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A sequential extraction procedure reveals that water management affects soil nematode communities in paddy fields

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ABSTRACT

The effects of management in maintaining high rice yield with less water have received increasing attention in sub-tropical regions where seasonal drought is very severe. To test whether water management affects soil ecological process we compared the soil nematode communities in paddy field soils following water management treatments imposed during late rice cropping. The treatments were continuously flooded rice cultivation (CF), non-continuously flooded rice cultivations without (ZM) and with (M) rice straw mulching. A sequential extraction procedure involving Baermann extraction (Baermann) followed by centrifugal sugar flotation (centrifugation) was used to extract the whole nematode community. Based on the analysis of nematode abundance, genera composition, trophic groups and other ecological indices (Margalef richness index, Shannon index, maturity index, enrichment index and structure index), water management significantly affected the nematode community, with the non-continuously flooded condition, in particular combination with rice straw mulching (M), stimulating nematode development. There was a high abundance, richness, and structure in the nematode community in mulched treatments, indicating improved biodiversity and biological interactions. We hypothesize that soil microclimate and available food resources are affected by water management and directly or indirectly influence the establishment of different nematode communities. We suggested that studies aiming to test natural or anthropogenic influences on nematodes might be distorted by sole use of the Baermann method. Although the Baermann step in a sequential extraction procedure gave valuable information on nematode responses to soil treatments, it was not sufficient to detect effects on the whole nematode community. Our results demonstrate that the sequential extraction procedure is an effective tool to obtain comprehensive information on the whole nematode community, with both steps providing complementary ecologically relevant information, on how the soil ecosystem is affected by human management.

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1. Introduction

Conventional flooding rice cultivation requires standing water in the paddy fields throughout the growing season. Due to increasing scarcity of water, water-saving technologies such as non-flooded (NF) cultivation are being developed to reduce water consumption while maintaining a high yield of rice (Bouman et al., 2007). This is especially necessary for food security in China where *per capita* fresh water availability is amongst the lowest in Asia (Cabangon et al., 2004). Currently, most studies on this issue have focused on northern China (Bouman et al., 2007; Kreye et al., 2007) where total rainfall is much less than that in southeast China. However, severe seasonal drought is prevalent in southeast China (Chen and Zhang, 2002; Liu et al., 2002) where continuous double- or triple-cropping rice systems lead to late rice being mainly grown in the drought season. An alternative to NF cultivation is non-continuously flooded (NCF) rice cultivation, involving a non-flooded condition in late rice growth with a flooded period in early rice growth when rainfall is more abundant. Although NF or NCF cultivation reduces irrigation water use, it may lead to lower grain yield (Cabangon et al., 2004). This disadvantage can be overcome by growing rice using mulches such as polyethylene film and rice straw under non-flooded conditions (Kreye et al., 2007). Because plastic film mulch is expensive, laborious and not environmentally sustainable, rice straw mulch is preferred (Qin et al., 2006).

Intensive studies of water management on water balance, nutrient cycling, agronomic traits and greenhouse gas emissions have made great contributions to our understanding of the non-flooded rice system (Cabangon et al., 2004; Qin et al., 2006; Kreye et al., 2007). However, evidence is still scarce about the changes in soil ecological process under different water management practices. With their functional roles in organic matter decomposition, nutrient release and plant productivity, nematodes have increasingly been seen as potential indicators of the soil food web condition and, by extrapolation to other soil organisms with similar feeding activity, of soil ecological process (Griffiths, 1994; Bongers and Bongers, 1998; Ferris et al., 2001; Chen et al., 2007b). Individual genus/species of nematodes can respond predictably to land management practices (Porazinska et al., 1999; Neher, 2001; Fiscus and Neher, 2002). Nematode species richness and trophic group composition can reflect soil biodiversity and functional state (Bongers and Bongers, 1998; Ferris et al., 2001). The community analysis approach continues to be developed, from a statistical viewpoint which takes no account of ecological role (Freckman and Ettema, 1993), through the maturity index which links life history and community succession (Bongers, 1990) and more recently to a series of integrated indices based on weighted analysis of functional guilds (Ferris et al., 2001). Therefore, interpretation of nematode community structure can provide a comprehensive summary of soil ecological process as affected by agricultural practices such as water management.

Accurate analysis of nematode community structure ideally requires extraction of all nematodes in the soil. However, many factors, including soil texture, secondary structure and moisture, and nematode communities themselves, may confound nematode extraction efficiency (Hooper and Evans, 1993; Ingham, 1994; Verschoor and De Goede, 2000). The most popular extraction techniques can be divided into active methods, which depend on nematode migration in water, or passive methods, which depend on nematode density or sedimentation. These are commonly represented by Baermann funnel and centrifugation methods, respectively (Hooper, 1986; Ingham, 1994; McSorley and Frederick, 2004). Although there are many studies optimizing individual extraction methods, few studies consider their relations with soil management, as soil management practices that affect soil properties and the nematode community will interact with nematode extraction efficiency indirectly. This may be especially true for paddy soil nematode extractions using the Baermann method under different water management, because nematodes may adapt to a specific soil environment and consequently determine their responses to water, which is important for the recovery efficiency during Baermann extraction. For instance, it was found that nematodes from dry regions responded more rapidly to drying and wetting events than those from wet regions, indicating that nematodes acclimated to their preceding environments (Treonis and Wall, 2005).

Previous studies have suggested that a combination of Baermann and centrifugation methods are necessary to extract the whole nematode community (McSorley and Frederick, 2004), however, this is time consuming. In this study, we utilized a sequential extraction procedure which first extracted nematodes by the Baermann method and then by centrifugation of the same soil sample. The objectives of our study were to (1) determine the influence of water management on the nematode community in paddy fields; (2) investigate whether the sequential extraction procedure would provide more ecological relevant information than either of the methods on their own.

2. Materials and methods

2.1. Site description

A field experiment was established in Yujiang county, Jiangxi province in southeast China (N28°15′, E116°55′) in 2002. The research area was representative of a typical sub-tropical moist climate with a mean annual temperature of about 17.7 °C, a maximum daily temperature of around 40 °C in summer and a rainfall of 1750 mm, about 50% of which falls from March to early July. The uneven distribution of rainfall causes strong seasonal drought in summer and/or autumn from July to October, and this pattern was observed during the field experiment (Qin et al., 2006).

The anthropogenic paddy soil was developed from alluvial deposits and has been used for rice cropping for more than 50 years. It is a sandy soil with 739 g kg^{-1} sand (2–0.02 mm) and 73 g kg^{-1} clay (<0.002 mm) fraction. At the start of the experiment soil (0–20 cm depth) contents of total organic carbon, total organic nitrogen, available N, available P, available K and pH (H_2O) were 14.8 g kg^{-1}, 1.5 g kg^{-1}, 95.1 mg kg^{-1}, 16.1 mg kg^{-1}, 74.2 mg kg^{-1} and 5.5, respectively.

2.2. Water management and cropping

The cropping system used had two rice crops in the same year, with early (or first) rice followed by late (or second) rice. We set