The Viability of Soil Microarthropods in Soils Treated with the Insecticide Imidacloprid

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Abstract

Soil microarthropods are ecologically important fauna. Soil microarthropods fragment litter and quicken the breakdown of organic matter, influencing decomposition and nutrient cycling. Microarthropods range in length from 0.2 to 10 mm and share physiological characteristics with other members of the phylum Arthropoda, including the hemlock wooly adelgid (*Adelges tsugae).* The Hemlock Wooly Adelgid (HWA) is environmentally and economically damaging in the eastern US. Insecticides utilizing the chemical Imidacloprid have been shown effective in treating against the HWA. Insecticides are commonly applied by drenching the soil around a tree, but few studies have been done to determine how the pesticide interacts with other insect species, specifically those in the area of greatest concentration. This experiment focuses on the effect of Imidacloprid on the population of soil microarthropods over time at the Coweeta LTER site (Macon County, NC). This experiment used soil cores and modified Tullgren extractors to collect soil samples that were analyzed for microarthropod content. The microarthropods were sorted to the level of order and sub-order, and SAS analysis performed to determine changes. We discovered no significant decrease in the population of microarthropods.

1. Introduction

Soil microarthropods occur in nearly all terrestrial ecosystems and play an important role in decomposition. Decomposition is a critical component of ecosystem health because it releases nutrients that are bound in organic matter. For this reason, microarthropods directly affect all of the flora and fauna in any ecosystem they inhabit[1]. In spite of this important role their small size and often underappreciated habitat make them easy to forget when making management decisions, such as pest control.

Microarthropods range in size from 0.2 to 10 mm in length, making them unidentifiable with the naked eye. It was once thought that soil microarthropods did not contribute a significant amount to decomposition due to their low biomass relative to macroarthropods; however, Peterson and Luxon[2] concluded that in spite of the low weight of microarthropods they compensate with large populations. Soil microarthropods occur in densities of approximately 88,000 to 133,000 m^{-2} in the deciduous forests of North Carolina and 102,000 – 166,000 m^{-2} in coniferous pine forests[3].

Soil microarthropods disperse fungal spores and stimulate the growth of bacteria and microbial biomass, all resulting in increased decomposition[4].They also fragment litter, directly influencing decomposition by increasing surface area for microbes and fungi to act upon[5]. The two groups of microarthropods examined in this study were of the order Collembola and a sub-order of Acari, Oribatid mites. Although microarthropods are extremely varied physically and ecologically these two groups dominate in most soils.

The Oribatid mites are the prevailing group of soil microarthropods in most organic soil horizons. There are approximately 1000 genera of Oribatid mites from over 150 families. These microarthropods change the populations of microbes in soil by feeding on antibiotic producing fungi, thus altering antibiotic outputs[6]. Like all microarthropods they also inadvertently spread fungal spores when feeding.

The order Collembola is very diverse in morphology and feeding habits. This order is also known as the springtails because of the forked structure that allows them to jump great distances; a Collembolan of 3 mm in length may be able to jump 75 to 100 mm. These soil microarthropods can be herbivores, carnivores, and even fluid feeders. Their

diet is varied among species, including decaying plant material, bacteria, fungi, arthropod feces, algae, and pollen. High numbers of Collembola have been known to cause damage to small scale agricultural projects[7].

Soil microarthropods play other ecological roles in addition to fostering decomposition. Both Collembola and Oribatid mites can mediate sperm transfer in some mosses. In instances where water transfer of sperm was stopped under laboratory conditions, soil microarthropods transferred sperm cells between plants at distances of up to 4 cm [8].

Soil microarthropods share similar physiological characteristics with other insect species as well. The hemlock wooly adelgid (*Adelges tsugae*) (HWA) is comparable in size and morphology to many microarthropods and it has become a major pest in eastern US forests. With the outbreak of the HWA in the eastern US, native species of hemlock (*Tsuga* spp.) are dying in high numbers and at an alarming rate. Hemlock trees are coniferous and fill a specific ecological niche in riparian areas of forests that are otherwise dominated by deciduous species. The HWA feeds on the tree's sap at the base of its needles, and a lack of natural predators in the eastern US has allowed the HWA to cause severe damage. Unfortunately, there are limited options to manage the pest; the most common and successful treatment method involves the use of Imidaclopid based pesticides. The large size of mature hemlocks makes foliar application of this chemical impractical; therefore, Imidacloprid is often applied into the base of the tree or on the soil surrounding the tree. It is then absorbed into the roots of the tree where it is carried to the needles and ingested by the HWA[9]. It is unknown whether Imidacloprid adversely affects microarthropod populations when applied directly to the soil.

