



Research article

Contribution of glomalin to dissolve organic carbon under different land uses and seasonality in dry tropics

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ABSTRACT

Glomalin related soil protein (GRSP) is a hydrophobic glycoprotein that is significant for soil organic carbon (SOC) persistence and sequestration, owing to its large contribution to SOC pool and long turnover time. However, the contribution of GRSP to dissolve OC (DOC) leach from soil is not yet comprehensively explored, though it could have implication in understanding SOC dynamics. We, therefore, aim to measure the contribution of GRSP to DOC, in a range of land uses and climatic seasons in the dry tropical ecosystem. Our results demonstrated that a significant proportion of GRSP (water soluble GRSP; WS-GRSP) leached with DOC (7.9–21.9 mg kg⁻¹), which accounts for 0.2–0.23% of soils total GRSP (T-GRSP). Forest exhibited significantly higher WS-GRSP and DOC leaching than fallow and agriculture. WS-GRSP and DOC accumulations were higher in the dry season (summer and winter) than in rainy. The extent of seasonal variations was higher in forest than in other two land uses, indicating the role of vegetation and biological activity in soil dissolve organic matter (DOM) dynamics. The regression analysis among WS-GRSP, T-GRSP, DOC and SOC prove that the accumulations and leaching of GRSP and other soil OM (SOM) depend on similar factors. The ratio of WS-GRSP-C to DOC was higher in agriculture soil than in forest and fallow, likely a consequence of altered soil chemistry, and organic matter quantity and quality due to soil management practices. Multivariate analysis reflects a strong linkage among GRSP and SOC storage and leaching, soil nutrients (nitrogen and phosphorus) and other important soil properties (pH and bulk density), suggesting that improving GRSP and other SOM status is an urgent need for the both SOC sequestration and soil health in dry tropical agro-ecosystems.

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1. Introduction

The leaching of dissolve organic carbon (DOC) from soil with water runoff is considered significant for soil organic carbon (SOC) dynamics and its movement to within and between ecosystems (Lal, 1998; John et al., 2003; Lai et al., 2016). It is highly dependent upon the factors, including soil type, topography, climate, soil microbial community composition, agricultural management practices and vegetation cover used (Filep and Rékási, 2011; Kindler et al., 2011; Janeau et al., 2014). Also, seasonal changes in soil temperature and hydrologic water cycle plays an essential role in

determining SOC retention or leaching (García-Oliva et al., 2003) and biological activity of the soil (Montano et al., 2007), which in turn determines OC export to the adjacent aquatic ecosystems. For instance, the river and coastal ecosystems of the Indian subcontinent are characterised by high concentration of DOC leaching from soils of the catchment preferentially in monsoon (rainy) season when utmost soil biological activity is recorded (Singh et al., 1989; Krishna et al., 2015).

The SOC pool consists of various components that differ in stabilization mechanisms and turnover rates. The DOC pool produced from soil is considered to mirror the composition of SOC at a given soil depth (Kaiser and Kalbitz, 2012). However, the fact that entire fraction of SOC does not equally contribute to DOC probably due to different water solubility (Uchimiya et al., 2013; Zappoli et al., 1999). Given that many previous studies have investigated the fate of DOC, though, these investigations mainly focused on the role

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of entire SOC pool, rather than on individual SOC fraction (Janeau et al., 2014). Among total SOC components, glomalin accounts for a relatively large proportion of SOC (2–15 mg g⁻¹ and contributes to an average 5–10% of total SOC) (Fokom et al., 2012) because it is hardly decomposed and less sensitive to environmental fluctuation (Rillig et al., 2001). Previous researcher strongly agreed that glomalin contributes to long-term SOC storage (Rillig and Steinberg, 2002; Fokom et al., 2012; Singh et al., 2016). However, the contribution of glomalin to soils DOC pool is uncertain and rarely explored until the present. In spite of the fact that quantifying glomalin and its contribution to DOC is critical for predicting SOC stocks and dynamics.

Glomalin is characteristically a heat stable glycoprotein of soil, which is produced by arbuscular mycorrhizal fungi (AMF) during symbiotic association with the roots of about 70% plant families (Rillig and Steinberg, 2002). The quantification of glomalin is often tagged as glomalin related soil protein (GRSP) (Fokom et al., 2012; Mengual et al., 2014; Singh et al., 2016). The accumulation of GRSP in soil is dependent on numerous factors including AMF richness, plant community composition, land use systems and soil properties (Treseder et al., 2007; Singh et al., 2016). GRSP in soil acts as a soil conditioner by improving soil's fertility including; aeration, water holding capacity, nutrients, and eventually plants productivity (Fokom et al., 2012).

Numerous researcher investigated the fate of GRSP, considered it as a hydrophobic protein (insoluble in water) that only soluble in an alkaline buffer at high temperature (Wright and Upadhyaya, 1996; Rillig et al., 2001). Taken into account these premises, several authors have reported a linear correlation between GRSP and water-insoluble aggregates in various soil types (Fokom et al., 2012), where GRSP acts as a cementing material of soil aggregate. In contrast, some authors have reported GRSP in the river and coastal ecosystems (Harner et al., 2004; Adame et al., 2012), which indicates that a significant quantity of GRSP probably leached with water as a component of DOC. Kalbitz and Kaiser (2008) have shown that soil derived hydrophobic and microbial-derived proteinaceous material contributes significantly to DOC derived from terrestrial ecosystems. It is, therefore, necessary step to know how much GRSP contributes to DOC pool, for the long-term aim to understand GRSP role in ecosystem C cycling.

