Discovery, The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences

Volume 13 Article 8

Fall 2012

Invertebrate Abundances and Diversity of a Six Year Old Organic Apple Orchard in Northwest Arkansas

Cory Johnson
University of Arkansas, Fayetteville

Brina Smith
University of Arkansas, Fayetteville

Mary C. Savin
University of Arkansas, Fayetteville

Recommended Citation
Johnson, C., Smith, B., & Savin, M. C. (2012). Invertebrate Abundances and Diversity of a Six Year Old Organic Apple Orchard in Northwest Arkansas. *Discovery, The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences, 13*(1), 38-45. Retrieved from https://scholarworks.uark.edu/discoverymag/vol13/iss1/8

Invertebrate Abundances and Diversity of a Six Year Old Organic Apple Orchard in Northwest Arkansas

Cory Johnson, Brina Smith†, and Mary C. Savin§*

ABSTRACT

Ground cover mulch applications in perennial systems can have multiple benefits, one of which may be to enhance the size and diversity of the ground surface faunal community. To determine if ground cover and organic fertilizer applications altered invertebrate communities, litters in an experimental 0.4-ha organic apple orchard in Fayetteville, Ark. were sampled during a four week period beginning in February 2012. The orchard was planted in 2006 in a replicated 4 × 3 factorial design with organic ground cover and fertilizer treatments applied annually each April. Invertebrates were extracted using Berlese funnels and hand sorting techniques. Ground covers (wood chips (W), urban compost (C), and shredded paper (P)) increased abundances per unit area, taxa richness, and diversity compared to the litter of the mowed control (M), with the largest abundances on an area basis occurring in W. Nutrient applications had little to no effect on invertebrate communities. Isopoda comprised a larger proportion of the litter community in P compared to M. Compost enhanced the proportion of Diplopoda and Haplotaxida and W enhanced the proportion of Diplopoda and Isopoda compared to M. In terms of direct abundances, Chilopoda and Gastropoda as well as Diplopoda and Isopoda were higher in W than in M. Habitat differences on the soil surface resulting from managing the orchard with different ground covers altered the community composition of the litter fauna expected to facilitate decomposition, but did not show a predominance of predators that might be expected to enhance pest control.

* Cory Johnson is a senior Crop Management major in the Department of Crop, Soil, and Environmental Sciences.
† Brina Smith is a research associate in the Microbial Ecology and Soil Biology Laboratory in the Department of Crop, Soil, and Environmental Sciences.
§ Mary C. Savin is the faculty mentor and Professor in the Department of Crop, Soil, and Environmental Sciences.

MEET THE STUDENT-AUTHOR

Cory Johnson

I grew up in Western Kentucky and Northwest Tennessee and graduated from South Fulton High School in South Fulton, Tennessee. I have since relocated to Stuttgart, Arkansas. I decided to pursue a degree in Crop Management and a minor in Pest Management from the University of Arkansas in Fayetteville. My interests include organic agriculture, horticulture, crop science, soil science, and entomology. After I complete my Bachelor of Science degree I would like to pursue a Master of Science degree in agronomy or a related field. I hope to have a successful career as a crop consultant after I complete my education. I am a member of the American Society of Agronomy, the Crop Science Society of America, and the Soil Science Society of America. On campus I am a member of the University of Arkansas Razorback Chapter of Ducks Unlimited. In my free time I enjoy traveling, fly fishing, duck hunting, bluegrass, and attending Razorback athletic events.

INTRODUCTION

Many agricultural practices have reduced biodiversity (Hendrickx et al., 2007; Reidsma et al., 2006). Forms of sustainable agriculture have been established with the goal of minimizing environmental impacts while maximizing economic food and fiber production. Organic agriculture attempts to meet this goal by prohibiting the use of synthetic chemicals and promoting a variety of other management practices, some of which should increase biodiversity (Hole et al., 2005). The greater the diversity of invertebrates in an agro-ecosystem, the greater the stability of the system is expected to be. The fewer the invertebrates, especially across different functional groups, the greater the potential for a problem or deficiency to develop in the ecosystem. Fruit orchard agro-ecosystems may promote the preservation of biodiversity, since an orchard is a permanent system with a variety of plant structures (Simon et al., 2010). In fact, organic management practices in a Pacific Northwest apple orchard have been found to increase ground dwelling arthropods (Epstein et al., 2000).

