INVERTEBRATE FAUNA ASSOCIATED with MULCH in URBAN ENVIRONMENTS

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Abstract An inventory of invertebrates associated with different types of mulches in central Ohio revealed that significantly more organisms occurred in mulched plots than in bare soil plots. Mulch often harbored more than twice as many organisms as bare soil. Furthermore, these invertebrates were more prevalent in the mulch itself than in the underlying soil. The compass side of the structure and the type of groundcover appeared to have little effect on the numbers of invertebrates in plots (groundcover and underlying soil). Collembola and acarines were present in more than half of the plots, often in very high numbers. Diplopods were the most plentiful macroarthropod, occurring in almost half (48.9%) of the plots. Other regularly encountered invertebrates included isopods, coleopterans, nematodes, chilopods, and earthworms. Isopterans, psocids, aranids, formicids, symphylans, diplurans, and dermapterans were occasionally encountered. Some organisms were more prevalent in a particular type of mulch, i.e., isopods in leaf litter; acarines and diplopods in hardwood mulch; pseudoscorpions, diplopods, and acarines in pine bark micro-nuggets; and symphylans in grass. Inorganic mulches tended to hold less moisture and harbored fewer invertebrates than organic mulches. Diplopods, earthworms, isopods, collembola, acarines, dipteran larvae, pseudoscorpions, psocids, aranids, and isopterans were found in significantly higher numbers at a mulch depth of 11 to 13 cm. Most invertebrates were present in significantly lower numbers at a mulch depth of 1 cm. Isopterans experienced a significant decrease in numbers at a soil temperature of 22°C, which was an ideal temperature for dipteran larvae, diplurans, pseudoscorpions, and symphylans. There was a dramatic drop in numbers of all invertebrates except psocids when the surface temperature reached 34°C.

Key Words Arthropods, nematodes, termites, soil temperature, soil moisture

INTRODUCTION

The use of mulch in urban landscapes has increased significantly in the past few years (Glenn, 1999). Decorative mulch is often applied in order to improve the aesthetic appearance of a building or landscape (Robinson, 1988), although mulches were originally recommended as urban substitutes for the natural leaf litter in a forest (Herms et al., 2001). Mulch provides a variety of ecological benefits when used correctly, including conserving moisture, stabilizing soil, reducing soil temperature fluctuations, preventing erosion and compaction, and reducing the need for herbicide applications and landscape maintenance (Robinson, 1988). For every benefit associated with mulch, there seems to be a detriment (Borland, 1988), especially when mulch is applied too thick or too often, which are fairly regular occurrences (Chatfield, 2000).

Sometimes mulches pose an immediate threat to the plants that they are meant to protect. Mulches that have been improperly composted can introduce plant pathogens to the plants around which they are applied (Herms et al., 2001). Soils that drain slowly may remain saturated, thereby harming plant roots and encouraging root rot diseases (Herms et al., 2001). Mulches often encourage the growth of fungi (Hoitink et al., 2002). Mulches may also reduce the availability of soil nutrients to plants. As microbes decompose organic mulches, they out-compete nearby plants for nitrogen (Lloyd et al., 2002). Especially during the winter months, mulch can shelter rodents that gnaw and damage tree and shrub trunks (Higgins, 2001).

Another potential problem of mulch is that it harbors pest species of invertebrates. Mulch provides many organisms with the necessities for survival, such as moisture, shelter, and food, either directly or indirectly. Mulch is thought to increase the occurrence of a variety of invertebrate pests, including ants (Meissner and Silverman, 2001), spiders (Dufour and Bachman, 1998), slugs (Zehnder, 1998), termites (Herms et al., 2001), booklice, plaster beetles, centipedes, millipedes, earwigs, isopods, fungus gnats, collembola (Koehler and Castner, 1997), white grubs, and cutworms (Baxendale and Wright, 1996). These organisms usually are not pests when they occur outdoors, but when they occasionally invade homes (Lyon, 1994), they are viewed as a nuisance. Some of these arthropods can injure or damage homes, plants, or people.

