single abundance peak in June. *H. pensylvanicus* had a second peak during August and September. Its decline in July may be an artifact of the small catch in that month. *Harpalus pensylvanicus* populations may increase in the late summer and early fall (Kirk 1973; House and All 1981; Rivard 1966). This species is commonly found in many agricultural crops, usually breeding in the autumn and overwintering as a larva (Kirk 1973). Its feeding habits have been described as facultatively phytophagous, with no significant preference for noctuid larvae over smooth dock seeds (Best and Beetle 1977). Additional studies indicated *H. pensylvanicus* readily attacked Japanese beetle, *Popillia joponica* Newman, grubs in the laboratory, while in the field, it existed on an ominvorous diet, feeding on old corn kernels, noctuid larvae, spotted cucumber beetles, *Diabrotica undecimpunctata howardi* Barber, and various seeds (Kirk 1973).

Poecilus chalcites, the second most abundant carabid in this study, is known to occur in several agricultural crops (Kirk 1971; Kirk 1975; House and All 1981; Los and Allen 1982). In South Dakota, *P. chalcites* was found to breed in the spring, reach peaks of abundance in July and September, and overwinter as an adult. This carabid frequents fields with moist soil and poor drainage (Kirk 1975). Unlike *H. pensylvanicus, P. chalcites* strongly preferred animal material (particularly when offered dead black cutworm larvae) over vegetable material in the laboratory (Best and Beetle 1977). In addition, Lesiewicz et al. (1982) observed that *P. chalcites* would attack large corn earworm larvae, *Heliothis zea* (Boddie). The other three abundant species, *Amara impuncticollis, A. cupreolata,* and *Agonum octopunctatum,* are general predators. Members of these genera were reported feeding on insect larvae and eggs (Frank 1971; Fox and MacLellan 1956).

Throughout the season, both *H. pensylvanicus* and *P. chalcites* reached their peaks in full-season drill-planted bean fields (4.21 and 5.27/trap, respectively) (Fig. 1). *Amara* spp. and *A. octopunctatum* appeared to be more abundant in double-cropped barley-beans (6.78 and 1.05/trap, respectively), but not in full-season conventional beans. These results suggest that the potential of predation by these five species (especially *H. pensylvanicus* and *P. chalcites),* is greater in double-cropped barley-bean and drill-planted fields.

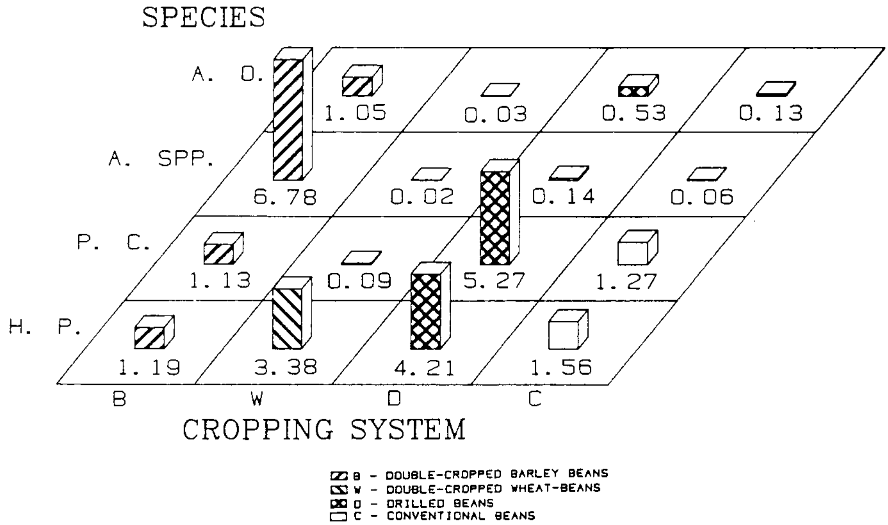

Fig. 1. Relative abundance of *Harpalus pensylvanicus* (H. p.), *Poecilus chalcites* (P. c.), *Amara* spp. (A. spp.), and *Agonum octopunctatum* (A. o.) in four soybean cropping systems in Westmoreland County. Values represent mean specimens per trap in each cropping system.

Because the number of fields sampled changed from nine in June to 12 for the rest of the season, pooled analyses could not be performed. Therefore, data on these abundant species were examined monthly. Most significant differences were found in June (Table 3), during which both *H. pensylvanicus* and *P. chalcites* were more abundant in drilled beans (12.1 and 20.4/trap, respectively), and *Amara* spp. more abundant in double-cropped barley-beans (26.9/trap) than in the other fields. *Amara octopunctatum* was more numerous in double-cropped barley-beans (4.0/trap) than in conventional beans (0.4/trap).

