Seasonal and Habitat-Specific Differences in Soil Insect Abundance from Organic Crops and Natural Forest at the Ang Khang Royal Agricultural Station, Chiang Mai, Thailand

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Abstract

Soil organisms play an integral role in decomposition and nutrient cycling, but pesticides and artificial irrigation from agriculture can kill soil organisms and thereby compromise the vital ecosystem services that they provide. Organic farming practices are known to alleviate the native effect of agriculture on soil insects. Soil insect abundance was examined in a variety of organic farms and in natural forest in northern Thailand using pitfall traps. More than 7,000 insects were collected and sorted to order. Soil insect abundance varied significantly with season, treatment, and agricultural crop. Insects were most abundant in Asian pear (AP), hill evergreen forest (HF), Chinese teas (CT), strawberries (ST), Asian maple trees (MT) and vegetables for human consumption (VH). Collembola were most abundant in most treatments, and ants were disproportionately common in samples from treatments with trees. There were more insects in the wet seasons than in the dry season in all treatments. Collembola, Orthoptera, Coleoptera and Hymenoptera differed significantly among different treatments, but Diptera did not.

Keywords: habitat differences, natural forest, organic crops, season, soil insects

Introduction

Soil insects and other soil fauna enhance ecosystem services by accelerating key determinants of ecosystem primary productivity including organic matter decomposition, soil mineralization, energy flow, nutrient cycling and by maintaining soil physical structure (Höfer et al., 2001; Moore et al., 2002; Coleman et al., 2004; Gladys et al., 2007; Palacios-Vargas et al., 2007; Yang and Chen, 2009). Soil insect diversity and abundance have been used as indicators of soil stress, soil quality, pollution, and environmental changes (Kuperman, 1996; Lobry de Bruyn, 1997; Höfer et al., 2001; Warren and Zou, 2002; Lindberg et al., 2002; Parisi et al., 2005). Explosive human population growth has led to global environmental problems including pollution, soil degradation, desertification, and biodiversity loss (Lavelle et al., 1997; Moore et al., 2002). The soil insect community is not immune to these anthropogenic perturbations (Hadjicharalampous et al., 2002; Lindberg et al. 2002; Ngai et al., 2008). Modern cultivation, chemical fertilization, artificial irrigation, pesticides, and herbicides are frequently employed in modern agriculture, and all are
detrimental to soil organisms (Bengtsson et al., 2005). The intensification of agricultural practices and the associated decline in natural habitats are the major drivers of biodiversity loss (Marinia et al. 2009).

Organic farming does not harm the soil fauna and preserves soil fertility (Hadjicharalampous et al., 2002). A variety of different crops are grown organically at the Ang Khang Royal Agricultural Station, Chiang Mai. In this study, we investigated the effects of different types of land use on the abundance and composition of the soil insects. We compared soil insect communities in natural hill evergreen forest (HF), and fields growing five different types of crops: Asian maple trees (MT), Asian pear (AP), Chinese teas (CT), strawberries (ST), and vegetables for human consumption (VH). Comparisons were also made between the dry and wet seasons.

**Materials and Methods**

**Study Area**

This research was conducted at the Ang Khang Royal Agricultural Station, Fang District, Chiang Mai province, Thailand (N 19º 51’ 02” - N 19º 56’ 00”, E 99º 01’ 27”- E 99º 04’ 25”). The total area in this study was approximately 9.49 hectares with an elevation ranging from 1080 to 1900 m MSL. Average temperature in the area was approximately 17.67°C and average annual rainfall was 1648.6 mm (Thailand Meteorological Department, 2009). Two different types of land were examined: 1) hill evergreen forest (HF) and 2) agricultural fields. Five different crops were grown in these fields: Asian pears (Pyrus pyrifolia, Rosaceae) (AP); Asian maple trees (Liquidambar formosana, Hamamelidaceae) (MT); strawberries (Fragaria chiloensis, Rosaceae) (ST); Chinese teas (Camellia sinensis, Theaceae) (CT) and vegetables for human consumption (VH).

**Sampling and Identification**

We sampled insects during the dry season between November 2008 and February 2009 and in the wet season between June and August 2009. Pitfall traps were used to collect soil insects. Each trap consisted of a cylindrical plastic bottle 7 cm in diameter and 15 cm in height. Pitfall traps contained 50 mL of 70% ethanol and 3 mL of glycerol. Ten traps were placed at 25 m intervals in a diagonal transect across each treatment with the top slightly below the soil surface. Five centimeters of litter was used to cover the pitfall trap. All traps were left for 48 hours before they were removed. Specimens from the traps were collected, separated, cleaned and preserved in vials that contained 95% ethanol.

The samples were identified to order and selected families based on the classification systems proposed by Alford (1999), Triplehorn and Johnson (2005), Inward et al. (2007) and Ek-Ammuay (2008). Voucher specimens were deposited in the Department of Entomology, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand.

