Applied Soil Ecology 75 (2014) 134–144

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

# Responses of the soil nematode community to management of hybrid napiergrass: The trade-off between positive and negative effects

Jie Zhao[a,b,1], Wei Zhang[a,b,1], Kelin Wang[a,b,*], Tongqing Song[a,b], Hu Du[a,b]

[a] Key Laboratory of Agro-ecological Processes in Subtropical Region, Institute of Subtropical Agriculture, Chinese Academy of Sciences, Changsha 410125, PR China
[b] Huanjiang Observation and Research Station for Karst Ecosystems, Chinese Academy of Sciences, Huanjiang 547100, PR China

ARTICLE INFO

*Article history:*
Received 5 August 2013
Received in revised form 23 October 2013
Accepted 28 October 2013

*Keywords:*
Nitrogen fertilization
Cutting frequency
Cutting intensity
Irrigation
Orthogonal experimental design
Soil health

ABSTRACT

An orthogonal experiment (form $L_{16}(4^5)$) was used to investigate how the soil nematode community (density, diversity, and faunal structure) and soil health were affected by hybrid napiergrass management. The experiment included four levels of the each of the following main factors: nitrogen fertilization, cutting frequency, cutting intensity, and irrigation. The soil nematode community was affected more by nitrogen fertilization and irrigation than by cutting frequency and cutting intensity. Hybrid napiergrass develops a large root system and the carbon stored in the roots might have buffered any adverse effects of cutting on soil nematodes in the present study. The responses to fertilization indicated that fertilization had both positive and negative effects on the soil community and that the net effect depended on the level of fertilization. Additional water applied in irrigation was detrimental to soil nematode communities in that it might reduce the oxygen content of soil and also increases the potential for the leaching of nutrients from soil. Additionally, we suggest that moderate N fertilization (460 kg $ha^{-1}$ $yr^{-1}$), moderate irrigation (one time $yr^{-1}$ during the dry season), and cutting (three times per year at 20 cm height) will maintain soil health and provide substantial hybrid napiergrass yields.



## 1. Introduction

Nematodes are ubiquitous in the soil environment and occupy key positions and play central role in soil food webs. They can be readily identified to the generic level based on morphological characters and can be classified to trophic group based on feeding structures; based on their morphology, they can also be readily separated into c-p guilds (colonizer–persister guilds) (Bongers, 1990; Bongers and Bongers, 1998; Ferris et al., 2001; Yeates et al., 1993). Faunal indices of nematode communities (the maturity index, structure index, and enrichment index) are well-established (Bongers, 1990; Ferris et al., 2001; Neher, 2001). All these attributes make soil nematodes useful as bioindicators of soil conditions (Bongers and Ferris, 1999; Ferris and Bongers, 2006; Todd et al., 2006). Moreover, the relationship of soil nematodes to ecological processes or soil functions is one of the primary concerns in soil biology and ecology (Zhao and Neher, 2013). Many previous studies report that soil nematodes have remarkable influences on plant biomass and diversity (e.g., Packer and Clay, 2000; Wardle et al., 2004), nitrogen mineralization (e.g., Neher et al., 2012), decomposition rate (e.g., Neher et al., 2012; Zhao et al., 2012), and ecosystem succession (e.g., De Deyn et al., 2003).

Fertilization, harvest/cutting, irrigation, weeding, and pest control are common management practices of agriculture, prataculture, and forestry ecosystems. Many studies reported the effects of these management practices on soil nematode communities. For examples, the abundances of most trophic groups were higher in fertilized than non-fertilized plots in a soybean field (Okada and Harada, 2007); the relative abundance of fungivores and herbivores increased, and that of bacterivores and carnivore-omnivores decreased following the applications of nitrogen fertilizations in vegetable greenhouse (Li et al., 2010). And it was the long-term application of nitrogen fertilization plus organic manure rather than the nitrogen fertilization alone that significantly influence the soil nematode communities compared with no fertilization treatment in a monoculture maize field in north-east China (Liang et al., 2009). Furthermore, the source of nutrients (organic or chemical fertilizers) apparently affected nematode communities differently (Forge et al., 2005; Villenave et al., 2010; Zhao and Neher, 2013). Harvesting of understory and/or overstory vegetations in native-species mixed plantations and eucalyptus monocultures in southern China significantly suppressed the soil nematode communities (Zhao et al., 2011, 2012, 2013b) and sod-cutting significantly reduced the total abundance of nematodes, density of nematode taxa, and the maturity index in a secondary