A long-term study is being conducted in Fayetteville, Ark. to investigate the effects of organic management practices on apple orchard systems. The biodiversity of the invertebrate community in the litter of this experimental organic apple orchard has not been investigated previously. There is a need to generate data specific to the Mid-southern region of the U.S. to assist fruit growers who wish to transition to and manage orchards organically. Invertebrate communities respond to ground cover management because ground covers can change habitat and resource availability. For example, the use of permanent cover crops in organic apple orchards, as opposed to the use of herbicide and disking natural vegetation, could lead to larger and more diverse arthropod populations (Fernández et al., 2008).

In this project, conducted during the late winter of 2012, the invertebrate community composition in the surface litters of an organically managed apple orchard was characterized to determine if different ground cover and organic fertilizer treatments altered abundances, taxa richness, diversity, and community structure. Ground cover treatments included a mowed control (M), wood chips (W), shredded paper (P), and urban compost (C). Fertilizers included the control; composted poultry litter; and a formulated, certified organic, pelletized poultry litter. It was hypothesized that organic ground cover (litter) and fertilizer treatments constitute beneficial habitat for diverse groups of invertebrates such that abundances, taxa richness, and diversity would all increase with ground cover treatments compared to the mowed control. Because of amounts of litter and difference among litter properties, ground covers were expected to alter invertebrate community composition differently. Fertilizers were expected to modify decomposition of ground covers, especially in paper and wood chips, and were thus expected to result in a significant interaction with ground cover in affecting community composition of fauna.

MATERIALS AND METHODS

Study Site and Experimental Design. The apple orchard encompasses approximately 0.4 ha and is located at the University of Arkansas (UA) Main Agricultural Experiment and Extension Center in Fayetteville, Ark. (36°N, 94°W). The orchard is located on two soil series (Captina and Pickwick silt-loam soils). Land was limed, received composted horse manure, and had a cover crop during the winter of 2005 before Enterprise/M26 trees grafted onto rootstock were planted in 2006. The four ground covers include urban compost (C), shredded paper (P), wood chips (W), and a mowed control (M). Each ground cover treatment is split and includes three fertilizers: a no fertilizer control where the ground cover provides nutrition, composted poultry litter, and a formulated, certified organic, pelletized poultry litter (Perdue Fertilizer Products 4-2-4 Perdue Agri-Recycle, Seaford, DE). Each tree receives one of four surface ground covers (2×2 m^2 surrounding area) to a depth of 7.5-12 cm and one of three nutrient applications at a rate equivalent to zero or 50 g N annually every April. Treatments are fully replicated in a 4×3 factorial design and arranged in a randomized complete block. The experimental design of the orchard is described more fully in Rom et al. (2010).

Sampling and Extraction. Preliminary trials were conducted in January to evaluate sample collection and extraction methodology. The M and P ground covers were not as deep nor covered as extensive an area as C and W. Therefore, from these preliminary trials it was concluded that P and M had to be sampled on an area basis while C and W could be sampled on the same area basis, but also at a defined volume.

Invertebrates were sampled from the organic ground surface litter layers during a four week period from February through March, 2012. A PVC core with an area of 314 cm^2 was used for each treatment tree and a volume of 3204 cm^3 was used for each W and C tree. The core was pressed into the litter layer until the top of the W or C litter was flush with the surface of the core or the core bottom was flush with the soil surface in P and M. In the W and C treatments, this ensured sampling of a defined volume, but did leave some litter remaining on top of the soil surface and below the core. Once the PVC core was in place, a metal pan was inserted below the core to retain the litter during sample collection and transfer to a sample bag. Each treatment tree (three replicates per treatment) was sampled in random order as determined by a random number generation function in Excel. The date, time, temperature, and wind speed were recorded at each sampling. Litter moisture was determined gravimetrically by oven drying a 10-g litter subsample at 55 °C for five days and calculating moisture according to equation (1):

$$\left(\frac{W-D}{W}\right)100 \qquad \text{Eq. (1)}$$

where W = moist mass of litter, and D = oven-dry mass of litter.

