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Short-term changes in soil biochemical properties as affected by subsidiary crop cultivation in four European pedo-climatic zones

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ABSTRACT

The goals of conservation agriculture are to preserve and enhance the soil resource base and the environment. Subsidiary crops (SCs), such as *Trifolium, Medicago, Vicia, Brassica, Raphanus* spp., are important components of conservation agriculture since they maintain the soil resource. However, the importance of SC species and environment on soil microbial communities are not well known. The overall objective of this study was to assess the effect of various subsidiary crops cultivation on soil microbial biomass and activity at four sites across Europe. The experiments were conducted during 2014 and 2015 at sites in the Nemoral (Sweden SLU), Oceanic (United Kingdom ORC), Continental (Switzerland AGS) and Mediterranean north (Italy UNI) pedo-climatic zones. The specific objectives were to determine: (i) the effect of SC growth on soil microbial biomass and activity, (ii) the site-specific effect of SC growth on soil biochemical properties. The SCs consisted of leguminous or brassicaceous species sown after wheat harvest, or clover species under-sown in wheat. At 0–30 cm depth, microbial carbon and nitrogen increased under SCs at most sites indicating that SCs cultivation may favor soil biological fertility. Effects of SCs were similar in the pedo-climatic zones where air temperatures are never below 0 °C (ORC and UNI). Arylsulphatase was the most sensitive enzyme to legumes in the Mediterranean north (UNI). Chitinase activity was enhanced by SCs in the Oceanic and Nemoral pedo-climatic zones. High precipitation and the low average temperature, typical of Continental and Nemoral zones, may represent limiting factors for soil enzyme activity under all selected SCs. Among the four pedo-climatic zones, the Mediterranean north represented the most suitable environment to promote SC growth and soil coverage. This study showed that SC cultivation affects soil quality enhancing biochemical activity; however the SCs effect were influenced by the different pedo-climatic conditions.

1. Introduction

Subsidiary crops (SCs), such as *Trifolium, Medicago, Vicia, Brassica, Raphanus* spp. are grown primarily for their agro-ecological services. Subsidiary crops can be non-leguminous species such as grasses (*Poaceae)* including cereals grown for that purpose, crucifers (*Brassicaceae*), other flowering plants, or legumes (*Fabaceae*). Leguminous species are widely used as SCs because of their ability to fix atmospheric nitrogen in symbiosis with Rhizobia. A large part of the N from legumes tends to be released soon after their suppression, as the residue decomposition process is generally rapid mainly due to their low C/N ratio (Radicetti et al., 2016). Moreover, legumes have a greater positive effect on soil microbial biomass than other species due to a higher root exudation rate (Chen et al., 2008).

The adoption of SCs, in combination with minimum soil tillage practices and within a well-planned crop rotation, is the main pillar of conservation agriculture (Creamer and Dabney, 2002; Pittelkow et al., 2015). Subsidiary crops protect the soil from erosion, in particular during the fallow period between the two main cash crops, and they provide a continuum of root systems in soil, promoting soil microbial

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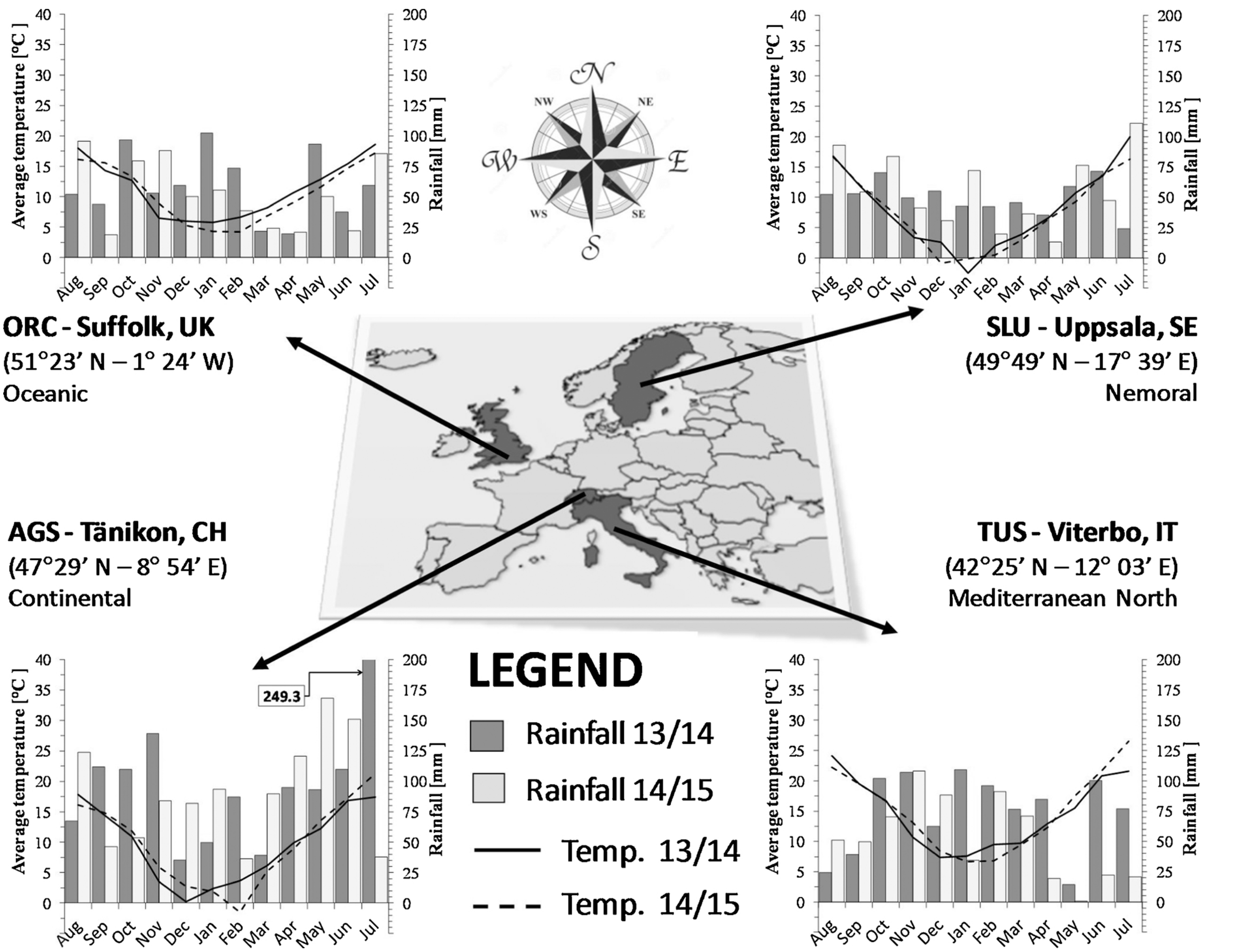

