Soil Biology & Biochemistry 76 (2014) 257–267

Contents lists available at ScienceDirect

Soil Biology & Biochemistry

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

Belowground carbon allocation by trees, understory vegetation and soil type alter microbial community composition and nutrient cycling in tropical Eucalyptus plantations

Rajasekaran Murugan [a,*], Francesca Beggi [b], Sanjay Kumar [c]

[a] Department of Soil Biology and Plant Nutrition, University of Kassel, Nordbahnhofstr. 1a, 37213 Witzenhausen, Germany
[b] Department of Organic Plant Production and Agroecosystems Research in the Tropics and Subtropics, University of Kassel, Steinstr. 19, 37213 Witzenhausen, Germany
[c] Regional Rice Research Station, University of Agricultural Sciences, Bengaluru 560 065, Karnataka, India

ARTICLE INFO

Article history:
Received 19 December 2013
Received in revised form
7 March 2014
Accepted 11 March 2014
Available online 2 June 2014

Keywords:
Eucalyptus tereticornis (eucalyptus)
Girdling
Microbial community composition
Mycorrhizal fungi
Plant–soil relationship
Phospholipid fatty acids

ABSTRACT

We studied the influence of plant functional groups on soil microbial community composition and nutrient cycling in a tropical Eucalyptus forest ecosystem with different plantation age and soil types by means of stem girdling (SG) and understory removal (UR). Fungal and bacterial communities were characterized using phospholipid fatty acids, and ectomycorrhizal fungi (EMF) colonisation was estimated visually. Total bacterial and saprotrophic fungal biomass was highest in soils treated with SG, followed by UR, through modification of plant belowground C allocation and N supply. EMF root colonisation, biomass of EMF, arbuscular mycorrhizal fungi (AMF) and the fungal-to-bacterial ratio were lowest in these soils. We found that EMF, AMF and the fungal-to-bacterial ratio were highest in sandy loam soils with a high C/N ratio and low pH. The fungal-to-bacterial ratio was higher in 5-year-old than in 15-year-old plantation. We propose that girdling of trees and removal of understory plants are important ecological components, due to their modification of plant belowground C allocation and N supply as key determinants of microbial community composition. Our results highlight the fact that soil abiotic factors play an important role in shaping the microbial community and nutrient cycling in tropical forest ecosystems.

1. Introduction

Soil microorganisms represent essential components of forest ecosystems. The plant functional groups from above-ground communities can influence below-ground communities and vice versa; this two-way interaction must be considered an important driver of plant diversity and productivity in terrestrial systems (De Vries and Bardgett, 2012; Wardle et al., 2012; Van der Wal et al., 2013). Changes in soil microbial community composition can be among the earliest indicators of soil quality in many ecosystem processes, long before changes in total carbon (C) and nitrogen (N) become measurable (Powlson and Jenkinson, 1981). Saprotrophic fungi along with bacteria are the major decomposing organisms in many soils (Van der Wal et al., 2013). The free-living saprotrophic fungi (SF) dominate the litter layer in forest ecosystems (Lindahl et al., 2007). Mycorrhizal fungi (MF) play a distinct and unique role in plant nutrition, stabilisation of soil aggregates and C sequestration in forest ecosystems through symbiosis (Jastrow et al., 2007; Clemmensen et al., 2013). Soil fungi play a number of critical roles in terrestrial ecosystems, influencing important processes such as nutrient acquisition, N and C cycling, and soil structure formation (De Vries and Bardgett, 2012; Van der Wal et al., 2013). The dynamics of the microbial community, especially of fungi and nutrient cycling, are not fully understood in tropical Eucalyptus plantations of different age and soil type.

Stem girdling is a common silvicultural practice used for killing trees without felling them, by terminating the supply of current photosynthates to roots for thinning and controlling the stocking of young forest stands (Zeller et al., 2008; Högberg et al., 2010). Ectomycorrhizal fungi (EMF) play a significant role in soil organic matter decomposition by releasing organically bound N (Högberg et al., 2008; Yardwood et al., 2009) and making it accessible to trees in exchange for carbohydrates (Kaiser et al., 2010). The EMF have therefore been characterised as the strongest sinks of N in forest soil (Lindahl et al., 2007; Högberg et al., 2008). It has been suggested that AMF are more sensitive to disturbance, organic matter quality and disruption by soil invertebrates than SF (Van der

* Corresponding author.

http://dx.doi.org/10.1016/j.soilbio.2014.05.022
0038-0717/

Wal et al., 2013). Soil microbial communities with a relatively high fungal biomass have been associated with reduced N losses (Högberg et al., 2007; De Vries et al., 2013). There is an increasing interest in studying the relationship between above-ground and below-ground communities and their influence on C and N dynamics (Kaiser et al., 2010; De Vries and Bardgett, 2012; Wardle et al., 2012). Although SF and MF play fundamentally different roles in the ecosystem, little is known about the composition and role of these two functional groups in different soil types and understory vegetation under Eucalyptus plantations.