In July, *H. pensylvanicus* was significantly more abundant in double-cropped wheat-beans (1.3/trap) than the others, but differences were much smaller than in June. The other three species showed no significant differences in July.

Table 3. Relative abundance of *Harpalus pensylvanicus, Poecilus chalcites, Amara* spp., and *Agonum octopunctatum* collected in pitfall traps from four soybean cropping systems in Westmoreland County in 1982.

Month	Cropping system†	No. traps	Mean number of specimens per trap*			
			H. pensylvanicus	*P. chalcites*	*Amara* spp.	*A. octopunctatum*
June	B	29	0.2 b	1.2 b	26.9 a	4.0 a
	D	29	12.1 a	20.4 a	0.5 b	2.0 ab
	C	30	1.0 b	3.8 b	0.2 b	0.4 b
July	B	30	0.2 b	2.9	0.1	0.2
	W	30	1.3 a	0.0	0.0	0.1
	D	29	0.3 b	0.2	0.0	0.1
	C	29	0.3 b	0.9	0.0	0.2
Aug.	B	30	3.3	0.2	0 2	0.0
	W	30	4.4	0.2	0.0	0.0
	D	29	2.2	0.1	0.0	0.0
	C	30	1.3	0.3	0.0	0.0
Sept.	B	29	1.0	0.2	0.3 a	0.0
	W	30	4.4	0.0	0.1 b	0.0
	D	29	2.1	0.2	0.0 b	0.0
	C	30	3.7	0.1	0.0 b	0.0

* Column means followed by the same or no letter in each month are not significantly different, Duncan's Multiple Range Test ($P \leq 0.05$).

† Cropping systems: B — soybeans double-cropped after barley; W — soybeans double-cropped after wheat; D — full-season drill planted; and C — full-season conventional.

In August, only *H. pensylvanicus* and *P. chalcites* were routinely found; yet no significant differences were detected among the cropping systems. In September, *A. octopunctatum* was not encountered in the samples, and among the other four, only *Amara* spp. showed a significantly higher number of individuals in double-cropped barley-beans (0.3/trap).

In general, these five carabid species were more prevalent in drill-planted and double-cropped fields. One reason for greater numbers of carabids in drill-planted and double-cropped fields could be the increased number of niches available in these habitats, particularly double-cropped fields (House and All 1981). During the 1982 season, adequate weed control in double-cropped and drill-planted fields was not achieved. Weeds and small grain stuble, combined with narrower row spacing in double-cropped fields, provided more niches to accommodate many different species and greater numbers of carabids. Similarly, narrowly planted rows in drilled fields had more plants per unit area, thus offering more structural diversity to carabids.

A second reason for the greater incidence of these species in drilled and double-cropped fields could be the increased levels of moisture in these fields. Rivard (1966) reported that carabids reached the highest population levels in cereal crops and related their abundance to increased humidity. Kirk (1971) observed the beetles during the day in deep soil cracks where the relative humidity approached 100%. Because double-cropping conserves moisture, carabids could be attracted to those fields. In drill-planted beans, conditions near the soil surface are kept moist and cool by a dense canopy which covers all of the between-row ground surface early in the season. Canopy closure in conventional wide-row fields occurs considerably later, if at all.

Pitfall trap efficiency could have been affected by the soil surface leaf litter. Previous work has shown that density and type of ground vegetation have a greater influence on carabid activity than the presence of prey (Greenslade 1964; House and All 1981). House and All (1981) reported that more carabids were found in no-tillage soybean fields than conventionally tilled fields, although the latter offered less resistance to carabid movement. In the present study, conventional fields received cultivation before and after planting, while drill-planted fields were plowed only prior to planting and the double-cropped fields were never plowed or cultivated.

Soil type had little influence on the below-ground or surface-dwelling arthropods. All fields except three had a Kempsville loamy soil with a 0 to 2 percent slope. One of the fields double-cropped after wheat (W2) had a Kempsville loam soil with a 2 to 6 percent slope, while B1 had a Savannah loam soil with a 0 to 2 percent slope and D2 had a Suffolk sandy loam with 0 to 2 percent slope.

Species Diversity

Species diversity was examined on a monthly basis in the different cropping systems. No significant differences were found among the cropping systems for mean number of species per field and mean specimens per trap except in June. In June, significantly fewer specimens per trap were found in conventional (6.0) than in double-cropped barley-beans (34.7) and drilled beans (36.3). As a general trend through the season, more carabids per trap occurred in narrow-row fields, particularly double-cropped systems. Also, a trend toward more species per field in double-cropped barley-beans than conventional beans was evident.

