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Effects of tillage systems on soil characteristics, glomalin and mycorrhizal propagules in a Chilean Ultisol

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Abstract

Tillage affects the soil physical and chemical environment in which soil microorganisms live, thereby affecting their number, diversity and activity. However, soil disturbance generally has the greatest impact on biological properties, including both free and symbiotic fungal populations. Interest in more ecologically sustainable agricultural systems is rising with increasing recognition that agricultural intensification can adversely affect environmental quality. This paper discusses the effect of tillage system on some soil characteristics, such as pH, C, N and S levels, total and Olsen-P contents including some P forms associated with organic matter, glomalin contents and arbuscular mycorrhizae (AM) parameters, such as root colonization, spore number and total and active hyphal length. Measurements were in the sixth year of an on-going tillage-rotation experiment conducted on an Ultisol under no-till (NT), reduced tillage (RT) and conventional tillage with stubble mixed into the soil (CTS) or stubble burnt (CTB). Soil was sampled at two dates; after wheat (*Triticum aestivum*) harvest (autumn) and 6 months after subsequent grassland seeding (spring). Higher C, N, S, total P and fulvic acid-P concentrations and pH occurred under NT and RT than under CTS and CTB after wheat harvest. However, results at the second sampling were not consistent. AM spore number and active hyphal length were highest under NT having the greatest incidence on AM root colonization and P concentration in shoots of the pasture. Glomalin concentration was higher under NT and RT than under CTS and CTB but no differences in calculated glomalin to total C (ca. 5%) were found. It is concluded that a less disruptive effect of NT influences positively all soil characteristics and also increases P acquisition by the following crop in the rotation system.

Keywords: No-tillage; Conventional tillage; Soil characteristics; AM propagules; Ultisol; Glomalin

1. Introduction

Alteration of soil conditions by tillage practices has complex effects on soil characteristics thereby affecting environmental conditions, the growth and activity of soil microorganisms and consequently,

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nutrient dynamics. According to the degree of disturbance by tillage systems, changes have been observed in soil water content, aeration and soil temperature, which influence the decomposition rate of residues left in the soil (Ma et al., 1999; Rochette et al., 1999; Espana et al., 2002). Also, such environmental changes can affect microorganisms in different ways; either in number, diversity or activity. Therefore, reduced and particularly no-tillage (NT) practices minimize soil disturbance, increase soil organic matter and improve soil structure compared with conventionally plowed soils (Carter, 1992; Franzluebbers et al., 1995, 1999).

Soil management practices involving the placement or incorporation of residues can change soil environmental conditions for soil organisms responsible in nutrient cycling and organic matter decomposition (Doran, 1980; Clapperton et al., 1997). Accumulation of organic matter and nutrients near the surface under reduced tillage produces beneficial effects on soil physical, chemical and biological properties (Beare et al., 1997; Tebrugge and During, 1999). These improvements are generally associated with enhanced rhizosphere biological activities (Gupta and Germida, 1988; Kladivko, 2001). It has been recently reported that fungal biomass is enhanced in the topsoil under NT (Frey et al., 1999). Although fungi, including those forming mycorrhizal associations with plant roots, may be numerically less abundant than bacteria, they can constitute up to 80% of soil microbial biomass (Lynch, 1990) being the primary decomposers of residues in soil.

Of special relevance in agricultural management systems are the arbuscular mycorrhizal (AM) fungi that are ubiquitous in soil, and play important roles in plant nutrition and soil aggregation (Beare et al., 1997; Jeffries and Barea, 2001; Rillig et al., 2002). To fulfill both functions, extraradical mycelium proliferate in the soil next to the root cortex from which hyphae absorb nutrients, especially those with low mobility such as P, Cu and Zn (Li et al., 1991; Burkert and Robson, 1994; Marschner, 1995). Extraradical hyphae are also very important in soil conservation as they are one of the major factors involved in soil aggregation (Miller and Jastrow, 1992). The improvement in aggregate stability is due to a physical effect of a network around soil particles, together with the hyphal production of significant amounts of an insoluble glycoprotein named glomalin (Wright and Upadhyaya, 1996), which cements soil components (Wright and Upadhyaya, 1998; Wright et al., 1999; Rillig et al., 2002). Glomalin is produced by hyphae of all members of AM fungi but not by other groups of soil fungi (Wright et al., 1996). Well-aggregated soils are more resistant to erosive forces, have better aeration and water infiltration due to heterogeneous protected C microhabitats that enhance microbial diversity (Blevins et al., 1984; Lupwayi et al., 1998) and activity (Palma et al., 2000). Recent reports have highlighted the quantity of C in glomalin relative to total organic C that may be higher than C in microbial biomass (4–5% against 0.08–0.2%, according Rillig et al., 2001). Glomalin may be useful as a sensitive indicator of soil C changes produced by land-use practices (Rillig et al., 2003) and could even be involved in C-sequestration (Rillig et al., 1999).

Mycorrhizal roots, AM spores and fungal mycelia constitute the main propagules left in the soil that colonize plant roots of the succeeding crop in a rotation system. However, hyphae remaining active from the previous crop are thought to be the main source of inoculum in soil (Sylvia, 1992). Living hyphal density can be affected by different agricultural management practices, including soil tillage.

Soil disturbance, both in field and in growth chamber experiments carried out with maize (*Zea mays*), strongly affects root colonization and P absorption during early growth (McGonigle et al., 1990; McGonigle and Miller, 1993). Several studies have supported the hypothesis of a causal relationship between soil disturbance and impaired plant growth due to reduced mycorrhizal effectiveness (Evans and Miller, 1988; Jasper et al., 1989; Fairchild and Miller, 1990). The network of mycorrhizal hyphae extending in the surrounding of root surfaces is an important inoculum source when roots senesce. Disruption of this network is a proposed mechanism by which conventional tillage (CT) reduces root colonization and P absorption. In the same way, hyphae and colonized root fragments are transported to the upper soil layer, decreasing and diluting their activity as viable propagules for the succeeding crop in rotation.

In Chile, volcanic soils cover >5 Mha, on which most cereals in the country are produced. These soils, having high P adsorption capacity need to be fertilized yearly with moderate amounts of phosphate fertilizers, which eventually accumulate in soil as unavailable P