Subterranean termites feed on and forage in wood-based mulch (Dureya et al., 1999). Mulch that is applied around the foundation of a structure can provide termites access to the structure, where they can damage wood and other cellulosic materials. To protect structures from infestation, a chemical barrier is sometimes applied to the soil adjacent to and underneath the building foundation. However, mulching around the foundation can provide termites a bridge across the chemical treatment and into the home (Forschler, 1998).

Each type of organic or inorganic mulch has specific physical and chemical properties and therefore specific effects on the soil, plants, and other organisms where it is applied (Robinson, 1988). It is useful to understand the relationships between mulch properties, the underlying soil, and the associated invertebrates. Relatively few studies have addressed the impacts of mulching on insects in urban ornamental landscapes.

The objective of our research was to characterize the invertebrates associated with different types of organic and inorganic mulch. We also investigated the effects of abiotic factors such as temperature and moisture on invertebrate populations.

MATERIALS and METHODS

Study Site

This study was conducted in Franklin, Delaware, and Licking Counties in central Ohio, USA. Sites were chosen randomly, but depended on voluntary cooperation of the owner or resident of the site. At each site, the substrate abutting the building foundation was categorized as: bare soil, grass, decorative vegetation, hardwood bark, pine bark micro-nuggets, pine bark mini-nuggets, regular pine bark nuggets, cypress, grass cuttings, leaf litter, large stone, small stone, pine needle, wood scrap, plastic, or recycled wood. The time of day and compass location (N, S, E, W) where the samples were taken were recorded. Any other applicable data, such as exposure of the site to sun or shade or surface water, were also recorded.

Sampling

Samples were taken during daylight from each side of the building where soil or groundcover contacted the foundation. Proximal samples were taken within 20 cm of the foundation, while distal samples were taken at least 20 cm away from, but within 46 cm of, the foundation. On each side of the building, up to four samples were taken: proximal groundcover and the underlying 2.5 cm of soil, and distal groundcover and the underlying 2.5 cm of soil. At the location where each sample was taken, the groundcover depth was measured to the nearest cm. Temperature was measured at three levels adjacent to the sampling location: subsurface, which was 2.5 cm below the soil surface; at the soil and groundcover interface; and at the upper surface of the groundcover. Two temperature measurements were obtained from bare soil.

When acquiring each sample, a 127 cm^2 (20 cm diameter, 13 cm height) metal ring was pushed into the ground to prevent the escape of organisms. The groundcover and soil were sealed in plastic bags, placed in a cooler, and taken to the laboratory. Two subsamples of soil were taken to calculate average soil moisture. Moisture was determined by weighing each subsample to the nearest 0.01 g, drying it in an oven at 60°C for a minimum of 3 days, and re-weighing it.

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Each bag containing mulch or soil was emptied into a Berlese funnel equipped with a 40-watt incandescent light bulb and a jar containing 100% ethyl alcohol, where the sample remained for at least 48 hours. Samples were observed under a dissecting microscope and the invertebrates were tallied and categorized. Diplopods, mollusks, nematodes, and annelids were identified to class; acarines, pseudoscorpions, opilionids, isopods, chilopods, and collembola were classified to order. The remaining arthropods were determined to at least family level.

Data Analysis

All counts were transformed using the square root (X+1) formula. Statistica™ (StatSoft, 1999) was used to perform the analyses of variance and regressions at an a of 0.05. Numbers of organisms were compared across mulch types, mulch depth, percent soil moisture, mulch versus underlying soil, compass orientation relative to the structure, proximity to the structure, and temperature of the soil, interface, and surface. Soil moisture levels were compared across mulch types and mulch depths. Moisture levels were compared within plots (proximal/distal) and between plots (side of building).