The remainder of the collected litter sample was placed into a homemade Berlese funnel (4 L) and was housed in a Biotronette Mark III Environmental Chamber at 27 °C with 24-hr lighting, 120 volts 50/60 Hz AMPS. A catch jar containing 70% ethanol was placed beneath each funnel to preserve organisms that migrated through the litter layer. After five days, litter was hand sorted to remove sedentary organisms that were not extracted by the funnel. Organisms were observed under a Zeiss dissecting microscope (Stemi 2000-C, Germany) and identified using the Soil Biology Guide (Dindal, 1990), *Larvae of Insects Vol. I, An Introduction to Nearctic Species, Lepidoptera and Plant Infesting Hymenoptera, 4th ed.* (Peterson, 1962), and *Larvae of Insects Vol. II, Coleoptera, Diptera, Neuroptera, Siphonaptera Mecoptera, Trichoptera* (Peterson, 1951). Identifications were verified by University of Arkansas Entomology Department personnel when requested.

Data Analysis. Means and standard deviations were calculated for abundance, taxa richness, and diversity. Diversity was calculated by the reciprocal of Simpson's (which will be called Simpson's) (2) and Shannon-Weaver (3) indices.

$$D=\left(\frac{1}{\Sigma p_i^2}\right) \qquad \text{Eq. 2}$$

$$H=-\left(\Sigma p_i \ln p_i\right) \qquad \text{Eq. 3}$$

Where p_i is the proportion of each taxon *i*. Statistical differences were calculated using PROC GLM in SAS 9.1 (SAS Institute Inc., Cary, N.C.) and means were separated using LSD ($P = 0.05$). Given the low abundances and frequency of no detection in multiple samples, abundances in Araneae, Lepidoptera, Blattodea, Hymenoptera, Heteroptera, and Orthoptera, and unidentified organisms were not analyzed statistically.

RESULTS AND DISCUSSION

Ground Covers and Abundances of Fauna. A total of 4342 organisms were recovered from all of the litter samples collected from the orchard (Table 1). Statistical analysis revealed a ground cover by fertilizer interaction in organism abundance, but for all other properties there was no significant interaction, and fertilizer was not significant. Therefore, data will be presented for the main effect of the ground cover only. The ground covers are visually different in properties and extent of coverage in the orchard (data not shown). The difference in ground surface coverage is evident in litter sample size (Table 2). Mass of litter was 50 to 60 times greater in W and C, respectively, compared to M. However, litter moisture was not different among W, P, and C, which was lower than M. The W litter sample had the highest organism abundances on an area basis, while abundances in C and P were similar and greater than M. In contrast, on a mass basis (per g litter) abundance in P and W were not different and were both higher than C and M.

Richness and Diversity of Litter Fauna Classified by Species and Order. In regards to richness and diversity of species, W and C were similar and higher than M (Table 3). Species richness in P was higher than in M but lower than W and C. Diversity in P was also lower than that in W and C and higher than in M when calculated using the Shannon-Weaver index. However, using the Simpson's diversity index, diversity in P was not different from that in C.

At the classification level of class/order, W had the highest richness, followed by C, which was higher than P, which was higher than M (Table 3). In terms of diversity, treatments followed similar trends as those calculated using species whether calculated by Simpson's or the Shannon-Weaver index. Diversity in P was greater than M and less than W regardless of index; it was not different from C using the Simpson's index; and it was different from C using the Shannon-Weaver index.

Thirty species across thirteen classes or orders were identified in total across all samples (Table 1). The thirteen classes or orders identified included class Gastropoda, (1922 organisms in total in the order Geophila among two species of snail), order Isopoda (940 organisms in total in one species of pill bug), subclass Oligochaete, order Haplotaxida (719 unidentified juveniles and 27 adults of one species of earthworm), class Diplopoda (359 organisms in one species of millipede), order Diptera (243 organisms across four species of fly), class Chilopoda (66 organisms in one species of centipede), class Araneae (16 individuals across three species of spider), and orders Coleoptera (33 individuals among 10 species of beetle), Lepidoptera (three individuals across three species of moth/butterfly), Blattodea (five individuals in one species of cockroach), Hymenoptera, (two individuals from one species of bee), Heteroptera (one true bug), and Orthoptera (one individual cricket). Five individuals could not be identified.

