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The Density and Diversity of Soil Invertebrates in Conventional and Pesticide Free Corn

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ABSTRACT

Soil invertebrates were collected from a historically pesticide free cornfield and an adjacent conventionally farmed cornfield in the spring and fall of 1991, 1992, and 1993. Thirty-seven taxa were identified from the 42 samples collected over the 3 year period. Both density and diversity were significantly lower in the conventionally farmed corn. A distinct soil invertebrate community was present in the pesticide free corn dominated by springtail saprophages compared to mites in the conventionally farmed cornfield. More predators and crop feeding invertebrates were present in the pesticide free corn. In terms of density and diversity, the soil invertebrate community was more robust in the pesticide free corn.

INTRODUCTION

Widespread use of insecticides and herbicides has greatly benefited agriculture but also has led to many problems. One of the more important biological issues is that these biocides may deplete invertebrates against which the chemicals are not directed and which may be otherwise beneficial (Edwards and Thompson 1973). More than 500,000 tons of pesticides are produced annually for application in United States agroecosystems to control insect pests, plant pathogens, and undesirable plants. As little as 1 % of these may actually affect the target organisms (Pimentel and Edwards 1982). Many soil invertebrates are important for the maintenance of nutrient cycles within the soil (Linden et al. 1994).

Early studies of pest control in agroecosystems dealt with pesticides and their ability to eliminate all insects regardless of trophic guild. Currently more is known about the long term affect of chemical inputs, such as insect resistance, ground water contamination, and overall degradation of the agroecosystem. As a result, alternate solutions to the insect pest problem have taken many different tacts. More recent studies involved cultural and biological controls (Risch et al. 1986, Kogan 1986), cover cropping and crop rotation (Brust and King 1994, House and Alzugary 1989), and effects of tillage practices (Stinner and House 1990, Stinner et al. 1986, Blumberg and Crossley 1983) on insect populations.

An opportunity to look at invertebrate community structure in a chemical-free agroecosystem presented itself with the identification of the Allison farm located near Macomb, Illinois. This farm had been cropped without pesticide use since first tilled. The objectives of this study were to evaluate invertebrate community composition, differences in seasonal trends in community structure, and differences in the trophic guilds of the invertebrates as compared to an adjacent farm using standard agricultural practices including biocide use.

SITE DESCRIPTION

The historically pesticide-free Allison farm is located at R3W, T8N, Sec 20, E1/2. SE1/4, Point Pleasant Township, Warren County, Illinois. The tillable portion of the farm consists of 4 plots totaling 77 acres. Samples for soil invertebrates were collected from a 21-acre corn plot. A conventionally tilled cornfield of 80 acres was used for comparison. It was located just across a dirt road from the pesticide-free plot to the east. Prevailing winds from the southwest prevented pesticide drift from delivering pesticides to the pesticide free fields. The soil at both locations is geologically part of the same map unit, i.e., a Sable silty clay loam (Fine-silty, mixed, mesic Typic Haplaquolls). This is poorly drained soil, so both fields have been drained by tiling for farming. The only significant difference between the two collection sites is the management systems employed since these soils were brought into production.

MATERIALS AND METHODS

Soil samples were taken using a 7.6 cm soil core sampler (Edwards 1991). A set of 6 samples was taken randomly from each field 7 times over a 3-year period. Samples were taken from each field during the early growing season of corn (late June, early July) and immediately before corn was harvested (mid-September) from 1991 through 1993. A set of samples was taken from each field prior to planting corn in 1992.

Soil samples were individually weighted in the laboratory to the nearest 0.01g. A small amount of soil from each sample was placed in a small aluminum dish, weighed, and then placed in a 120^{o} oven for 48 hrs. Weights of the dried soil were taken and dry soil weight extrapolated for the entire sample.

Three of the 6 soil samples from each field and date were placed in Berlese funnel extractors (Edwards 1991) and allowed to sit for 48 hrs. Invertebrates extracted in the Berlese funnels were preserved in 95% ethyl alcohol. A few drops of Biebrich Scarlet-Eosin B stain were added to each sample to color the invertebrates, making sorting and identification easier (Williams 1974). The 3 remaining samples were washed through a no. 30 (500 *u*) sieve bucket (Edwards 1991) and the invertebrates collected by hand sorting.