During the spring and summer of 2001, 706 samples were processed, tallied, and analyzed. The total number of samples included 183 plots (25.9%) on the north side of the building, 165 (23.4%) on the east, 177 (25.1%) on the south, and 181 (25.6%) on the west. A total of 303 samples were mulch samples, and 403 were soil samples; 100 samples lacked groundcover and consisted of soil alone. A total of 348 samples were taken proximal to the foundation, and 358 were distal.

RESULTS and DISCUSSION

Significantly more organisms occurred in mulched plots than in bare soil plots [F(1, 400) = 272.10, P < 0.0001] (Figure 1). Many organisms were more than twice as plentiful in mulched plots than in bare soil. Isopods were the only organism not found in significantly higher numbers in mulched plots as compared to bare soil (F(1, 400) = 2.58, P = 0.109]. Hardwood mulch was the most popular type of groundcover in central Ohio, comprising 38.5% of the total samples (Figure 2). Cypress and bare soil were the next most popular, comprising 17.3% and 13.5% of the total,

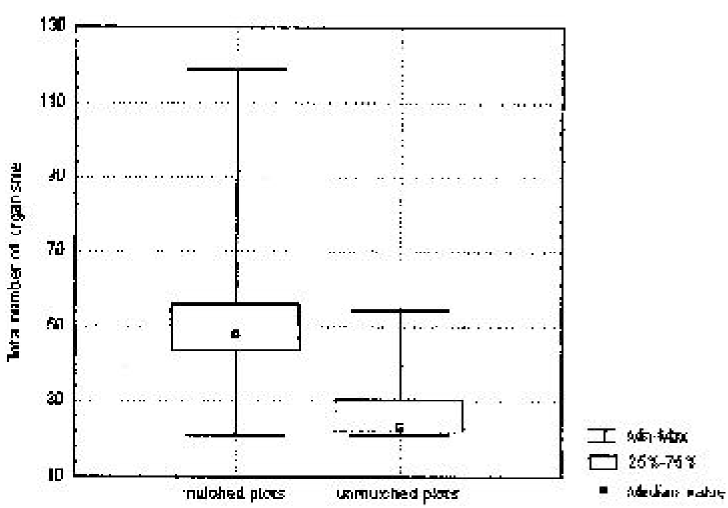

Figure 1. Total number of organisms in mulched and unmulched plots. F(1, 400) = 272.10, P < 0.0001.

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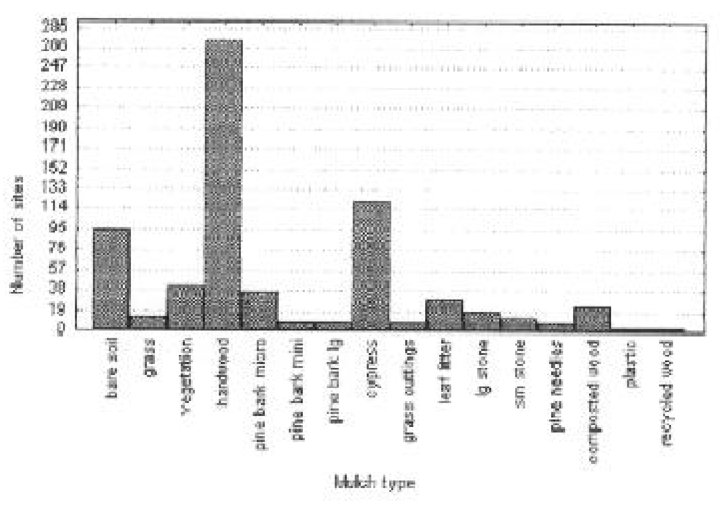

Figure 2. Total number of each groundcover type investigated in central Ohio during spring and summer 2001.

respectively. Plastic and recycled wood mulches each made up less than one percent of all samples (0.7% each).

