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Effect of Good Agricultural Practices under no-till on litter and soil invertebrates in areas with different soil types

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ABSTRACT

Good Agricultural Practices (GAPs) under no-till (NT) includes a mixed crop rotation; cover crops; integrated pest, weed and disease management; nutrient restoration; and a rational use of agrochemicals. When applied all together, GAPs promotes high productivity, while maintaining the production capacity of resources. In the Pampas region of Argentina, there is a need to assess the effects of these practices on soils, particularly on soil fauna, as they play an important role in soil functioning. The aim of this study was to evaluate the effect of the application of GAPs under NT on invertebrates and to assess whether this effect is different between soil types. We hypothesized (1) that GAP will produce an increase in the abundance, as well as changes in the faunal composition of litter and soil invertebrates; (2) that the effects will differ with soil type, and (3) that the changes in soil invertebrate fauna will be explained by soil properties. We compared two contrasting NT treatments -with and without GAP application-, replicated in three agricultural areas, on different soil types (Entic Haplustolls to Typic Argiudolls) situated across a west–east transect in the Pampas region of Argentina. A positive (Natural environment) and a negative (Conventional tillage) reference sites were included in the comparison. Litter and soil invertebrates and soil properties were assessed at each sampling site. Overall, our results indicated that the application of GAPs in productive NT fields increases litter and soil invertebrate abundance and modifies faunal composition. In the litter layer, four of the five taxa present were favoured by GAPs with an increase in the abundances of ants, prostigmatid mites, earthworms and collembolans. GAPs also induced changes in invertebrate faunal composition, from the initial NO-GAP situation to the present state under GAP system. The observed changes in litter and soil invertebrates, changes in faunal abundance and composition can be expected to translate to changes in soil functioning. Our last hypothesis was partially confirmed in that soil properties have to be considered in the examination of differences in fauna between treatments with there are only subtle differences in practices, as in the present study.

1. Introduction

No-till (NT) has been widely adopted across the entire Pampas region of Argentina, including areas previously considered not highly productive. NT currently accounts for over 78% of the total area cultivated with soybean (*Glycine max*), maize (*Zea mays*), sunflower (*Helianthus annuus*), wheat (*Triticum aestivum*) and sorghum (*Sorghum bicolor*) (AAPRESID, 2012; Albertengo et al., 2013). Soybean and maize are the dominant crops, with more than 20 and 6 million hectares cultivated in the 2012/2013 crop cycle, respectively (MAGyP, 2014). Interestingly, even when soil cover crops and appropriate rotation schedules under NT are recognized as necessary to achieve all the NT benefits for soil quality, most farmers only grown single species crops, use NT seeders and a chemical winter fallow. These practices have led to physical, chemical and biological soil degradation even under NT (Díaz-Zorita et al., 2002; Parra et al., 2009; Domínguez et al., 2010; Bedano et al., 2011). In response to a decline in soil quality, a group of farmers organized the Argentine No-till Farmers Association (AAPRESID) and started to adopt and promote crop species rotation; cover crops; integrated pest, weed and disease management; nutrient restoration; and a rational use of agrochemicals as an integral part of a NT system. Together these practices are called

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"Good Agricultural Practices" (GAPs), in accordance with the definition of the Food and Agricultural Organization (FAO) described in Poisot et al. (2004). Nowadays, AAPRESID considers that only when all the GAPs are implemented is management considered a sustainable "no-till system" achieving high productivity, while maintaining the production capacity of resources (Albertengo et al., 2011). Farmers from AAPRESID have reported higher yields when GAPs are applied as an integral part of the NT system.

The important role of soil fauna in soil functioning is well known, in particular in the formation of stable soil aggregates, pore size and function, the production and decomposition of organic matter, and population stability of the various soil inhabiting organisms (El Titi, 2003). Soil fauna can be separated into mesofauna and macrofauna according to their body width. Soil mesofauna (0.1 and 2 mm) is dominated by mites (Acari) and springtails (Collembola), which are among the most abundant and widespread soil arthropods in most soils and both have important roles in soil organic matter cycling through their feeding activities (Bedano et al., 2006a,b). Soil macrofauna (>2 mm) includes earthworms, ants, termites, and beetles, and are important in both organic matter cycling and soil structure formation (Lavelle et al., 2006).

With sustainable agricultural practices becoming a priority for farmers and the general public alike, a more complete understanding of the soil ecosystem is needed (Stubbs et al., 2004). In the Pampas region, the dissemination of GAP's benefits under NT by AAPRESID, does not include an assessment of the effects of these practices on soils and particularly on soil fauna. In this region, there is evidence showing a negative effect of NT -without GAP- on soil macrofauna (e.g., Domínguez et al., 2010) and mesofauna (Arolfo et al., 2010). To date there has been no evaluations of GAP applications on reversing the decline in soil quality.