Each sample was placed in a dissecting pan sorted at 3X with the aid of a magnifying lamp. Invertebrates were mounted on slides and identification was made to the lowest recognizable taxonomic level. Density was expressed as the number of individuals per kilogram of dry soil. Invertebrates were keyed and trophic guilds determined using Borror et al. (1976), Curran et al. (1989), Dillon and Dillon (1972), Eddy and Hodson (1982), Peterson (1960, 1962).

Invertebrate community structure was evaluated using Simpson's index of diversity calculated using densities and trophic guild relationships (Brower et al. 1990). Analysis of variance was used to show differences between invertebrate communities in terms of the fields and dates. Pearson chi-square was used to show differences between trophic guild frequencies according to habitat.

RESULTS

A total of 42 samples was taken from each site over the sampling period. Thirty-seven taxa and invertebrates were identified from the soil samples, 26 in the conventional corn (Table 1) and 31 in the pesticide free corn (Table 2). Twenty of the taxa were common to both fields, while 11 were found only in the conventional corn and 6 only in the pesticide free corn.

The conventional corn habitat had invertebrate densities ranging from 0.92/kg of dry soil in June of 1991 to 9.09/kg of dry soil in September of 1991 (Table 1). Saprophages and predators accounted for the largest proportion of the community through the study. At peak densities saprophages constituted 70% of the community and predators another 25%. The major saprophages were orbabatid mites (Table 1). The primary predators throughout the study were mesostigmatid mites and lithobiomorphid centipedes Table 1). Though crop feeders were not present during 1991, they were abundant in 1992 accounting for no less than 12% of the organisms present. Polyphages were also abundant during this year but were absent or represented by only a few during 1991 and 1993. Organism density during 1992 was generally lower than in the other 2 years of sampling.

The pesticide free corn had soil invertebrates densities which were significantly higher than in the convention corn ranging from 3.11 organisms kg dry soil in July of 1993 to 33.25 kg dry soil in September of 1991 (Table 2). About half of the density in the June 1991 sample was due to a phoridid which is considered a parasite to other insects. As in the conventional corn the dominant trophic guild throughout the sample period was the saprophages accounting for 61 to 86% of the density. However, unlike the mite dominated conventional corn, the pesticide free corn was dominated by springtails throughout the study period. Also crop feeders were present in the pesticide free samples through the study period sometimes accounting for as much as 10% of the invertebrate density.

There was a wide range in the number of taxa present at the two treatment sites from 3 in conventional corn during June 1991 to 21 in the pesticide free corn in September of 1991. In spite of the range in number of taxa between sampling dates and treatment sites, there were some consistencies in calculated diversity indices. Both the highest and lowest taxa diversity occurred in 1992 in the convention corn treatment, a Simpson's diversity of 0.907 occurred in September and 0.604 in June respectively (Table 3). A consistent trend in diversity occurred through the study period with significantly lower ($p = 0.05$) diversities in June compared to higher diversities in September samples. There was no significant difference between any of the years within the June or September samples or between the treatments.

Trophic guild diversity using Simpson's index was also tested (Table 3). Trophic guild diversity varied between dates in the pesticide free corn and conventional corn. While these differences were significant in all but 2 dates, September of 1991 and April 1992, there was no consistent trend between treatments. The highest trophic diversity, 0.725, occurred in the conventional corn treatment in September of 1992 just as the highest taxa diversity had. Trophic diversity was also high in the pesticide free corn in June of 1991 and 1992.

DISCUSSION

Soil invertebrate densities related most to the date the samples were taken. Samples from both the pesticide free corn and the conventional corn always had lower densities in the early season, April, June, July. Densities in the September samples were about 3 times higher than those in the early season. Arthropod and phytophagous insect density has been shown to increase in old fields between June and September (Suttman and Barrett 1979). The number of taxa present followed the same pattern as density. The density from June to September was the result of larger numbers of saprophages and predators, primarily springtails and mites. Brust and King (1994) found that predators peaked in August. Because herbicides destroy the microhabitat of soil invertebrates, one would expect weed buildup in pesticide free corn to contribute to many more predatory species (Brust and King 1994). This was observed in this study. In addition, crop feeders, including sminthurid springtails, midge larvae, and scarabid beetles, occurred in the pesticide free corn.