Imidacloprid is similar to nicotine in its chemical composition and effects in the body. In addition to its use as a treatment for the adelgid, Imidacloprid is also marketed under the Frontline and Advantage brands for use in flea and tick treatments. Imidacloprid is part of the nicotinoid family of compounds that acts on the nervous system by blocking acetylcholine receptors. Imidacloprid has been shown to have relatively low toxicological effects on mammals because these receptors are often located in the muscle of mammals while they occur predominantly in the central nervous system of insects[10].

The objective of this research is to determine if the application of Imidacloprid in the soil or into the base of hemlocks changes population dynamics over time in the two dominant soil microarthropod groups, the order Collembola and sub-order Oribatida.

2. Methods

The study area for this experiment was the Coweeta Hydrologic Lab and LTER site, USFS (Macon Co., NC). A section of stream in the Dryman Fork basin measuring 33.3 m in length was set aside and all hemlock trees within 16.6 m of the stream were treated with the insecticide Imidacloprid. The insecticide was applied by an independent, certified contractor by injecting the tree trunk or drenching the soil around the base of the trees.

Six trees were selected at random from those treated and three soil cores were taken from around each tree. Soil cores were taken with 5 cm diameter PVC pipe in lengths of approximately 5 cm. Cores were taken at the soil surface with leaf litter and detritus included in the core. The samples were then placed in a cooler with ice packs and taken back to the lab. Modified Tullgren funnels[11] were used for a period of one week to collect microarthropods. Soil fauna collection was limited by 2 mm mesh on the extractors.

There was a total of four sample dates used in this study, all in 2006. Each date had a total of 36 samples taken, 18 control and 18 treated. The first sample was taken on May 5, one week prior to the application of Imidacloprid. Three other samples were taken post-application on the May 26, August 27, and November 11. A grid was set up around each sample area to ensure that samples were not taken within one half meter of a previous sample. This was to ensure that disturbance from prior sampling did not alter findings.

Soil microarthropods were identified to the order and sub-order level and sorted into five categories: Collembola, Prostigmata, Mesostigmata, Oribatida, and other. There was originally a distinction made between mature and immature Oribatid mites, however, for a more accurate statistical analysis these two groups were combined.

Abiotic factors such as soil temperature (°C) and percent soil moisture were also measured and recorded in this study. A HydroSense meter (Campbell Scientific) was used to measure percent soil moisture. On May 5 three soil moisture readings and one temperature reading were taken for each tree / every three sites. For all three dates following, three soil moisture readings and one temperature reading were taken for every site / three times per tree.

Statistical analysis was done using SAS statistical software (SAS Inc. 2006). A Poisson curve, Proc GENMOD, was used for the data because of their non-normal distribution. Of the five initial categories only the Oribatid mites and Collembola were included in the statistical analysis since together they accounted for >90% of the total microarthropods extracted. In the analysis there were three categories used to determine population changes: Oribatid mites only, Collembola only, and total microarthropod (Oribatid + Collembola).

Comparisons were made between the control and treatment area for each of the four dates. A comparison was also done to compare the post-treatment totals (i.e. last three dates) between control and treatment areas. There were separate analyses done to compare contiguous dates from the control and from the treatment area.

3. Results

Between the first sample on May 5 and the second sample on May 26 in the treated area the number of microarthropods decreased significantly for the total microarthropod category (P=0.0170) as well as for Oribatid mites (P=0.0054) (Figure 1). The Collembola did not decrease in the treated area for these dates, nor did any of the categories decrease in the control area. Between May 26 and August 27 the population numbers rebounded in the treatment area and increased significantly for the total microarthropod and Oribatid mite categories (P=<0.0001). The Collembola in the treated area once again remained unchanged, as did the control.

Between August 27 and November 11 a reverse trend occurred and the Oribatid mite and total microarthropod categories remained stable in the treated area while the Collembola decreased significantly (P=<0.0001). The control area did not have significant population changes between these dates either.

Comparisons between control and treatment areas were not significant on May 5, May 26, or August 27 for any of the 3 categories. On November 11 there was a significant decrease in Collembola (P=0.0447) between the control and treatment site and no change in the number of Oribatid or the total microarthropod populations.

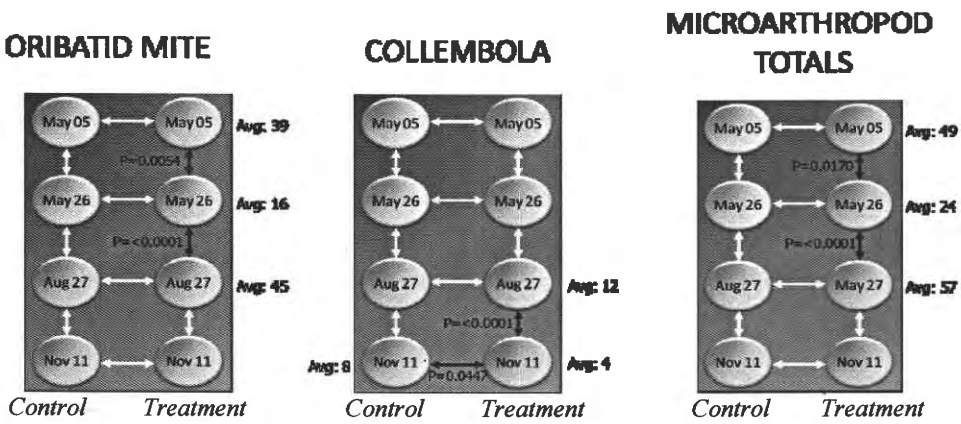

Figure 1: Comparison of microarthropod averages.