The OC poor and structurally unstable soils, such as those found in the upland dry tropical ecosystems of central India are often subjected to intense erosive rains associated with the tropical monsoon climate. The high temperature in soils of such kind of tropical environment also contributes to the accelerated production of DOC relative to those under temperate climate conditions (Janeau et al., 2014). It is due to warm and more humid condition that tends to result in elevated biological activity and hence higher DOC production during organic matter decomposition (Christ and David, 1996; Montano et al., 2007). Further, several previous works conducted in the temperate climate have shown that the type of vegetation and land use can dramatically influence the production of DOC in soil. For instance, Puttock et al. (2013) observed that significantly higher concentration of DOC was produced from forested soils than in grassland. Similarly, a study conducted in pan-Europe has found that DOC loss from soil to adjacent stream tended to be higher in forested sites than cropland (Kindler et al., 2011). Besides this, the distribution of land use and vegetation characteristics differs with climate, region and soil type, and inconsistencies in the release of DOC occurred (Janeau et al., 2014). It is, therefore, difficult to draw any conclusion on the impact of diverse soil uses on DOC production under different climatic conditions and soil types. Specifically, in the dry tropical ecosystems, where little data exist to date, this becomes even more difficult.

SOC depletion in soil can alter soil quality by reducing soil stabilization, water holding capacity, soil quality and ultimately soils productivity (Lal, 1998). Thus, studying SOC components and dynamics is of great relevance in terms of soil management, especially in the shallow soils with low organic matter content existing in the area of study. The objective of this study was, therefore, to evaluate GRSP and DOC leaching as influenced by land uses and seasonality in dry tropical ecosystem. We hypothesized that GRSP contribution to DOC in soils of present tropical environment will be highest in forest and that the transition from forest to fallow and agriculture sites will be accompanied by a reduction in their concentration, as higher vegetation diversity and density in forests supports more enrichment of microbial communities and in turn GRSP and DOC production (Filep and Rékási, 2011; Fokom et al., 2012). Also, due to high rainfall and biological activity, we hypothesized that the GRSP contribution to DOC in soils will be lower during the rainy season compared with dry season (summer and winter).

2. Materials and methods

2.1. Site description and soil sampling

We conducted this study in the dry tropical environment of the Sonbhadra, India (21° 29' – 25° 11' N and 78° 15' – 84° 15' E). The altitude varies from 313 m to 483 m. Mean annual temperature is 27 °C and mean annual rainfall is 1215 mm (1980–2010; Chaturvedi and Raghubanshi, 2015). The area experiences tropical monsoon climate, which is characterised by a low temperature in winter (November–February), high in summer (March–June) and moderate during rainy (July–October) season (Fig. 1). Rainfall is strongly seasonal with nine dry months per year and with 85% of annual rainfall falling from July to October (Singh et al., 1989). The vegetation is a naturally diverse tropical dry deciduous forest (Sagar and Singh, 2004). Where, rainfall seasonality resulted in fall of the leaves in most of the tree species at the end of the rainy season, which corresponds to a new input of organic matter to the soil (Rai et al., 2016a). Soils are moderately weathered, sand-rich residual ultisol, reddish to reddish-brown in colour, extremely poor in nutrients and have moderate water holding capacity (Singh et al., 1989; Rai et al., 2016b). Soil sampling were carried out in three different land uses; undisturbed forest located in Hathinala east (24° 17' N, and 83° 6' E), severely deforested fallow site in Hathinala west (24° 8' N, and 83° 51' E), and from a 10 year old agriculture field located in village Saudih (24° 16' N, and 83° 6' E). Here, forest site principally occupied by *Shorea robusta*, *Terminalia tomentosa*, *Diospyros melanoxylon* and *Bridelia retusa* species (Sagar and Singh, 2004) deciduous tree species. Conversely, the fallow site

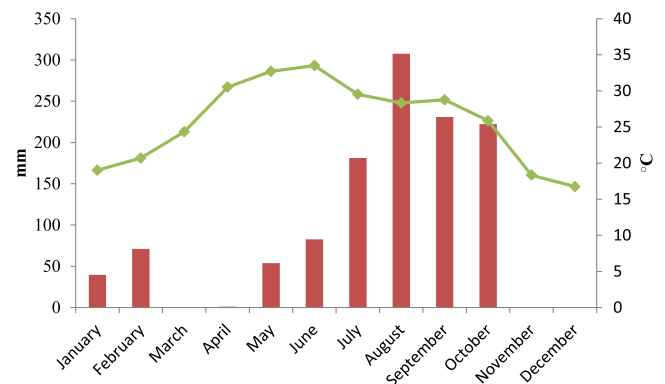


Fig. 1. Pattern of rainfalls (mm; bars) and mean air temperature (°C; lines) in the dry tropical ecosystem (Sonbhadra, India).

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