Although conventional corn had the same density and diversity patterns, overall density was significantly lower. Brust and King (1994), Suttman and Barrett (1979), and House and Alzugaray (1989) showed lower numbers of invertebrates in conventional corn compared to reduced chemical-use farms. In conventional corn, the higher September densities were due to larger numbers of saprophages such as oribateid mites and onychiurid springtails. This is similar to the findings of Edwards and Thompson (1979) who demonstrated that with increased chemical use the numbers of predatory mites decreased while oribatid mites numbers increased. It has also been shown that outbreaks of scavenging oribatid mites may occur after cornfields are sprayed (Risch et al. 1986). Though density was low in the conventional corn treatment, number of taxa in the September samples was often high primarily due to occurrence of onychiurid springtails and mesostigmatid mites. Conventional tillage can expose invertebrates to unfavorable conditions while redistributing some invertebrates deeper in the soil (House and Alzugaray 1989).

Diversity, a measure of community structure, is higher in more complex communities. High diversities occurred in the pesticide free corn later in each year. Although this site is a monoculture in terms of agricultural practices, weedy vegetation constituted a large portion of the overall plant community due to the lack of herbicide use. Lack of insecticides and herbicides allow for a more diverse invertebrate community. The more diverse plant community created larger numbers of microhabitats for many different invertebrates.

Soil invertebrate taxa diversity did not fluctuate greatly in the conventional corn. Lowered populations and taxa composition of all types of invertebrates were observed in conventional cornfields. Whitford et al. (1982) illustrated that the decomposition rate of creosote bush litter was reduced dramatically after chlordane treatment killed virtually all of the insects and mites. A well-balanced soil invertebrate community is an essential part of the soil ecosystem. The soil invertebrate community decomposes crop residues to form humus and recycle mineral nutrients for succeeding crops. This process is vital and associated with high quality, productive soils (Linden et al. 1994). Differences in invertebrate diversity in both treatments in June of 1992 were probably the result of an unusually dry spring. Due to the dominance of saprophages, trophic guild diversity was lower than taxa diversity.

The maintenance of the pesticide free tillage practice has resulted in a larger more diverse population of soil invertebrates, particularly mites. Our data also lends support to the recognition of chemical-free farming producing a more healthy soil ecosystem.

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Table 1. Density of soil invertebrates collected in the spring and fall from 1991 to 1993 in conventionally farmed corn. Trophic guild identification numbers are: 1 = plant feeders, 2 = predators, 3 = crop feeders, 4 = saprophages, 5 = parasites, 6 = pollinators, 10 = gall formers, 12 = polyphages.

Taxa ID No.	Taxa	Trophic Guild I.D. No.	Conventional-Corn						
			6/91	9/91	4/92	6/92	9/92	7/93	9/93
			Density as No./kg of dry soil						
2	Phoridae	5					0.13		
3	Cecidomyiidae	3				0.17			0.13
6	Sciaridae	4					0.49		
9	Cecidomyiidae(larva)	10		0.17	0.16		0.31		0.13
10	Oribatei	4		2.34	0.60	0.68		0.32	1.79
11	Myrmicinae	1		0.34				0.12	
12	Campodeidae	4							0.42
14	Japygidae	4	0.22						
17	Poduridae	4					0.26		0.32
18	Staphylinidae	12	0.22		0.13		0.13	0.12	
19	Onychiuridae	4		1.55			0.65		0.13
20	Mesostigmata	2		1.06			0.43		0.25
22	Isotomidae	4		0.34					
24	Oligocheta	4	0.48	2.10				0.27	
25	Sminthuridae	3			0.29				
31	Staphylinidae(larvae)	12			0.13		0.13		
33	Fungivoridae(larva)	4			0.43		0.12		0.13
34	Trupaneidae(larva)	3				0.17	0.18		
38	Lithobiomorpha	2		1.19					
39	Scarabaeidae	3					0.12		
45	Drosophilidae	4				0.14			
46	Coccidellidae(larva)	2					0.37	0.12	
47	Erotylidae	4					0.12		
48	Melyridae(larva)	12					0.12		0.13
49	Aphididae	3					0.13		
66	Cicadellidae	3							0.13
	Total Density		0.92	9.09	1.74	1.16	3.69	0.95	3.56