The Shannon-Weaver Index (H'), which includes both species richness and evenness, was utilized to compare the carabid diversity among the cropping systems. This index was chosen because it measures carabid response to different farm management strategies and changes in the field habitat (Dritschilo and Erwin 1982). Conventionally-grown beans usually were found to have relatively higher numbers of H' for the first three months, indicated that fewer total species were present and individuals were not evenly distributed among different species.

Another diversity index, the Berger Parker dominance index (d), which is not greatly influenced by the total species number, was employed. This index expresses the proportion of the total population that is attributed to the dominant species. However, this index failed to separate the cropping systems; there were no great differences between the numbers of d for conventional beans and those obtained for the other cropping systems. Differences in species diversify among the cropping systems, as measured by H' and d, are insignificant. The total number of carabids present appears to be more important for comparisons than either species number or species evenness.

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LITERATURE CITED

Best, R. L., and C. C. Beegle. 1977. Food preferences of five species of carabids commonly found in Iowa cornfields. Environ. Entomol. 6: 9-12.

Deitz, L. L., R. L. Rabb, J. W. Van Duyn, W. M. Brooks, J. R. Bradley, Jr., and R. E. Stinner. 1976. A guide to the identification and biology of soybean arthropods in North Carolina. N. C. Agri. Exp. Stn. Tech. Bull. 238: 264 pp.

Doane, J. F. 1981. Seasonal captures and diversity of ground beetles (Coleoptera: Carabidae) in a wheat field and its grassy borders in central Saskatchewan. Quaest. Entomol. 17: 211-33.

Dritschilo, W., and T. L. Erwin. 1982. Responses in abundance and diversity of cornfield carabid communities to differences in farm practices. Ecology 63: 900-4.

Fehr, W. R., and C. E. Caviness. 1977. Stages of soybean development. Iowa State Univ. Coop. Ext. Serv. Spec. Rep. 80. 11 pp.

Fox, C. J. S., and C. R. MacLellan. 1956. Some Carabidae and Staphylinidae shown to feed on a wireworm, *Agriotes sputator* (L.), by the precipitin test. Can. Entomol. 88: 228-31.

Frank, J. H. 1971. Carabidae (Coleoptera) as predators of the redbacked cutworm (Lepidoptera: Noctuidae) in central Alberta. Can. Entomol. 103: 1039-44.

Greenslade, P. J. M. 1964. Pitfall trapping as a method for studying populations of Carabidae (Coleoptera). J. Animal Ecol. 33: 301-10.

House, G. J., and J. N. All. 1981. Carabid beetles in soybean agroecosystems. Environ. Entomol. 10: 194-6.

Kirk, V. M. 1971. Ground beetles in cropland in South Dakota. Ann. Entomol. Soc. Amer. 64: 238-41.

Kirk, V. M. 1973. Biology of a ground beetle, *Harpalus pensylvanicus*. Ann. Entomol. Soc. Amer. 66: 513-18.

Kirk, V. M. 1975. Biology of *Pterostichus chalcites,* a ground beetle of cropland. Ann. Entomol. Soc. Amer. 68: 855-8.

Lesiewicz, D. S., J. L. Lesiewicz, J. R. Bradley, Jr., and J. W. Van Duyn. 1982. Serological determination of carabid (Coleoptera: Adephaga) predation of corn earworm (Lepidoptera: Noctuidae) in field corn. Environ. Entomol. 11: 1183-6.

Los, L. M., and W. A. Allen. 1982. Abundance and diversity of adult Carabidae in insecticide treated and untreated alfalfa fields. Environ. Entomol. 12: 1068-72.

McWhorter, R. E., J. F. Grant, and M. Shepard. 1984. Life history of a predator, *Calleida decora* (Coleoptera: Carabidae), and the influence of temperature on development. J. Agri. Entomol. 1: 68-77.

Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. J. Theoret. Biol. 13: 131-44.

Price, J. F., and M. Shepard. 1980. Sampling ground predators in soybean fields. pp. 532-543. *In* M. Kogan and D. C. Herzog, [eds.], Sampling methods in soybean entomology. Springer-Verlag, New York. 587 pp.

Rivard, I. 1966. Ground beetles (Coleoptera: Carabidae) in relation to agricultural crops. Can. Entomol. 98: 189-95.

Southwood, T. R. E. 1978. Ecological Methods with Particular References to the Study of Insect Populations. John Wiley and Sons, N. Y. 524 pp.