**Results**

**Soil Insect Collections**

We collected 7,287 individual insects in this study: 1,892 individuals (25.96% of total individuals) in AP, 1,761 individuals (24.17%) in HF, 1,433 individuals (19.67%) in CT, 812 individuals (11.14%) in ST, 746 individuals (10.24%) in MT and 643 individuals (8.82%) in VH (Figure 1).

Eight orders were collected: Collembola (springtails), Orthoptera (grasshoppers, locusts and crickets), Blattodea (cockroaches and termites) (Inward et al., 2007), Dermaptera (earwigs), Hemiptera (true bugs), Coleoptera (beetles), Diptera (flies) and Hymenoptera (ants), were found. More than half of all specimens were Collembola (4,361 individuals, 59.85%); the other orders were represented by fewer individuals: Orthoptera (941 individuals, 12.91%); Hymenoptera (823 individuals, 11.29%); Coleoptera (556 individuals, 7.63%); Diptera (469 individuals, 6.44%); Dermaptera (78 individuals, 1.07%); Hemiptera (23 individuals, 0.32%) and Blattodea (36 individuals, 0.49%) (Figure 2).
Figure 1 Number of insect individuals collected from forest and agricultural areas at the Ang Khang Royal Agricultural Station, Chiang Mai, Thailand. HF, hill evergreen forest; MT, Asian maple tree; AP, Asian pears; CT, Chinese teas; ST, strawberries and VH, vegetable for human consumption.

Figure 2 Number of individuals in five insect orders collected from different treatments at the Ang Khang Royal Agricultural Station, Chiang Mai, Thailand.

Effect of Treatment in Different Seasons on Insect Individuals

The proportion of Collembola in samples from each treatment type varied considerably: HF (82.31% of total individuals), AP (70.35%), CT (69.23%), MT (56.66%), ST (22.64%) and VH (7%). To compare ordinal abundance among treatments and between seasons, only five orders (Collembola, Orthoptera, Coleoptera, Diptera and Hymenoptera) were examined because the remaining orders (Dermaptera, Hemiptera and Blattodea) were represented by very few specimens. Collembola, Orthoptera, Coleoptera, and Hymenoptera but not Diptera differed significantly in abundance ($P < 0.01$) among seasons and treatments (Table 1). Diptera did not differ significantly among seasons or treatments. Insects were significantly more abundant in permanent trees (AP, HF and MT) than in annual crops (ST and VH) and they were significantly more abundant in the wet season than in the dry season across all habitat types (Table 1; Figure 3).

Dominant Insect Families under Different Treatments

Insect family abundance of five orders Orthoptera, Blattodea, Coleoptera, Diptera, and Hymenoptera was classified. Thirteen families were presented in five orders as following: order Orthoptera, two families (Acrididae and Gryllidae); order Blattodea, one family (Blattellidae); order Coleoptera, five families (Carabidae, Coccinellidae, Scarabaeidae, Scolytidae, and Staphylinidae); order
Diptera, four families (Drosophilidae, Sciariidae, Sphaeroceridae, and Tipulidae) and order Hymenoptera, one family (Formicidae). There were treatment-specific differences in the abundance of different insect groups. For example, ants (Formicidae) dominated samples in three of the treatments with standing trees (AP, HF and CT), and crickets (Gryllidae) were most common on land used for growing annual crops. Drosophilidae was most common in HF and MT while Sciariidae was most common in HF and VH (Figure 4).

Discussion

Soil insect communities at the Ang Khang Royal Agricultural Station were dominated by Collembola, and hill evergreen forest (HF) had the highest abundance of Collembola in this study. These results are similar to the findings of a previous study conducted at Doi Suthep-Pui Nation Park, which also found more Collembola in hill evergreen forest than in other land use types (Sopsop, 2000). Collembola assist the degradation of organic matter and the mineralization of nutrients into the soil which, in turn, increase its fertility (Coleman et al., 2004). Collembola also stimulate litter decomposition and soil microstructure formation (Rusek, 1998; Lussenhop and BassiriRad, 2005). Collembola can be used as soil bioindicators of environmental change (Sukprasert, 2004; Samways, 2005; Monnig and Bradley, 2008), suggesting that the soil in HF is most amenable to Collembola and other soil insects.

More insects were found in the tree-covered landscape types AP, HF, MT and CT than in areas used for growing annual crops. There are at least two plausible reasons why there are more insects in AP and CT. Firstly, AP and CT are both in close proximity to primary forest from which insects can disperse. Secondly, low vegetation is rarely disturbed in these two forest types compared to annual crop production areas. The abundance of soil insects was greater in the wet season than in the dry season, which is similar to other studies (Reddy and Venkataiah, 1990; Wiwatwitaya, 1996).