The understory vegetation is an important ecological component in many forest ecosystems worldwide, particularly in the tropical and subtropical regions (Nilsson and Wardle, 2005; Wardle et al., 2012). Understory vegetation influences not only above-ground processes such as tree-seedling regeneration, forest succession, species diversity, and stand productivity, but also soil biota, including decomposition, soil aggregation, nutrient cycling and soil water conservation (Van der Wal et al., 2006; Wubet et al., 2012; Zhao et al., 2012) at different temporal and spatial scales (Wardle et al., 2012). However, understory vegetation has usually been overlooked in ecological forestry studies and very little attention has been paid to how understory vegetation affects the composition and function of microbial communities in forest ecosystems, especially in tropical forests.

It is well established that the soil biotic and abiotic conditions determine the nature of interactions between plants and soil microorganisms (De Deyn et al., 2009; Oehl et al., 2010). Recently, Birkhofer et al. (2012) found that the abiotic soil properties explained the highest amount of variation in soil fungal biomass and diversity across land use. Soil texture was proved to be the strongest abiotic factor in shaping the AM fungal community (Oehl et al., 2010; Wubet et al., 2012) and bacterial community (Lauber et al., 2008) across land use types. Further, abiotic factors (i.e. soil type and fertility) play a major role in driving the activity, structure and diversity of soil microbial communities (Jastrow et al., 2007; Oehl et al., 2010; Birkhofer et al., 2012). However, much less is known about how microbial communities vary under Eucalyptus forest ecosystems with different plantation age and soil types, including variation in soil fertility.

To reduce area under waste land, afforestation with Eucalyptus has been widely practised in India, due to its ability to adapt to different climate, soil type and water regime (Stone, 2009). Total area under Eucalyptus plantation in India was about 3 million ha by the year 2011 (ICFRE, 2011). In turn, large areas of Eucalyptus monoculture plantations usually resulted in forest degradation and soil erosion (Calder et al., 1993; Stone, 2009). On the other hand, not only microbial biomass but also soil organic C and total N concentrations were increasing with plantation age (Mishra et al., 2003; Cao et al., 2010). Shifts within the soil fungal community, especially from biotrophic MF to SF apparently have a stronger influence on soil biological processes than a general shift from fungi to bacteria (Strickland and Rousk, 2010; Van der Wal et al., 2013).

In this study, we assess the effects of plant functional group loss (stem girdling, understory removal) and different soil types on the composition of soil microbial communities in two Eucalyptus plantations of different ages (5 and 15 years old). Specifically, we test the hypotheses that (1) plant functional group loss alters the composition of soil microbial communities by reducing the below-ground C input and soil nutrient properties; (2) soil physico-chemical characteristics change with increasing plantation age and, subsequently, soil microbial communities change with plantation age; and (3) the microbial biomass and community composition vary between two different soils.

2. Materials and methods

This study was conducted in two Eucalyptus plantations located in the semi-arid region of Thandarai and Dhusi village, Kanchipuram district of Tamilnadu state, India. The climatic and soil characteristics of the study sites are shown in Table 1. Eucalyptus plantations are widespread in this area, and the predominant species is *Eucalyptus tereticornis*. The soils belong to the group red lateritic ultisol derived from Granite-Gneiss rock with varying texture from sandy loam to clay loam. The sites with 5- and 15-year-old Eucalyptus plantations (E5 and E15, respectively) were selected for this study. Both plantations were established in clay loam (Thandarai village) and sandy loam (Dhusi village) soils and were maintained similarly by Tamilnadu State Forest Plantation Corporation Limited (TAFCORN). Processes and methods of planting were uniform when both plantations were established. The understory ground cover includes *Andropraphis paniculata* Nees, *Scoparia dulcis* L., *Hemidesmus indicus* (Linn) Shultz and *Wikstroemia indica*, with *A. paniculata* as the dominant

Table 1
Geographic location, main environmental characteristics, soil physical and geochemical parameters of the two plantations before treatments were applied under two regions.

Site			Plantation age	Treatment	Soil pH	Sand	Silt	Clay	SOC	Total N	Soil C/N ratio
						(g kg^{-1})					
Thandarai	Location	12°7′14″N 79°9′3″E	**5**								
				Control	6.16	132	466	402	27.80	1.93	14.4
	Elevation	130 a.s.l		Stem girdling	6.00	111	440	449	28.32	1.80	15.7
	MAT	33 °C		Understory removal	5.92	209	371	420	28.67	1.83	15.7
	MAP	680 mm	**15**								
				Control	6.20	124	419	457	26.61	1.79	14.9
				Stem girdling	5.86	164	412	424	26.67	1.84	14.5
				Understory removal	6.32	119	421	460	25.40	1.79	14.2
				ANOVA	ns	ns	ns	ns	ns	ns	ns
Dhusi		12°46′N 79°40′E	**5**								
				Control	4.56	662	221	117	23.63	1.24	19.1
	Elevation	89 a.s.l		Stem girdling	4.79	643	256	101	21.01	1.15	18.3
	MAT	35 °C		Understory removal	4.72	652	211	137	22.39	1.18	19.0
	MAP	560 mm	**15**								
				Control	4.68	593	252	155	22.22	1.31	17.0
				Stem girdling	4.58	612	218	170	20.94	1.16	18.1
				Understory removal	4.62	645	236	119	21.77	1.26	17.3
				ANOVA	ns	ns	ns	ns	ns	ns	ns

Statistical significance was determined at $P < 0.05$; ns – no significant difference between treatments using ANOVA.