Numbers of organisms from each mulch sample were also compared to the numbers in the soil underlying the mulch. Significantly more isopods ($F = 5.81$, $P = 0.016$), collembola ($F = 6.32$, $P = 0.012$), acarines ($F = 6.48$, $P < 0.0001$), coleopterans ($F = 15.85$, $P < 0.0001$), psocids ($F = 13.29$, $P = 0.001$), slugs ($F = 6.83$, $P = 0.009$), aranids ($F = 6.48$, $P = 0.011$), and isopterans ($F = 7.86$, $P = 0.005$) occurred in the mulch samples than in the corresponding soil sample (d.f. = 1, 400). These findings indicate that not only are these invertebrates found more frequently in mulched sites than in bare soil, but they are more prevalent in the mulch itself than in the underlying soil.

Diplopods were the most frequently encountered macroinvertebrate, occurring in 48.9% of all plots (groundcover and underlying soil). Isopods were found in 29.53% of the plots, followed by coleopterans, 26.1%; nematodes, 22.83%; chilopods, 22.1%; and earthworms, 21.3%. Symphylans, formicids, aranids, psocids, and diplurans were found in fewer than 15% of the plots. Isopterans, pseudoscorpions, dipteran larvae, hemipterans, opilionids, and dermapterans were found in less than 5% of the plots. Collembola and acarines were the most common microinvertebrates, occurring in more than half of the plots. They were often present in large numbers in dry soil (<10 % moisture) and in samples where there were no other invertebrates.

Several invertebrates were more prevalent in specific types of mulch. Significantly more diplopods ($F = 2.212$, $P = 0.005$), acarines ($F = 9.34$, $P = 0.012$), pseudoscorpions ($F = 1.80$, $P = 0.031$), and snails ($F = 2.20$, $P = 0.006$) occurred in pine micro-nuggets than in other mulch types (d.f. = 15, 689). Plots mulched with hardwood contained significantly more diplopods ($F = 2.12$, $P = 0.005$) and acarines ($F = 9.34$, $P = 0.012$) when compared to other substrates. Isopods appeared more often in leaf litter ($F = 1.92$, $P = 0.019$) (Figure 3), while symphylans were more prevalent when the groundcover consisted of grass/sod [$F = 2.30$, $P = 0.003$]. For other invertebrates, the type of mulch did not significantly affect the numbers present.

Subterranean termites were only found in the samples when wood mulch was present, but no preference among wood mulches was evident [$F(12, 272) = 0.29$, $P = 0.991$]. On several occasions termites were observed foraging in wood mulch at a site even though they were not

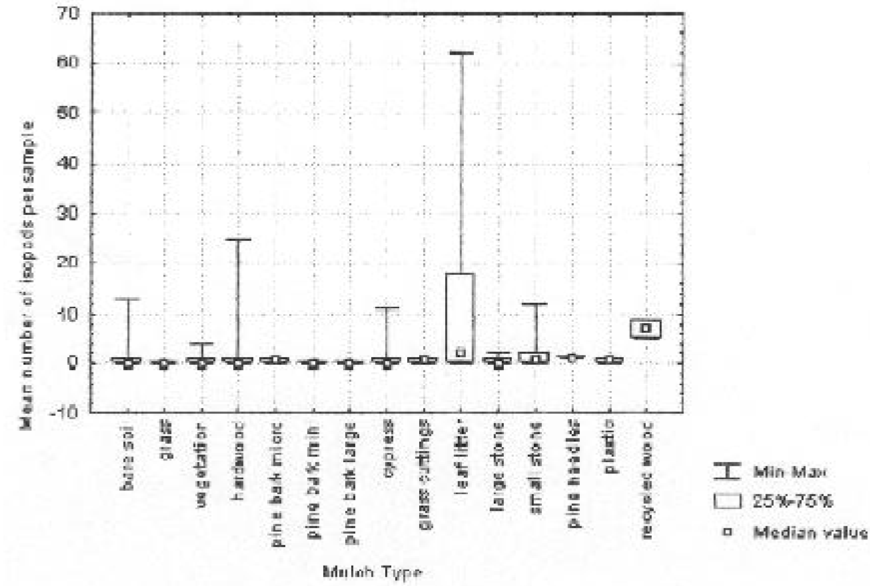

Figure 3. Mean number of isopods found in sixteen types of groundcovers in central Ohio.

