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Abundance and activity of soil organisms in fields of maize grown with a white clover living mulch

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Abstract

The effects of a white clover (*Trifolium repens*) living mulch on the soil detritus food-web during maize (*Zea mays*) culture were studied on Andosols for 2 years. In the first year, the use of white clover (W) and Italian ryegrass (I; *Lolium multiflorum*) was compared against the control treatment in the absence of fertilization. In the second year, combinations of white clover and inorganic fertilizers were studied. Bacterial and fungal substrate-induced respiration and the population densities of protozoa (flagellates, naked amoebae, ciliates), nematodes, and microarthropods (mites, collembolans) increased with the use of white clover living mulch. In the first year, nematode and microarthropod populations increased throughout the growing season in the living mulch plots. In the second year, the communities of soil organisms under the white clover living mulch had reached a more mature successional stage and were characterized by increased populations of organisms in the fungal pathway of organic matter decomposition and by a high population density of higher trophic groups (e.g., mesostigmatid mites and ciliates). The higher litter decomposition rate in the living mulch plots suggested that the function of the detritus food-web was enhanced under the living mulch system. On the other hand, inorganic fertilization only increased populations of nematodes and mesostigmatid mites in mid-summer, possibly owing to better maize growth, and had no effect on other soil organisms.
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1. Introduction

Living mulch, a sophisticated use of cover crops, has been proposed as a means of responding to the environmental concerns (Hartwig and Ammon, 2002). Living mulches are cover crops that are maintained as a living ground cover throughout the growing season of the main crop, and are distinguished from cover crops that are killed using herbicides or machines before the main crop is planted. Living mulches have many benefits common to cover crops in other forms. For example, the use of living mulches has been shown to reduce water runoff and soil erosion in maize (*Zea mays* L.) cropping on slopes (Hall et al., 1984). Living mulches also help to control weeds (Ilnicki and Enache, 1992; Brandsaeter et al., 1998), which may ultimately result in reduction in herbicide inputs.

Little is known about the effect of living mulches on soil (belowground) organisms. Wheat (*Triticum aestivum* L.) cropping with white clover (*Trifolium repens* L.) supported a larger population of earthworms (Lumbricidae) than conventional monocropping in Ireland and Britain (Schmidt et al., 2001). Increased biomass of microbes and earthworms and a large population of Collembola on the soil surface were recorded in grass white clover systems in Switzerland (Jäggi et al., 1995). The organic matter supplied by living mulches, which includes both residues derived from dead plant parts and organic materials released from living roots, may help preserve soil organisms and enhance their ecosystem functions, such as nutrient cycling, soil structure preservation, and pest population control, all of which result in improved soil productivity.

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Studies focusing on the mechanisms by which soil biota sustain soil fertility and productivity have revealed the importance of distinguishing between the fungal and bacterial pathways of organic matter decomposition (Beare, 1997). The two pathways are governed by different mechanisms (Wardle, 2002) and differ in their rates of decomposition and mineralization. Fungivorous fauna, such as most non-plant-parasitic stylet-bearing nematodes and various microarthropods, are expected to be dominant in soils dominated by fungi, whereas bacterivorous fauna, such as protozoa and non-stylet-bearing nematodes, are expected to be dominant in bacteria-dominated soils. Both top-down and bottom-up controls of trophic groups have a significant impact on decomposition processes. Hence, the assessment of simultaneous changes in the abundance of various soil biological groups is an essential step for understanding the use of living mulches that are intended to preserve soil organisms and sustain soil quality.

Andosols, which are soils derived from volcanic ash, are found in all parts of the world where significant depths of volcanic ash and ejecta have accumulated. They are usually very fertile and as a result, are widely and intensively cultivated. However, these soils have high porosity and low bulk density, and are thus vulnerable to disturbance. Intensive cultivation increases the risk of wind and water erosion and often has a conspicuous negative impact on soil organisms (Miyazawa et al., 2002; Nakamura, 1988). Therefore, the adoption of cultivation systems that would provide protection of these soils is required. One study showed that a living mulch system with white clover suppressed weeds and produced yields of sweet corn as high as those attained through conventional cropping (Miura and Watanabe, 2002), and this demonstrates the promise of practical use of living mulches on Andosols. However, studies on the effect of living mulches on soil preservation are also necessary.