* Corresponding author. Tel.: +86 731 84619720; fax: +86 731 84612685.
*E-mail address:* kelin@isa.ac.cn (K. Wang).
[1] These authors contributed equally.

0929-1393/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.apsoil.2013.10.011

Scots pine forest in the Netherlands (de Goede, 1996). Forge and Simard (2000) and Sohlenius (2002) reported that the abundance of total nematodes and most of their trophic groups were apparently lower in clear-cut plots than in forested plots in Sweden and Canada, respectively. Irrigation, weeding and pest control also impact soil nematode communities (e.g., Ferris et al., 2004; Freckman et al., 1987; Porazinska et al., 1998a, 1998b; Sohlenius and Wasilewska, 1984; Zhao et al., 2013a). There are two likely reasons for the changes of soil nematode communities following these management practices. The first reason is that the management practices alter the food resource (e.g., leaf litter, dead roots and root exudates) inputs to soil, which may exert a bottom-up control on soil nematodes (e.g., Wardle et al., 2004; Zhang and Zak, 1998; Zhao et al., 2011). Another likely reason is that the management practices alter the soil physicochemical properties and soil microclimates (e.g., Huhta et al., 1983; Lohm et al., 1977; Russell et al., 2006; Wei et al., 2012; Zhao et al., 2012), which alter the soil nematode communities.

Hybrid napiergrass (*Pennisetum hydridum*), also known as elephant grass, has been widely cultivated in tropical and subtropical areas, where it is mainly used for raising livestock. Hybrid Napiergrass is a tall perennial $C_4$ grass that is predominantly clonally propagated and that can withstand repeated cuttings; it rapidly regenerates after cutting, producing a high yield of high quality leaves and stalks that are palatable to livestock (Lowe et al., 2003). Local farmers commonly manage hybrid napiergrass to provide forage for their livestock, to maintain soil nutrients, and to reduce soil erosion (Yu and Wang, 2007). Because of the increasing demand for energy, however, napiergrass has been increasingly grown as an energy crop (renewable energy) for the production of ethanol (Brandon et al., 2011; Gao et al., 2011; Sang and Zhu, 2011; Zhang et al., 2011). Because the human demand for meat and energy is expected to increase world-widely, the land area planted with forage and energy crops (including hybrid napiergrass) are also likely to increase.

Although the potential for high yield makes hybrid napiergrass an excellent forage and energy crop, unsound management practices could reduce forage yield, forage quality, and soil quality. Fertilization, cutting, cultivation, irrigation, and weed control are commonly used in the management of forage crops, and achieving high yields of hybrid napiergrass depends on nitrogen fertilization; nitrogen fertilizers significantly increased the production of napiergrass cultivars (both above- and belowground biomass) and increased the nitrogen content of leaves and stalks (Ashraf and McNeilly, 1987; Rahman et al., 2010; Rosolem et al., 2002; Vicente-Chandler et al., 1959; Wadi et al., 2003). Given that appropriate cutting frequency and intensity is essential for managing most forage species, cutting frequency and intensity may also affect the total yield, tiller number, and nutrient content of napiergrass. Thus, napiergrass yields increased but forage quality decreased with length of harvest interval (Sunusi et al., 1997; Vicente-Chandler et al., 1959). Tiller number was higher in the grasses cut at 30-cm height than at 0-cm height, and was higher in the grasses cut at 60-day than at 90-day intervals (Wadi et al., 2004). Lower cutting height not only reduced forage yield but also suppressed the regrowth of napiergrass in the following season (Tudsri et al., 2002). The forage quality (e.g., nutrient level, protein content, cellulose content, and oxalate content) was also significantly affected by cutting height and interval (Rahman et al., 2010; Tudsri et al., 2002; Vicente-Chandler et al., 1959; Wadi et al., 2004).