Soil development is governed by five different soil-forming factors, namely climate, vegetation, relief, parent material, and time (Jenny, 1941). Within a continuum of possibilities, there are recognizable soil types that originate, depending on variations in these factors, which largely determine the dominant physical and chemical soil properties (Kibblewhite et al., 2008). Evaluation of GAPs on soil must recognize the natural differences between soil types. Here, we compared two contrasting NT treatments, which were replicated in three agricultural areas with different soil types, across a west-east transect in the Pampas region of Argentina. The treatments consist of a "no-till system", where NT with Good Agricultural Practices is applied (GAP), and a NT system without GAP application (NO-GAP). For both treatments the management history of each plot is well documented by farmers.

This study is part of BIOSPAS project (Biology of Soil and Sustainable Agricultural Production, www.biospas.org), a multidisciplinary research project aiming to find biological indicators of sustainability under NT farming by means of a polyphasic description (Wall, 2011). Previous studies (Duval et al., 2013) found no differences in SOM concentration in the top 10 cm between GAP and NO-GAP treatments. There were also no differences in soil bulk density. A biological indicator was developed that discriminate between GAP and NO-GAP soils. This was the ratio between the abundance of a selected group of bacteria within the GP1 group of the phylum Acidobacteria and the genus Rubellimicrobium of the phylum Alphaproteobacteria (Figuerola et al., 2012). Agricultural management was also found to have a strong influence on β-diversity patterns, with the NO-GAP having a significantly lower β-diversity and narrower breadth compared with GAP, because of loss of endemic taxon groups (Figuerola et al., 2014). Soil fatty acid profiles from Phospholipids (PLFA) and Neutral Lipids (NLFA) fractions clearly discriminated between GAP and NO-GAP, whereas GAP soils were particularly characterised by higher concentrations of the fatty acid 20:0 and total NLFAs concentration in winter (Ferrari et al., 2015).

To the best of our knowledge, the effects of GAPs on litter and soil invertebrates have not been systematically investigated. Therefore, the objective of this study was to evaluate the effect of the application of GAPs under NT on litter and soil invertebrates and to assess whether this effect differs between soils types. We hypothesized that (1) GAP will produce an increase in the abundance, as well as changes in the faunal composition of litter and soil invertebrates; (2) that the effects will differ between soil types, and (3) that the changes in soil invertebrate fauna will be explained by associated changes in soil properties.

2. Materials and methods

2.1. Study sites

The study sites were located in the most productive zone of the Pampas Region of Argentina, at Bengolea (Córdoba province; 33° 01′ 32.9″ S, 63° 37′ 36.4″ W), Monte Buey (Córdoba province; 32° 58′ 17.0′′ S, 62° 27′ 02.4′′ W) and Pergamino (Buenos Aires province; 33° 56′ 42.6″ S, 60° 33′ 35.6″ W) (Fig. 1). In Bengolea and Monte Buey the climate is temperate subhumid with a mean annual temperature of 17 °C; in Pergamino the climate is temperate humid with a mean annual temperature of 16 °C. Mean annual precipitation is 870, 910 and 1000 in Bengolea, Monte Buey and Pergamino, respectively. The slope in all sites is lower than 0.5% and the altitude is on average 223, 110 and 66 m a.s.l. in the three areas, respectively.

The sites were selected according to soil type, from the Entic Haplustolls (sandy loam) in Bengolea, Typic Argiudolls (silty loam) in Monte Buey, to the Typic Argiudolls (silty clay loam) in Pergamino. The three sites have soil types with increasing clay and decreasing sand concentration from Bengolea (west) to Pergamino (east).

2.2. Treatments

The treatments were defined according to a set of definitions of GAPs provided by FAO (www.fao.org/prods/GAP/index_en.htm) and AAPRESID (http://www.aapresid.org.ar/ac/wp-content/uploads/sites/4/2013/02/manual.pdf), described in Poisot et al. (2004) and Albertengo et al. (2011). The final treatments and study sites were defined after thoughtful discussion between the scientists and the farmers participating of the BIOSPAS project. Four treatments were defined: (1) Good agricultural practices under NT (GAP): subjected to intensive crop rotation (including winter cover crops), nutrient replacement, and minimized agrochemical use (herbicides, insecticides and fungicides) (Table 1); (2) No-till management without good agricultural practices (NO-GAP): high crop monoculture (soybean), low nutrient replacement and high agrochemical use (herbicides, insecticides and fungicides) (Table 1); (3) Conventional tillage (CT): Mouldboard and disc ploughing, low nutrient replacement and high agrochemical use; (4) Natural Environment (NA): undisturbed natural grassland adjacent to the cultivated treatments (less than 5 km), where no cultivation was practiced for (at least) the last 30 years. Both the NA and CT reference sites, were located near the NT treatment.

The treatments were replicated three times in the three agricultural regions with different soil types, situated across the west-east transect described previously, with the exception of CT, which was not available in Bengolea. Table 1 summarizes the information on the agricultural practices and crop yields of the different study sites. All sites had been under NT for at least five years before sampling (100% of NT), with the exception of a chisel