Table 2. Density of soil invertebrates collected in the spring and fall from 1991 to 1993 in a historically pesticide free cornfield. Trophic guild identification numbers are:
1 = plant feeders, 2 = predators, 3 = crop feeders, 4 = saprophages, 5 = parasites, 6 = pollinators, 10 = gall formers, 12 = polyphages.

Taxa ID No.	Taxa	Trophic Guild I.D. No.	Without Pesticides-Corn						
			6/91	9/91	4/92	6/92	9/92	7/93	9/93
			Density as No./kg of dry soil						
1	Geophilomorpha	2	0.13						
2	Phoridae	5	2.69	0.36				0.15	
3	Cecidomyiidae	3	0.66	0.40					0.14
4	Chrysomelidae	3	0.22	0.52					0.47
6	Sciaridae	4	0.27	0.18	0.16		0.58	0.45	0.76
7	Carabidae(larva)	2		0.16			0.22		0.14
8	Ponerinae	2		1.10					
9	Cecidomyiidae(larva)	10	0.14	0.37	0.35		0.86		1.62
10	Oribatei	4		5.44	0.59	0.15			
11	Myrmicinae	1		0.16					
12	Campodeidae	4		0.96	0.21				0.14
13	Entomobryidae	4	0.14						
14	Japygidae	4	0.12	0.18					
17	Poduridae	4	0.12	2.68	0.21			0.15	
18	Staphylinidae	12	0.52	1.02		0.14	0.36	0.29	0.28
19	Onychiuridae	4	0.24	9.22	0.16	2.01	2.80	1.47	2.13
20	Mesostigmata	2		4.35	0.88	0.15	1.01		0.53
21	Delphacidae	3	0.14						
22	Isotomidae	4	0.36	3.27	0.16	0.72	1.75	0.45	1.76
23	Galumnidae	4		0.69					
24	Oligocheta	4		1.67	0.16		0.94		
25	Sminthuridae	3		0.16	0.37				
26	Symphyla	3		0.20					0.28
37	Chrysomelidae(larva)	3				0.14			
38	Lithobiomorpha	2				0.14			
45	Drosophilidae	4		0.16					
47	Erotylidae	4					0.79	0.15	0.76
49	Aphididae	3					0.40		
63	Chilopoda	2							0.14
66	Cicadellidae	3					0.65		
70	Anthophoridae	6					0.22		
	Total Density		5.75	33.25	3.25	3.45	10.58	3.11	9.15

Table 3. Taxa and trophic diversity of soil invertebrates collected from a conventionally farmed cornfield and a historically pesticide free cornfield.

INVERTEBRATE DIVERSITY IN SOIL CORE SAMPLES

	Sampling Dates						
	6/91	9/91	4/92	6/92	9/92	7/93	9/93
	WITHOUT PESTICIDES - Corn						
Density (#/kg dry soil)	5.75	33.25	3.25	3.45	10.58	3.11	9.15
Number of Taxa	13	21	10	7	12	7	13
Taxa Diversity (Ds)	0.749	0.857	0.854	0.610	0.864	0.721	0.856
Number of Guilds	6	7	4	4	6	3	5
Trophic Diversity (Ds)	0.649	0.428	0.646	0.294	0.497	0.253	0.583
	CONVENTIONAL - Corn						
Density (#/kg dry soil)	0.92	9.09	1.74	1.16	3.69	0.95	3.56
Number of Taxa	3	8	6	4	15	5	10
Taxa Diversity (Ds)	0.620	0.818	0.777	0.604	0.907	0.766	0.714
Number of Guilds	2	4	4	2	6	4	5
Trophic Diversity (Ds)	0.368	0.453	0.594	0.418	0.725	0.572	0.374