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Soil suppressiveness and its relations with the microbial community in a Brazilian subtropical agroecosystem under different management systems

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ABSTRACT

The ability of soils to detain the onset of a disease in a susceptible host is called soil suppressiveness. Soil suppressiveness can often be attributed to the activity of soil microorganisms. Considering that soil management can drastically affect microbial soil communities, the objective of this work was to evaluate the impact of different crop systems and tillage practices on the suppression of wheat head blight, caused by the soil-borne fungus *Fusarium graminearum*, assessing the relationships between soil suppressiveness and microbial activity and diversity. Samples were taken from a long-term (30 years) experimental set-up in a Paleudult soil under conventional tillage or no-tillage management and three cropping systems: oat (*Avena strigosa*)/maize (*Zea mays*); vetch (*Vicia sativa*)/maize; and black oat + vetch/maize + cowpea (*Vigna sinensis*). The soil-borne fungus *F. graminearum*, the causal agent of wheat head blight, was used as model pathogen and wheat (*Triticum aestivum*) as model host plant. No-tillage soil samples showed the highest level of *F. graminearum* suppression by significantly reducing plant disease intensity. Of the cropping systems tested, the vetch + black oat/maize + cowpea system showed the highest suppressiveness and the oat/maize system showed the lowest. Microbial biomass, respiratory activity and the activity of the chitin degrading enzyme β-glucosaminidase followed the same trend, being associated to soil organic matter. *Chitinophagaceae*, *Acidobacteriaceae*, *Xanthomonadaceae* and *Burkholderiaceae* were associated to soil suppressiveness.

1. Introduction

Plant diseases caused by soil-borne pathogens result in significant losses in many economically important crops. Soil-borne pathogens are difficult to control because of their persistence in soil through the formation of survival structures, the usual wide host range and the inefficiency of chemical controls (De Coninck et al., 2015).

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On the other hand, every soil has some level of resistance or some capacity to control diseases (Anees et al., 2010). The ability of a soil to detain the onset of a disease in a susceptible host, even in the presence of a significant inoculum density of the pathogen, is called soil suppressiveness (Klein et al., 2011).

Soil suppressiveness varies from soil to soil in a continuum from highly conducive to strongly suppressive soils (Anees et al., 2010). Although abiotic factors, such as soil physicochemical properties, may contribute to the suppression of a given pathogen, suppressiveness is essentially a phenomenon mediated by soil microorganisms, since sterilization processes turn suppressive into conducive soils (Garbeva et al., 2004). General and specific suppression have been described. General suppression is the widespread but limited ability of soils to suppress the growth or activity of soil-borne pathogens and is related to the total microbial biomass and activity in soil, while specific suppression is related to the effects of individual or select groups of microorganisms during some stage in the life cycle of a pathogen (Weller et al., 2002). Suppressive soils are the result of a combination of both general and specific suppression.

Soil management practices can influence microbial biomass and activity, as well as the microbial community diversity, affecting soil suppressiveness as a result. In general, soil suppressiveness is associated with higher carbon levels and enhanced biological activity (Stirling et al., 2012). In subtropical soils, conservation tillage systems, especially no-tillage, are expected to reduce organic C losses, by decreasing the mineralization and the erosion processes, while cropping systems with high plant residue input increase retention of C in the soil (Diekow et al., 2005). In this context, the microbial community as a whole is favored, resulting in higher microbial biomass and activity (Garbeva et al., 2006; Souza et al., 2014). Crop systems with high plant diversity can also positively affect microbial community by altering the microbial diversity and increasing the abundance of microbial groups associated with soil suppressiveness, such as *Bacillus* and *Pseudomonas* (Garbeva et al., 2006). Thus, it is possible to enhance the suppressiveness of a soil by selecting appropriate management practices.

Considering that soil management can drastically affect microbial communities, the objective of this work was to evaluate the impact of different crop systems and tillage practices on the suppression of phytopathogens in a long-term field experiment, assessing the relationships between soil suppressiveness and microbial activity and diversity.