Figure 1: Comparison of all sample dates and sites across three microarthropod categories: Oribatid mite, Collembola, and Total Microarthropod (Oribatid + Collembola). Significant differences indicated by red arrows with corresponding averages.

Comparisons of post-treatment totals saw no changes between control and treatment for any category. Soil temperature and moisture readings appeared not to play a clear role in microarthropod populations. The averages for the May 5th and May 26th sample dates were very similar in both soil moisture (17.8% and 17.1% respectively) and soil temperature (15.5°C and 15.9°C respectively).

4. Conclusion

The results of this study do not conclusively indicate that Imidacloprid negatively affects microarthropod populations. The relation of populations between the treatment and control sites (Figure 2) make the significant changes observed in Oribatid mite and total microarthropod populations in the treated site negligible.

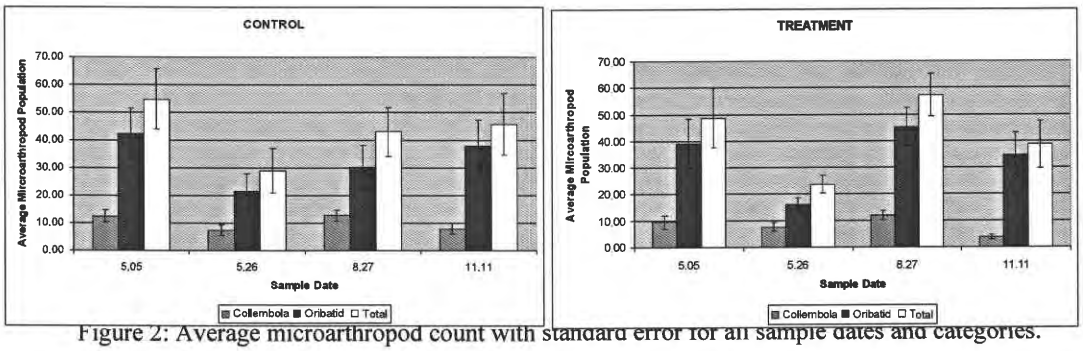

Figure 2: Average microarthropod count with standard error for all sample dates and categories.

Soil temperature and moisture were stable for the two sample dates in May and provide no explanation for the sudden decrease in both the control and treatment area. Although it was not supported by temperature data in this study, the microclimate sensitivity of soil microarthropods makes seasonal changes a normal occurrence. Diurnal temperature fluctuations, in fact, have been shown to alter forest floor mite populations[12].

The effect of Imidacloprid and other insecticides on populations of microarthropods should not be assumed from the findings of this study. The sample number in this study was not sufficient to truly determine the relationship between the two.

The high cost of Imidacloprid was a major factor in limiting the number of samples in this study. Conversely, the small size and microclimate sensitivity of microarthropods require large sample sizes to accurately determine trends. Because of these reasons more research is necessary on this subject before a conclusion can be drawn.

Another factor that may have skewed the results in this research was the use of two different modes of Imidacloprid application. Both soil drenching and trunk injection were used at the treatment site. The initial plan of application was that trees with branches extending over the stream banks would be treated via drenching and others by injection. White paint rings were used to determine trees that would be drenched. On the first sample date after application, May 26, there was some discrepancy in trees with rings and those overhanging the stream. If soil drenched trees and injected trees were separated in later studies there may be different results.

The further study of Imidacloprid in the environment is also highly encouraged. The toxicity of Imidacloprid in the cone of the hemlock needs to be studied. Research on the pesticide indicates that it is highly toxic to certain species of birds, fish, and some beneficial insects. Another concern due to its toxicity to fish is the application of Imidacloprid in soils adjacent to streams or water bodies, the area most likely to contain hemlocks[10]. This chemical should be watched closely because Imidacloprid is thought to bind to organic material, potentially reducing biotic uptake in the short term and masking long term changes[13].

The importance of hemlocks in the eastern US would suggest that the application of Imidacloprid will become very common in the near future, and thorough research, including more comprehensive research with microarthropods, should be done to ensure it this pesticide does not adversely affect other areas of the ecosystem.

5. References

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