Ground covers can change the abundances of organisms by directly impacting the number of organisms and indirectly by impacting the proportion of the total community they comprise. The organisms contributing to the M litter were not only less abundant (Table 2) with fewer species (Table 3), some species were different than in the other treatments. Lepidoptera were found only in M (Table 1). Gastropoda, Diptera, and an unidentified organism were also found in M (Table 1). Gastropoda (snail) made up a large percentage of the communities in all ground covers (average of 24-54% in all four ground covers), but abundances of Gastropoda in W were higher than in C, P, and M (Table 4). However, ground covers did not change distributions of organisms within the community, such that abundances of Gastropoda as a proportion of the total community were not different across ground cover treatments (data not shown, $P = 0.067$). Chilopoda (centipede) and Diplopoda (millipede) were also higher in numbers in W compared to other treatments (Table 4), while Chilopoda abundances as a proportion of the total community were not different across ground cover treatments (data not shown, $P = 0.47$). Diplopoda (millipede) comprised a similar portion of the community (about 10%) in W and C and were more abundant than in P and M (Table 5).

Isopoda contributed a sizeable fraction of the community in W and P (Table 5). In addition to relative abundances, Isopoda were not different from each other in terms of sheer abundances in W and P (Table 4). While Isopoda abundance in P was not significantly different than in C and M, abundance in W was significantly higher than in C and M (Table 4). In contrast to the community composition in W and P, Haplotaxida (earthworm) is relatively more abundant than Isopoda (pill bug) in C. In fact, Haplotaxida abundance changed in the orchard from ground cover treatments such that the relative contribution of earthworms to the community is higher in C than any other treatment (Table 5). Abundances (direct or as a proportion of the total community) for Diptera (fly larvae, $P = 0.08$ for direct and $P = 0.43$ for proportion) and Coleoptera (beetle, $P = 0.43$ for direct and $P = 0.08$ for proportion) were not different across ground cover treatments (data not shown).

During this single sampling and collection of invertebrates from the University of Arkansas organic apple orchard, 4342 organisms were identified into thirty different species. With the exception of the mowed control M, the organic ground covers provided abundant and diverse populations of invertebrates. All litters (P, C, and W) improved abundances, richness, and diversity of fauna, even the P treatment that did not cover an equivalent soil surface area or volume as C and W. In the current study, biodiversity was improved with organic ground cover application management in the apple orchard agro-ecosystem, while organic fertilizers had minimal effect on invertebrate communities. The importance of ground cover management compared to fertilizer management in impacting the arthropod community has been observed previously where ground cover management comparisons included mulch, tillage, and herbicide treatments (Miñarro et al., 2008). Organic management has been shown to increase diversity of the arthropod community compared to conventional management in apple orchards (Fernández et al., 2008) and compared to integrated pest management practices in a kiwifruit orchard (Todd et al., 2011). Application of composted poultry manure mulch increased predators and prey in ground invertebrate communities compared to synthetic mulch, a herbicide treated orchard, and a bare ground control orchard floor (Mathews et al., 2004). Extent of richness and diversity improvements varied among treatments. From the thirty different species collected during sampling, W and C had the most species, followed by P and lastly by M. Improved biodiversity is expected to improve the stability of an ecosystem. Annual applications of ground covers should improve the overall health of the orchard because of higher biodiversity of the invertebrate communities residing within the litter.

Based on the observed increase in relative abundance, the organic litter applications appear to be beneficial to organisms that facilitate decomposition, or the breakdown of organic matter, such as Haplotaxida, Isopoda, and Diplopoda. However, different faunal groups became more abundant in different ground covers. Changes to resources and the habitat caused by ground cover applications likely explain, at least partially, the reactions of different arthropods in different ground covers (Miñarro et al., 2008). Compost increased relative abundance of Haplotaxida, while W and P did not. Earthworms facilitate decomposition of litter, contribute to enhanced nutrient cycling and nitrogen availability, build soil organic matter, and enhance soil structure (Edwards, 1998; Lee, 1985). Larger sized detritivorous invertebrates have been known to facilitate decomposition of litter as well as other important processes in soil (Lavelle et. al, 2006). In particular, earthworm contributions to N cycling could have strong impacts on nutrient availability in the C treatment compared to other treatments, and this deserves further study.

The organic litter materials in W may be providing the necessary food, shelter, and aeration to sustain a large(r) community of invertebrates. Compost and W applications have resulted in similar and significantly greater accumulations of litter mass than P and M. However, abundances of three classes or orders of organisms were higher in W compared to all other ground covers. Wood chips and P, which had similar total abundances when measured on a mass basis (per g litter), in terms of relative abundance in the total community, had more Isopoda than M, although Isopoda in C was also not different from W or M. Isopoda were numerous in this study (940 out of 4342 individuals collected), and they have increased in abundance in response to organic management in apple orchards as compared to conventional management (Fernández et al., 2008). Haplotaxida, Isopoda, and Diplopoda all require sufficient organic matter resources (ground cover and plants) to sustain populations in ecosystems and have been recommended as a group of bio-indicator organisms for successful restoration (Snyder and Hendrix, 2008).