2. Materials and methods

2.1. Soil sampling and experimental design

The soil used for this study was taken from a long-term field experiment located at the Agronomic Experimental Station of the Federal University of Rio Grande do Sul (UFRGS), in Eldorado do Sul – RS, Brazil, with geographic coordinates 30°50′52″S and 51°38′08″W. The regional climate is classified as humid subtropical (Köppen climate classification Cfa), with local annual mean temperature of 19.4 °C and rainfall of 1440 mm. The soil management experiment was established in 1985 on a degraded sandy clay loam Typic Paleudult that had been conventionally cultivated since 1969 (Bayer et al., 2002).

The field experiment was designed as randomized blocks with split-split-plot arrangement. The experiment consists of three tillage systems, set in the main plots (15 m × 20 m), three cropping systems, set in subplots (5 m × 20 m) and two nitrogen (N) rates applied to maize crops, set in sub-blocks perpendicular to the length of plots and subplots, resulting in individual sub-subplots of 5 m × 10 m. In this study, only two tillage methods and the three cropping systems were sampled from the zero N plots. Conventional tillage (C), characterized by the incorporation of crop residues and a soil disturbance up to ≈200 mm of depth, and no-tillage (N), with crop residues maintained on soil surface and minimum soil disturbance, were selected due to their contrasting characteristics. The three crop systems were selected and show a wide variation of crop residue quality and quantity entering the soil: a low input oat (*Avena strigosa*)/maize (*Zea mays*) grass rotation (O); an intermediate vetch (*Vicia sativa*)/maize legume/grass rotation (V); and a high input oat + vetch/maize + cowpea (*Vigna sinensis*) mixed crop rotation (M). Each soil sample (0–7 cm) was composed by 15 subsamples randomly collected during maize growth (30 days after seedling). Soil samples were sieved (2-mm mesh) and properly stored until their further use. A portion of each sample (0.2 kg) was used for chemical analysis by standard methods (Sparks, 1996) (Table 1).

2.2. Soil suppressiveness assay

An *in vivo* infection assay was carried out in order to examine the effect of the different management systems on soil suppressiveness. The soil-borne fungus *Fusarium graminearum*, the causal agent of wheat head blight, was used as model pathogen and wheat (*Triticum aestivum*) as model host plant. The experiment was performed as described (Rasmussen et al., 2002). Specifically, soil samples were placed in 50 mL flasks, and the wheat seeds were inoculated with the pathogen in a concentration of 1.5×10^6 conidia/mL. In each pot, three seeds were placed, with four replicates for each of the individual samples. The negative control, representing the minimum level of suppression, consisted of washed and autoclaved sand. The plants were kept at 21 °C for 19 days, with photoperiod of 12 h. The disease index (DI) was estimated according to a score proposed previously (Knudsen et al., 1999) ranging from 0 (no symptoms) to 4 (plant death). The percentage of disease suppression was calculated as: (sand DI − test soil DI) × 100/sand DI.

2.3. Soil biochemical characteristics

Soil samples were evaluated for soil microbial biomass C according to the methodology proposed by Horwath et al. (1996) that uses the soil chloroform fumigation and incubation approach. Non-fumigated samples were also used to determine the global respiratory activity of the soils. The method proposed by Parham and Deng (2000) was used to determine the activity of the chitin degrading enzyme β-glucosaminidase.

2.4. Analysis of soil bacterial diversity

Soil DNA was extracted from 0.3 g of each soil sample using the

Table 1
Chemical analysis of a Paleudult under different soil management and cropping systems.

Systems[a]	P	K	Clay	OM	pH	Al	Ca	Mg
	mg dm^{-3}		%			mmol$_c$ dm^{-3}		
CO	15.0	152	31	1.7	5.2	3	21	10
NO	53.0	214	26	2.4	5.6	0	25	14
CV	3.8	132	33	2.0	4.7	8	19	8
NV	26.1	155	26	3.1	4.8	5	20	16
CM	42.9	154	31	2.4	5.1	5	20	14
NM	23.9	207	23	3.6	5.1	3	28	15

[a] C = conventional tillage, N = no-tillage, O = oat + maize, V = vetch + maize, M = oat + vetch/maize + cowpea.