present at the random sample point. Long et al. (2001) reported that termites consumed significantly more cardboard monitors buried in pea gravel than in other mulches or in bare soil. However, cardboard was the only food available in the plots with inorganic mulches, whereas the wood mulch provided a competing food resource. Termites were never observed in gravel mulch in field sites in central Ohio. Termites were less frequent in bark mulch than in wood mulch; lignins and waxes in bark may discourage feeding by termites (Mattern, 1989). The only time a termite was encountered in bark mulch during this study is when an alate appeared in a sample, and its origin may well have been a place other than the soil beneath that sample site since no other termites were found in the area.

Landscape professionals recommend a mulch depth of 5-7.5 cm (2-3 in.). Significantly higher numbers of organisms were found in plots where mulch was deeper than the recommended depth. Diplopods ($F = 1.73$, $P = 0.038$), collembola ($F = 2.15$, $P = 0.006$), acarines ($F = 2.00$, $P = 0.011$), dipteran larvae ($F = 2.63$, $P = 0.001$), pseudoscorpions ($F = 4.26$, $P < 0.001$), psocids ($F = 2.02$, $P = 0.011$), aranids ($F = 3.11$, $P < 0.001$), and isopterans ($F = 2.92$, $P = 0.00113$) were all found in significantly higher numbers when mulch was 11-13 cm deep (d.f. = 17, 283). Furthermore, a mulch depth of 1 cm was often associated with a significant decrease in the numbers of organisms, particularly hemipterans ($F = 2.21$, $P = 0.005$), dipteran larvae ($F = 2.63$, $P = 0.001$), opilionids ($F = 3.37$, $P < 0.001$), pseudoscorpions ($F = 4.26$, $P < 0.0001$), and psocids ($F = 2.02$, $P = 0.011$) (d.f. = 17, 283).

Water content of the soil, either underlying the mulch or from bare soil plots, varied dramatically, ranging from 1.15 to 56.6%. This variation could neither be attributed to the geographic side of the building nor the distance from the building, but soil under organic mulches tended to hold more moisture than did inorganic mulches. Soil underlying hardwood mulch, pine bark mini-nuggets, grass cuttings, leaf litter, and composted wood had significantly higher moisture levels (mean = 19.6%) [$F(12, 305) = 1.72$, $P = 0.043$] when compared to the other groundcovers and to bare soil (mean = 10.7%). Significantly higher soil moisture levels were associated with mulch depths

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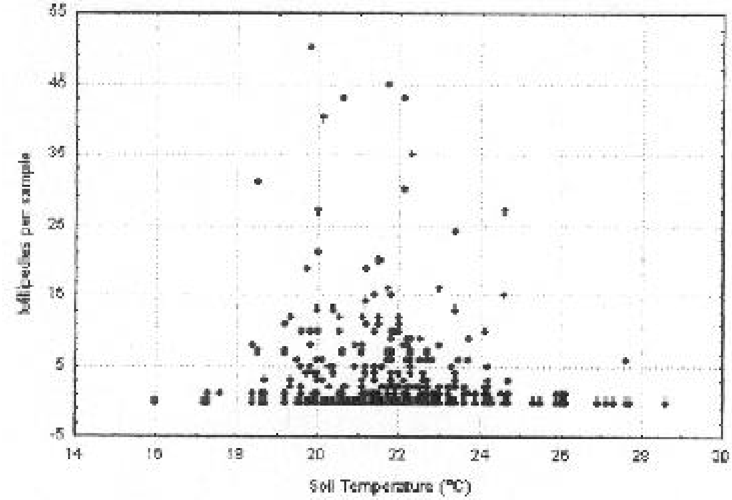