Many of the organisms identified were early in-star decomposers and few were found to be predacious organisms, such as Araneae (spider) and Chilopoda (centipede). Samples contained low relative abundances of prey items for Araneae and Chilopoda, such as the larval stages of Diptera (fly) and Coleoptera (beetle). The low relative abundances may partially explain the lack of predators; however, other studies have found predators to be important ground surface arthropod community members (Fernández et al., 2008; Mathews et al., 2004; Miñarro et al., 2008; Ruano et al., 2004). Our results showing a lack of generalist predators may indicate a concern for adequate pest management because of the potential lack of an important biological mechanism to keep prey abundance in check or may reflect the time of year that sampling occurred. Managing the ground habitat so that it is used by predators for reproduction, shelter, and sources of prey should provide a means of improving the ground-dwelling generalist predators (Mathews et al., 2004).

The community composition of the ground cover litters is likely to be temporally variable (Mathews et al., 2004; Ruano et al., 2004). Our community structure, the early developmental stages of organisms collected, and the lack of predators detected, could reflect at least partially the time of year that the sampling was conducted (Ruano et al., 2004). Increasing the number of samplings and sampling approaches could increase total abundances, and richness and diversity estimations for the orchard (Fernández et al., 2008). Predominant faunal groups have been found consistently, although abundances changed throughout a season (Mathews et al., 2004). In other studies invertebrates in different orders have differentiated management approaches during different times of the year (Ruano et al., 2004).

In summary, managing an apple orchard in Northwest Arkansas with repeated annual ground cover applications can be beneficial to invertebrates by improving richness, abundance, and diversity. Treatments that included a mowed control (M), wood chips (W), shredded paper (P), and compost (C), and no fertilizer, composted poultry litter, and a formulated, certified organic, pelletized poultry litter were examined during this study for differences among invertebrate communities. Orchard biodiversity was enhanced by using organic W, C, and P ground cover (litter) treatments as compared to M. In particular, relative abundances of Diplopoda, Haplotaxida, and Isopoda were increased in general and also differentiated ground cover treatments. Because different invertebrate taxa appear to respond differently to ground cover treatments, ground cover type needs to be considered if promotion of specific decomposer populations is desired. The lack of predators needs further investigation.

ACKNOWLEDGEMENTS

Research on the organic apple orchard is supported by funds from the USDA Integrated Organic Program (Grant 2008-51300-04819), Arkansas Division of Agriculture, and the University of Arkansas. We thank each person who assisted us in our research project. We thank David Longer, Professor of Crop Science in CSES for letting us use his growth chamber to house funnels during the experiment. We thank Ashley Dowling, Assistant Professor of the University of Arkansas Department of Entomology for his guidance in the identification of organisms. We also thank Kamela Mitchell, Alex Henson, and Bryant Baker for technical assistance.

LITERATURE CITED

Dindal, D. 1990. Soil Biology Guide. John Wiley and Sons, Inc., Hoboken, N.J.

Edwards, C.A., ed. 1998. Earthworm Ecology. CRC Press LLC, Boca Raton, Fla.

Epstein, D.L., R.S. Zack, J.F. Brunner, L. Gut, and J.J. Brown. 2000. Effects of broad-spectrum insecticides on epigeal arthropod bio-diversity in Pacific Northwest apple orchards. Environ. Entomol. 29:340-348.

Fernández, D.W., L.I. Cichón, E.E. Sánchez, S.A. Garrido, and C. Gittins. 2008. Effect of different cover crops on the presence of arthropods in an organic apple (*Malus domestica* Borkh) orchard. J. Sustain. Agric. 32(2):197-211.

Hendrickx, F., J.P. Maelfait, W.V. Wingerden, O. Schweiger, M. Speelmans, S. Aviron, I. Augenstein, R. Billeter, D. Bailey, R. Bukacek, F. Burel, T. Diekkotter, J. Dirksen, F. Herzog, J. Liira, M. Roubalova, V. Vandomme, and R. Bugter. 2007. How landscape structure, land-use intensity and habitat diversity affect components of total arthropod diversity in agricultural landscapes. J. Appl. Ecol. 44:340-351.