In the present study, it was hypothesized that living mulches would enrich populations of soil organisms and promote the functions of the soil detritus food-web. The main objective of our study was thus to clarify how the populations of different groups of soil organisms would respond to the use of white clover living mulch. The study also assessed how inorganic fertilizers, which are most commonly used in agriculture, would modify any changes in the community of soil organisms that resulted from the use of living mulches.

2. Materials and methods

2.1. Experimental design and treatments

Field experiments were conducted in 2002 and 2003 at the University Farm of the University of Tokyo (35°44′N, 139°32′E). The soil was a volcanic ash of the Kanto Loam type (Humic Andosols; 29% sand, 38% silt, 33% clay; pH 6.2). Total C and N concentrations of the topsoil (0–30 cm) averaged 4.54 and 0.29%, respectively. The field used for this study had been conventionally cultivated with various summer crops, such as maize and potatoes (*Solanum tuberosum* L.), for more than 20 years, and had been subjected to frequent tillage operations, including mechanical weed control. Temperature and precipitation during the maize growing season (from May to September) averaged 23.2 °C and 819 mm in 2002 and 22.5 °C and 930 mm in 2003, and differed little from the long-term averages.

In 2002, the first year of this study, the control treatment (N) and two living mulch treatments, white clover (W) and Italian ryegrass (I), were arranged in a randomized complete block design with three replications. Individual plots were 14 m × 3 m. White clover (*T. repens* cv. 'Grasslands Huia') and Italian ryegrass (*Lolium multiflorum* Lam. cv. 'Harukaze') were sown on 23 April 2002 at a rate of 100 and 200 g seeds m^{-2}, respectively. The white clover was clipped at a height of 5 cm on 29 July and the Italian ryegrass was clipped to a similar height on 28 June and 29 July. Maize (*Z. mays* L. cv. 'KD670') was planted at a rate of 3.7 seeds m^{-2} with 90-cm row spacing on 2 July. The seeds were placed at about 5 cm depth in a slit prepared with a drill seeder. No chemical fertilizer was applied. Although herbicide application and the use of cultivator are common weeding practices in this region, their possible effects on soil organisms were unknown in this soil ecosystem. Manual hoeing was thus chosen to minimize the potential disruptive effects on soil biota. Weeds in the N plots were periodically removed by means of manual hoeing; weeds in the W and I plots were not controlled. Neither herbicide nor pesticide was applied in any plot.

In 2003, the second year of this study, treatments with and without a white clover living mulch and with and without chemical fertilizer were established in the same field. On 24 September 2002, all the plots were rotary-tilled to a depth of about 20 cm after the aboveground parts of the maize had been removed. The former W plots were sown with white clover and the former N plots remained unsown. These plots were then divided into halves to create new plots, which were 7 m × 3 m in size. On 20 May 2003, after white clover had been clipped at 5 cm above ground level, a compound inorganic fertilizer was broadcasted over the soil surface in half of the plots at a rate equivalent to 10.0 g m^{-2} of N, 6.5 g m^{-2} of P, and 11.1 g m^{-2} of K. The remaining half of the plots were not fertilized. Maize was sown on the same day and in the same manner as in 2002. The experimental design was therefore a 2 × 2 factorial arrangement with three replications. The factors were the use of living mulch, with white clover living mulch (L+) and without living mulch (L−), and fertilization, with fertilizer (F+) and without fertilizer (F−). Weeds in the L− plots were periodically removed by means of manual hoeing, but no weed control was conducted in the L+ plots. Neither herbicide nor pesticide was applied during the experiment.

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