Managing of hybrid napiergrass also provides an opportunity for exploring how soil nematode community responds to different agricultural/pratacultural management practices. The management practices of hybrid napiergrass are somewhat different from and more intensive than those of cereal crops, vegetables, fruit trees, and timber trees. For example, the annual amounts of fertilizers applied to napiergrass are usually higher than applied to other plants. Moreover, the cutting intensity and frequency of napiergrass are usually greater than for cereal crops and trees. Therefore, analysis of the responses of the soil nematode community to management of napiergrass may improve our insight of mechanisms on how and why ecological processes or soil functions are affected by the hybrid napiergrass management. However, little is known about the soil nematode community composition under napiergrass. One study, which focused on plant-parasitic nematodes, reported that the most abundant plant-parasitic nematodes found on napiergrass in Florida were *Belonolaimus* and *Criconemella* spp. (McSorley et al., 1989). Another study described the soil nematode community composition in monocultured napiergrass soils in Embu, central Kenya (Kimenju et al., 2009). The responses of the nematode community to napiergrass management practices have not been reported.

The current paper concerns the effects of intensive management practices (i.e. nitrogen fertilization, cutting frequency, cutting intensity, and irrigation) on the soil nematode community in a napiergrass field. The cultivar studied was 'Guimu-1' (HNG), which is a hybrid of *P. hydridum* (a cross of *Pennisetum americanum* with *P. purprueum*) × *P. purprueum* (Xiao et al., 2008). In addition to describing the effects of management practices on the nematode community, we used the nematode community data to make inferences on the effects of management practices on soil health.

## 2. Materials and methods

### 2.1. Site description

This study was carried out at the Huanjiang Observation and Research Station for Karst Ecosystems (107°51′–108°43′E, 24°44′–25°33′N), Chinese Academy of Sciences (CAS), Guangxi Province, China. The climate is subtropical monsoon with a distinct wet (from April to September) and dry season (from October to March). The mean annual temperature and precipitation are 18.5 °C and 1389 mm, respectively. The watershed is a peak-cluster depression area typical of karst regions (Chen et al., 2012; Nie et al., 2011; Qi et al., 2013). The soil is calcareous soil which developed from dolostone base (Drew, 1983; Zhang et al., 2007).

### 2.2. Experimental design

An orthogonal experimental design in the form of $L_{16}(4^5)$ was used to investigate the effect of main factors (each with four levels), which were nitrogen fertilization, cutting frequency, cutting intensity, and irrigation, on the soil nematode community. The 16 treatments (or treatment assemblies) were randomly assigned to plots in each of three blocks (Table 1). The 16 plots (each plot was 2 m × 5 m) in each block were designated in 2011. Each plot was surrounded by a 1-m-wide buffer strip, and each block was surrounded by a 2-m-wide buffer strip. In February 2011, the hybrid napiergrass (HNG) seedlings were planted in a local nursery. In late April 2011, the ∼30-cm-tall seedlings were transplanted into each plot with a spacing of 60 × 60 cm between planting hole and with two HNG seedlings per hole. The four levels of nitrogen fertilization were 0 (A1), 230 (A2), 460 (A3), and 690 kg N $ha^{-1}$ $yr^{-1}$ (A4) (Table 1). Urea (containing 46% N) was chosen as the nitrogen fertilizer and was applied to the surface soil near HNG stalks and then covered with soil. Nitrogen fertilization was first applied 10 days after transplanting and was subsequently applied the next day after cutting (according to the treatment cutting schedule). The four levels of cutting frequency were one time of cutting per year (B1) conducted only in November; two times of cuttings per year (B2) conducted in July and November; three times of cuttings (B3) in