Hole, D.G., A.J. Perkins, J.D. Wilson, L.H. Alexander, P.V. Grice, and A.D. Evans. 2005. Does organic farming benefit biodiversity? Biol. Conserv. 122:113-130.

Lavelle, P., T. Decaëns, M. Aubert, S. Barot, M. Blouin, F. Bureau, P. Margerie, P. Mora, and J.P. Rossi. 2006. Soil invertebrates and ecosystem services. Europ. J. Soil Biol. 42:S3–S15.

Lee, K.E. 1985. Earthworms. Their Ecology and Relationships with Soils and Land Use. Academic Press, N.Y.

Mathews, C. R., D.G. Bottrell, and M.W. Brown. 2004. Habitat manipulation of the apple orchard floor to increase ground-dwelling predator and predation of *Cydia pomonella* (L.) (Lepidoptera: Tortricidae) Biol. Contr. 30:265-273.

Miñarro, M., X. Espadaler, V.X. Merlot, and V. Suárez-Álvarez. 2008. Organic versus conventional management in an apple orchard: Effects of fertilization and tree-row management on ground-dwelling predaceous arthropods. Agric. For. Entomol. 11:133-142.

Peterson, A. 1962. Larvae of Insects, Part I, An Introduction to Nearctic Species, Lepidoptera and Plant Infesting Hymenoptera, 4th ed. Edwards Brothers, Inc., Ann Arbor, Mich.

Peterson, A. 1951. Larvae of Insects, Part II, Coleoptera, Diptera, Neuroptera, Siphonaptera Mecoptera, Trichoptera. Edwards Brothers, Inc., Ann Arbor, Mich.

Reidsma, P., T. Tekelnburg, M. van de Berg, and R. Alkemade. 2006. Impacts of land-use change on biodiversity: An assessment of agricultural biodiversity in the European Union. Agric. Ecosys. Environ. 144:86-102.

Rom, C.R., M.E. Garcia, J. McAfee, H. Friedrich, H.S. Choi, D.T. Johnson, J. Popp, and M. Savin. 2010. The effects of groundcover management and nutrient source during organic orchard establishment. Acta Hort. 873:105-114.

Ruano, F. C., Lozano, P. Garcia, A. Peña, A. Tinaut, F. Pascual, and M. Campos. 2004. Use of arthropods for the evaluation of the olive-orchard management regimes. Agric. For. Entomol. 6:111-120.

Simon, S., J.C. Bouvier, J.F. Debras, and B. Sauphanor, 2010. Biodiversity and pest management in orchard systems. A review. Agron. Sustain. Develop. 30:139-152.

Snyder, B.A., and P.F. Hendrix. 2008. Current and potential roles of soil macroinvertebrates (earthworms, millipedes, and isopods) in ecological restoration. Restoration Ecol. 16(4):629-636.

Todd, J.H., L.A. Malone, B.H. McArdle, J. Benge, J. Poulton, S. Thorpe, and J.R. Beggs. 2011. Invertebrate community richness in New Zealand kiwifruit orchards under organic or integrated pest management. Agric. Ecosyst. Environ.141:32-38.

Table 1. Total numbers of organisms identified in the four ground cover treatments (litters) of the organic apple orchard in Fayetteville, Ark.

Class or Order	Organism identified	# Individuals				
		Total	Wood chips	Compost	Shredded Paper	Mowed Control
Aranea	*Hydrous triangularis*	1	1			
	Steatoda triangulosa	7	4	1	2	
	Ummidia audouini	8	7		1	
Blattodea	*Periplaneta americana*	5	1		4	
Chilopoda	*Zygethobus ecologus*	66	46	3	17	
Coleoptera	*Aeolous melillus*	2		2		
	Alica chalyne	1	1			
	Capnochroa fuliginosa	3	3			
	Conotrachelus nenuphar	1		1		
	Leptinotarsa decemlineara Say.	2	1	1		
	Ludius divercatus	3	1	2		
	Philonthus sp.	5	2	2	1	
	Pterostichus sp.	3		3		
	Rynchaenus pallicornis	11			11	
	Unknown Species	2		2		
Diplopoda	*Cylindroiulus* sp.	359	266	75	18	
Diptera	*Bibio* sp.	225	204	21		
	Sarcophaga seruritera	1				1
	Tachinidae (family level)	3		3		
	Tipula hermannia	14	6	7	1	
Gastropoda	*Polygra septemvulva*	1918	1357	241	315	5
	Pupoides albilabris	4		3	1	
Haplotaxida	*Lumbricus rubellus*	27	15	12		
	juvenile earthworms	719	312	299	108	
Heteroptera	*Acanthocephala terminalis*	1		1		
Hymenoptera	*Camponotus* sp.	2	2			
Isopoda	*Armadillidum vulgare*	940	547	78	315	
Lepidoptera	*Heliothis armigera*	1				1
	Malacosma americanum	1				1
	Nephelodes emmedonia	1				1
Orthoptera	*Gryllus pennsylvanicus*	1	1			
Unidentified	Unidentified	5	4			1

