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Small-scale variability in the contribution of invertebrates to litter decomposition in tropical rice fields

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Abstract

Sustainable management of agricultural systems includes promoting nutrient cycles, which can reduce the need for application of fertilizer. As rice is one of the most important food resources in the world, sustainable management of rice paddies is increasingly in demand. However, little is known about the influence of invertebrates on decomposition processes in these ecosystems. We hypothesized that invertebrates contribute significantly to the decomposition of rice straw in paddies and that their relative contribution is affected by the distance to other landscape structures within fields. We placed rice straw in litterbags of two different mesh sizes which prevent (20 μm × 20 μm) or allow (5 mm × 5 mm) access of invertebrates in six irrigated rice fields for 84 days. In each field, bags were set on three transects running from the bund to the center of the field. Invertebrates significantly increased total rice straw litter mass loss by up to 45% (total decomposition: fine-meshed bags 64%; coarse-meshed bags 83%). Litter mass loss in bags accessed by invertebrates decreased with increasing distance from the bund. Such a spatial trend in litter mass loss was not observed in bags accessed only by microbes. Our results indicated that invertebrates can contribute to soil fertility in irrigated rice fields by decomposing rice straw, and that the efficiency of decomposition may be promoted by landscape structures around rice fields.

Zusammenfassung

Nachhaltigkeit im bewässerten Tiefland-Reisanbau ist ein wesentlicher Bestandteil zur Sicherung der Nahrungsgrundversorgung eines großen Teils der Weltbevölkerung. Das Verständnis der komplexen Prozesse im Nährstoffkreislauf in Agrarökosystemen kann zu einer Erhöhung der Bodenfruchtbarkeit führen und den Bedarf an Düngemitteln drastisch reduzieren. Die Grundlage für eine natürliche Stickstoffzufuhr, zur Förderung des Pflanzenwachstums, ist die Zersetzung von totem organischem Material, was eine stabile Gemeinschaft von Bodenorganismen voraussetzt. Nichtsdestotrotz ist das Wissen über den Einfluss der Makrofauna auf Zersetzungsprozesse im Boden von Reisökosystemen rar.

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Ziel dieser Studie war es, den Einfluss von Invertebraten auf die Zersetzungsrate von Reisstroh zu untersuchen und deren Effektivität in Abhängigkeit landschaftlicher Strukturvielfalt in direkter räumlicher Nähe zu den Untersuchungsflächen einzuschätzen. Um zu differenzieren, wie stark der jeweilige Anteil von Invertebraten und Mikroorganismen am Streuabbau ist, wurden Streubeutel mit zwei verschiedenen Maschenweiten (20 μm und 5 mm) verwendet und für 84 Tage auf die Bodenoberfläche bewässerter Reisfelder gelegt. Der Einfluss der Entfernung vom Reisfeldufer auf die Zersetzungsrate sollte mit Hilfe von Transekten, die vom Rand bis zur Mitte von sechs Versuchsfeldern gezogen wurden, ermittelt werden.

Invertebraten erhöhten nicht nur die Menge an insgesamt abgebautem Stroh bis zu 45%, verglichen mit der reinen mikrobiellen Zersetzung, ihr Einfluss nahm auch vom Rand zur Mitte des Feldes hin ab. Die Abbaurate der Mikroorganismen blieb innerhalb des Feldes dagegen relativ konstant.

Unsere Ergebnisse zeigen deutlich, dass Invertebraten einen großen Einfluss auf die Zersetzung von Reisstroh haben und damit die Bodenfruchtbarkeit positiv beeinflussen können. Zusätzlich konnte eine positive Korrelation zwischen Ufernähe und Abbaugeschwindigkeit von Invertebraten in Reisfeldern nachgewiesen werden, was auf eine höhere Nährstofffreisetzung in den Randbereichen der Felder hindeutet.

Keywords: Litter mass loss; Detritivores; Nutrient supply; *Oryza sativa*; Litterbags; Philippines

Introduction

The breakdown of organic matter is a crucial mechanism for nutrient cycling and productivity in terrestrial and aquatic ecosystems (Cebrian & Lartigue, 2004). Invertebrates play a key role in the decomposition process in both terrestrial (Swift, Heal, & Anderson, 1979) and aquatic systems (Webster & Benfield, 1986). Among other things, invertebrates break down bigger particles and make them available for microorganisms that decompose the material further and are responsible for nutrient release. These microorganisms are in turn one of the most important sources of energy for many soil (Swift et al., 1979) and aquatic animals (Perry & Sheldon, 1986; Hamilton, Lewis, & Sippel, 1992). Invertebrate decomposers are also known to act as scavengers (Parmenter & MacMahon, 2009). Besides their importance in the decomposition process, invertebrate decomposers were found to be an important food resource for predators (Ishijima et al., 2006; Oelbermann, Langel, & Scheu, 2008). In rice fields, for example, the use of decomposers, like chironomid larvae, as secondary food source allows generalist predators, as e.g. some groups of aquatic Heteroptera, to maintain high abundances throughout the whole rice cycle (Settle et al., 1996). Therefore, the role of invertebrate decomposers in food webs is crucial for the maintenance of ecosystem functions related to nutrient cycling, habitat structure, and community dynamics.

Rice cultivation is one of the most important, stable, and successful agricultural branches in tropical regions, especially in Southeast Asia (Kurihara, 1989). Toward the end of the Green Revolution, after the mid-1960s, rice production was intensified all over the world, especially in Asia (Bambaradeniya & Amarasinghe, 2003). The negative impacts of these agricultural practices for invertebrate foodwebs in rice fields have been shown mainly for predators and parasitoids, which are the most important natural pest control agents (Schoenly et al., 1996; Ives & Settle, 1997; Drechsler & Settele, 2001), or on the pest species themselves (Kiritani, 1992; Settele, 1992; Cohen et al., 1994). In contrast, studies on the detritivorous invertebrate fauna in rice ecosystems focused solely on the diversity or the abundance of invertebrate decomposers (Simpson et al., 1993a, 1993b; Simpson, Roger, Oficial, & Grant, 1994) with only speculations about their functional role for decomposition and therefore nutrient dynamics. The lack of such studies in rice fields is surprising since the soil fauna is known to contribute substantially to nutrient dynamics and productivity in agro-ecosystems (Benckiser, 1997). Generally, there is no conceptual consensus about the role of invertebrate decomposers in freshwater ecosystems. Moreover, studies in tropical freshwater ecosystems have been done mainly in streams (Hagen et al., 2012), and to our knowledge, virtually no information on the contribution of invertebrates to litter decay in other tropical freshwater ecosystems, such as rice fields, is available. In general, the contribution of fauna to the decomposition process in the tropics is suggested to be high both in terrestrial and aquatic habitats (Wall et al., 2008). However, compared to terrestrial habitats invertebrate activity and litter characteristics might be of lower importance during the initial phase of litter decay in aquatic ecosystems as due to higher leaching of organic and mineral compounds mass loss tends to be high (Treplin & Zimmer, 2012).

The decomposition process in irrigated rice fields may differ from "real" aquatic systems in many aspects. For example, tillage and application of fertilizer and pesticides can change soil and water properties. Various studies have demonstrated an influence of nutrient concentrations in water on microbial-driven decomposition dynamics, with prevalent positive effects of nutrient addition on the decay rate (Webster & Benfield, 1986). Thus, the intensive application of fertilizers may lessen the relative importance of invertebrates in the decomposition process. Furthermore, fields are often