Fig. 1. Localization and weather conditions (monthly average of the daily temperatures and monthly total amount of rainfall) during the field experiments in 2013/2014 and 2014/2015 years of the four experimental sites.

biomass and its activity through rhizodepositions that provide uniform supply of organic C, as an energy source for microorganisms (Kumar et al., 2006; Paterson, 2013). The root system of SCs may increase soil microbial abundance and activity by enhancing the stabilization of soil macro-aggregates (Gyssels et al., 2005), which are ‘hot spots’ for soil microorganisms (Nannipieri et al., 2003; Sexstone et al., 1985). Some SCs with tap roots can penetrate deeply and help break up hard pans and bring nutrients up from deep layers while other SCs with fibrous roots, especially grasses, will increase soil carbon through their extensive root systems (Sarrantonio, 2012). Before cover crop suppression the presence of plant roots has a large impact on soil microbial communities and root exudates supply energy to soil microbes more efficiently than decomposing roots and crop residues (Calderon et al., 2016). In addition to their below ground effect, SCs can produce a large amount of above ground biomass. They promote nutrient cycling, and thus soil fertility, particularly when they are incorporated into the soil as green manure (Mancinelli et al., 2013; Fageria et al., 2005) or when they are mowed and left on the soil surface as organic dead mulch (Hartwig and Ammon, 2002). The beneficial effect of SCs on soil is, thus, the sum of all the above described aspects. However, most of the studies do not discriminate among these different aspects, which contribute to the overall beneficial outcomes. Additional knowledge may be obtained when assessing the effect on soil before SCs suppression during their growth cycle; in this way it can be highlighted a specific effect due to root exudation and relative products.

The impacts of SCs on soil nutrient biogeochemical cycling are usually documented in relation to the soil organic carbon pool variation (Mukumbareza et al., 2016), which drives soil microbial activity, inducing a priming effect of native soil organic matter (SOM) (Insam and Domsch, 1988; Blagodatskaya and Kuzyakov, 2008; Murphy et al., 2011). Changes in agronomic practices may cause long-term changes of the total soil organic carbon content (Poeplau and Don, 2015). In the short-term, differences in soil C and N labile pools and soil enzyme activities can be used as indicators of biological activity and they are widely used to detect soil responses to agricultural management practices (Ramos et al., 2010; Zhou et al., 2012). The greater soil microbial biomass and activity occurring after SC suppression contribute to biogeochemical nutrient cycling (Chavarria et al., 2016; Mbuthia et al., 2015). In this context, soil biochemical properties as related to soil microbial activity are often used as indicators of ecological changes and can be used to evaluate mineralization process dynamics based on substrate availability and seasonal fluctuations (Mancinelli et al., 2013; Marinari et al., 2015).

The benefits to the agro-ecosystem provided by SCs strongly depend on pedo-climatic conditions (Mondal et al., 2015), land use intensity (Wittwer et al., 2017) and SC type (Poffenbarger et al., 2015). These factors in turn affect crop productivity, the decomposition rates of SOM, and the abundance of substrates that can be directly used by the soil microbes (Davidson and Janssens, 2006; Marinari et al., 2015). Depending on SC species and pedo-climatic conditions SCs are likely to influence the biochemical properties differently. The short-term effect after SC suppression on soil properties (i.e. the joint effects of the above