Table 2. Litter amount, moisture content, and organism abundance on an area and mass basis (mean ± standard deviation) in four ground cover treatments for litter fauna in an organic apple orchard (n = 9).

Treatment	Litter (g)	Litter moisture (%)	Abundance per area sampled	Abundance per g litter
Wood chips	801 (381)a[1]	34.5 (14.7)b	309 (148)a	0.45 (0.28)a
Compost	938 (210)a	35.5 (9.4)b	84 (62)b	0.11 (0.09)b
Shredded Paper	219 (169)b	36.5 (17.6)b	88 (89)b	0.39 (0.20)a
Mowed control	15.4 (12.5)b	59.9 (25.7)a	1.1 (1.4)c	0.09 (0.12)b

[1]Means within a column that are followed by a similar letter are not significantly different (*P* = 0.05).

Table 3. Richness and diversity (mean ± standard deviation) for litter fauna in an organic apple orchard receiving four ground cover treatments when organisms are classified at the species level and class or order level (n = 9).

Treatment	Species			Class or Order		
	Richness	H[1]	D	Richness	H	D
Wood chips	8.1 (1.8)a[2]	1.3 (0.2)a	3.0 (0.7)a	7.3 (1.2)a	1.3 (0.2)a	3.0 (0.7)a
Compost	6.7 (2.1)a	1.2 (0.3)a	2.6 (0.9)ab	5.6 (1.3)b	1.1 (0.3)a	2.6 (0.8)ab
Shredded Paper	4.6 (1.5)b	0.8 (0.3)b	2.0 (0.6)b	4.3 (1.3)c	0.8 (0.3)b	2.0 (0.6)b
Mowed control	0.9 (1.0)c	0.2 (0.4)c	0.7 (0.8)c	0.8 (0.8)d	0.1 (0.3)c	0.7 (0.8)c

[1]H = Shannon-Weaver diversity index and D = Simpson's diversity index.
[2]Means within a column that are followed by a similar letter are not significantly different (*P* = 0.05).

Table 4. Abundance of organisms (as sampled in 314 cm^2 area) in different classes or orders in the ground cover treatments (litters) of the organic apple orchard in Fayetteville, Ark.

Treatment	Chilopoda	Diplopoda	Gastropoda	Isopoda
Wood chips	5.1 (4.6)a[1]	29.6 (12.7)a	150.8 (76.1)a	60.8 (51.0)a
Compost	0.3 (0.5)b	8.3 (11.7)b	27.1 (21.1)b	8.7 (20.5)b
Shredded Paper	1.9 (4.2)b	2.0 (2.6)b	35.1 (22.9)b	35.0 (52.8)ab
Mowed control	0.0 (0.0)b	0.0 (0.0)b	0.56 (0.88)b	0.0 (0.0)b

[1]Means within a column that are followed by a similar letter are not significantly different (*P* = 0.05).

Table 5. Organism abundance (as sampled in a 314 cm^2 area and classified to class or order) as a proportion of the total ground cover treatment (litter) community in an organic apple orchard in Fayetteville, Ark.

Treatment	Diplopoda	Haplotaxida	Isopoda
Wood chips	0.10 (0.04)a[1]	0.12 (0.09)b	0.21 (0.14)ab
Compost	0.09 (0.13)a	0.40 (0.29)a	0.07 (0.13)bc
Shredded Paper	0.02 (0.02)b	0.09 (0.14)b	0.31 (0.28)a
Mowed control	0.00 (0.00)b	0.00 (0.00)b	0.00 (0.00)c

[1]Means within a column that are followed by a similar letter are not significantly different (*P* = 0.05).