Figure 4. Relationship between the numbers of diplopods and soil temperature.

of 5-11 cm (mean = 22.6%), as compared to mulch depths >12 cm (mean = 12.6%) [F(14, 267) = 3.30, P < 0.0001]. Moisture levels significantly impacted the overall numbers of organisms [F(52, 124) = 1.56, P < 0.0001], but did not significantly affect each type of organism individually. Extremely dry plots generally contained few organisms; those present in such cases tended to be acarines and/or collembola. As far as effects on particular organisms, earthworms were found more often in soils with 25-35% moisture levels [F(52, 283) = 2.57, P = 0.003], while nematodes were more prevalent in wetter soils, from 25-46% moisture levels [F(52, 283) = 2.78, P < 0.0001].

Soil temperatures appear to have a significant influence on mulch- and soil-inhabiting organisms. While all the organisms had temperature ranges that were optimal, as illustrated by diplopod numbers (Figure 4), the means of these temperature ranges were different for each group. Dipteran larvae (F = 1.76, P = 0.049), diplurans (F = 1.83, P = 0.038), pseudoscorpions (F = 1.84, P = 0.037), aranids (F = 1.83, P = 0.038), and symphylans (F = 2.11, P = 0.014) were most abundant when soil temperature was 22°C (d.f. = 13, 268). Isopterans were most prevalent when the soil temperature was 17°C [F(13, 268) = 2.76, P = 0.001] and the mulch surface temperature was 19°C [F(18, 262) = 2.08, P = 0.007], while psocids were more prevalent at 29°C [F(15, 200) = 4.59, P < 0.0001]. All organisms experienced a significant drop in numbers when the surface temperature reached 34°C, except for psocids, which increased significantly in numbers [F(18, 262) = 2.122, P = 0.006]. These data are considered to be preliminary since the analyses include only samples taken during the spring and summer. More data points over a wider range of temperatures are needed to draw valid conclusions.

Coleopterans were commonly observed in urban landscapes. The major families of Coleoptera represented in the mulch and soil samples were Carabidae, Curculionidae, Dermestidae, Elateridae, Scarabaeidae, and Staphylinidae. The staphylinids, carabids, and elaterids were present in adult and larval forms. Curculionids were only found in the adult stage; dermestids and scarabs were found only in the larval stage.

Several types of aranids were present in the research plots. The main aranids families included Gnaphosidae, Dysderidae, Hahniidae, Lycanidae, and Salticidae. Most were found on the surface of the mulch, but some types occurred within mulch samples and emerged when the samples were placed in the Berlese funnel. The gnaphosids and dysderids were particularly more common within the mulch than on the surface, which is expected because these spiders are nocturnal and seek shelter during daylight hours (when sampling occurred). Opilionids and salticids were frequently observed on the sides of buildings immediately adjacent to the plots.

Mulches harbor many types of invertebrates, particularly diplopods, chilopods, collembola, isopods, acarines, aranids, nematodes, psocids, and earthworms. Hence, mulches in close proximity to a structure should be examined when attempting to identify the source of an indoor pest infestation. The side of the structure and the type of groundcover appeared to have little effect on the numbers of organisms present. However, the number of invertebrates varied significantly based on the moisture level, the type and depth of groundcover, and the temperature of the underlying soil, interface, and groundcover surface. Inorganic mulches tended to hold less moisture and generally did not harbor as many organisms as organic mulches. Avoiding deep mulch (i.e., > 7.5 cm), which encourages significantly higher numbers of many invertebrates, can be a proactive step in reducing the number of organisms around a building. If isopterans are known to be present in the area, applying wood mulch will encourage their presence, particularly when mulch is thicker than the recommended depth.

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