More Orthopterans were recorded from ST and VH than from other treatments. Differences in vegetation cover and accessibility of traps to the insects can partly explain the composition of the insect population in each treatment. Traps set in treatments with flat, open terrain were generally more accessible to insects thus more insects were collected. In ST and VH, which have fewer trees, there were more Orthoptera than in other areas, and most of these Orthoptera were crickets. Crickets feed on roots, seedling and decaying vegetable leaves of strawberries and vegetables, especially in newly disturbed area.

Flies were also more abundant in native forest area than in cultivated areas. Soil dwelling Diptera are found in a wide range of ecosystems from climax forests to agro-ecosystems and are involved in many important biological processes such as decomposition and nutrient cycling (Frouz, 1999). Drosophilidae and Sciariidae were more abundant in native forests (HF) than in agriculture. These families generally feed on decaying plant material (Frouz, 1999; Remsen and Grady, 2002, Nielsen and Nielsen, 2004; Nielsen and Nielsen, 2007), which is abundant in hill evergreen forests at Ang Khang.

Table 1  The mean number of individuals of five orders: Collembola, Orthoptera, Coleoptera, Diptera and Hymenoptera at the Ang Khang Royal Agricultural Station, Chiang Mai, Thailand.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>All orders(^2)</th>
<th>Collembola</th>
<th>Orthoptera</th>
<th>Coleoptera</th>
<th>Diptera</th>
<th>Hymenoptera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>5</td>
<td>24.497**</td>
<td>36.164**</td>
<td>11.758**</td>
<td>4.975**</td>
<td>1.757</td>
<td>7.615**</td>
</tr>
<tr>
<td>Season</td>
<td>1</td>
<td>333.029**</td>
<td>173.621**</td>
<td>59.472**</td>
<td>11.008**</td>
<td>15.153**</td>
<td>82.177**</td>
</tr>
<tr>
<td>Treatment x Season</td>
<td>5</td>
<td>16.708**</td>
<td>29.678**</td>
<td>9.298**</td>
<td>4.240**</td>
<td>3.693**</td>
<td>4.988**</td>
</tr>
</tbody>
</table>

\(^{1}\) ANOVA, denotes significant **P < 0.01.

\(^{2}\) Eight orders: Collembola, Orthoptera, Blattodea, Dermaptera, Hemiptera, Coleoptera, Diptera and Hymenoptera.
Figure 3 Mean insect abundance (± SE) of insects collected at the Ang Khang Royal Agricultural Station, Chiang Mai, Thailand. HF, hill evergreen forest; MT, Asian maple tree; AP, Asian pears; CT, Chinese teas; ST, strawberries and VH, vegetable for human consumption.

Figure 4 Percentage of soil insect numbers of 13 families from five orders (Orthoptera, Blattodea, Coleoptera, Diptera and Hymenoptera) found under different treatments at the Ang Khang Royal Agricultural Station, Chiang Mai, Thailand. HF, hill evergreen forest; MT, Asian maple tree; AP, Asian pears; CT, Chinese teas; ST, strawberries and VH, vegetable for human consumption.

Ants are important in below ground processes through the alteration of the physical and chemical environments and through their effects on plants, microorganisms and soil organisms (Folgarait, 1998). They constitute a large fraction of animal biomass and act as ecosystem engineers (Lobry de Bruyn, 1999). Ants were common in AP, HF and CT where there was vegetative cover. They were more abundant during the wet seasons than during the dry seasons, which corroborate the results of Watanasit et al. (2000). This is because humidity plays an integral part in softening the soil, which
presumably enables them to build nests more easily (Watanasit et al., 2000). In turn, their nesting habits also greatly influence soil structure and their presence or absence has a strong influence on the distribution of other kinds of insects (Watanasit et al., 2000; Seymour and Collett, 2009). Furthermore, they are important in many food webs, providing prey for a number of birds, reptiles and mammals; they also increase nutrient cycling (Seymour and Collett, 2009).

Conclusions

The abundance of soil insects at a site in northern Thailand varied significantly with season, treatment, and agricultural crop. The rank order of insect abundance was: AP, HF, CT, ST, MT and VH. Eight insect orders were recorded, and Collembola was the dominant order in all treatments. The rank order of Collembola abundance was: HF, AP, CT, MT, ST and VH. Collembola, Orthoptera, Coleoptera, and Hymenoptera were significantly different among treatments while Diptera showed no difference. Except Collembola, ants (Formicidae) were the dominant ground insects under tree covers. Gryllidae is a major group of omnivorous scavengers which was commonly found feeding on the decaying leaves of vegetables. Insects were significantly more abundant in permanent trees than in annual crops and they were significantly more abundant in the wet season than in the dry season across all habitat types.

Acknowledgments

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