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Soil carbon, nitrogen, pH, and earthworm density as influenced by cropping practices in the Inland Pacific Northwest

Karl J. Umiker *, Jodi L. Johnson-Maynard, Timothy D. Hatten, Sanford D. Eigenbrode, Nilsa A. Bosque-Pérez

University of Idaho, Department of Plant, Soil and Entomological Sciences, P.O. Box 442339, Moscow, ID 83844-2339, USA

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ABSTRACT

Farmers within the Inland Pacific Northwest are gradually transitioning to direct seed (DS) practices that reduce soil disturbance and increase surface residue compared to conventional tillage (CT). Despite this transition the impacts of DS practices on soil properties and fauna in commercial fields has been little studied in the region. During the spring and summer of 2002 and 2003 we compared soil organic carbon (SOC), total nitrogen (TN), pH, and earthworm and cocoon densities in CT and DS fields planted to either spring wheat or pea in the Palouse region of northern Idaho. In 2002 mean SOC within the 0–10-cm depth was greater in DS fields (2.05%) than at the same depth in CT fields (1.79%), however SOC within the 30–40-cm depth was lower under DS compared to CT. Mean soil pH within the 0–10-cm depth was 5.35 under DS and 5.61 under CT indicating that pH stratification can occur when tillage is reduced. Tillage effects on SOC, TN, and pH were not found in 2003. Tillage also did not significantly influence earthworm densities, which averaged 39 individuals m^{-2} in 2002 and 57 individuals m^{-2} in 2003. Correlations were detected in 2003 DS fields between soil properties (SOC and TN) and earthworm and cocoon densities at depths above 30 cm while in 2002 correlations in DS fields occurred with cocoon density, but not with earthworm density. Direct seed management can increase near-surface SOC and TN concentrations compared to CT practices, however, SOC concentrations deeper in the soil appear to remain the same or possibly decrease. Higher SOC and TN near the soil surface, as found in DS fields, appear to promote greater earthworm densities, which may improve long-term soil productivity.

1. Introduction

The Palouse region of northern Idaho and eastern Washington, USA is characterized by deep, silt loam-textured soils that are formed in loess and are well suited for cereal and legume production. The Palouse region is approximately 800,000 ha in size and is one of the most productive wheat (*Triticum aestivum* L.) growing regions in the United States (Hall et al., 1999); however, with slopes of up to 30% or more, tillage-related erosion threatens the region's productivity (Busacca et al., 1985, 1993; Mulla, 1986). Direct seed (DS) management, a tool in many conservation tillage (ConsT) systems, limits soil erosion by reducing soil disturbance and conserving surface residue (Veseth and Karow, 1999). Adoption of ConsT practices in previously plowed fields has been shown to increase soil carbon levels with an average rate of 570 kg C ha^{-1} $year^{-1}$ (West and Post, 2002). Results of some studies, however, show that ConsT practices promote greater carbon levels at the soil surface but deplete carbon with depth (Etana et al., 1999; Yang and Wander, 1999; Baker et al., 2007; Gál et al., 2007) potentially resulting in no net change in soil carbon storage compared to conventionally tilled systems. In addition to influencing soil organic carbon (SOC), reduced tillage has also been shown to stratify pH (Limousin and Tessier, 2007) and alter other soil properties (Grant and Lanfond, 1993; Franzluebbers et al., 1995) that may ultimately influence plant productivity and therefore, SOC levels.

Direct seed management directly influences soil properties through lack of disturbance, but also has indirect effects that arise from its influence on soil organisms such as earthworms. Although earthworms are considered to be biological indicators of soil quality (Doran and Zeiss, 2000), little information is available concerning tillage- or crop-related effects on earthworm populations within the Palouse region. The surveys of Fender (1985) and James (2000) covered portions of the Palouse region but focused on non-agricultural lands. Fauci and Bezdicek (2002) surveyed agricultural fields on the Palouse, and found four exotic earthworm species with *Aporrectodea trapezoides* being the most common, but earthworm density and soil properties were not measured. In a replicated research station plot experiment, the density of earthworms was significantly greater under no-till (NT) (150 individuals m^{-2}) vs. conventional tillage (CT) (38 individuals m^{-2}) (Johnson-Maynard

* Corresponding author at: University of Idaho, Ag. Sci. Bldg. Rm 242, Moscow, ID 83844-2339, USA. Tel.: +1 208 885 7505; fax: +1 208 885 7760.
E-mail address: kumiker@uidaho.edu (K.J. Umiker).

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et al., 2007), paralleling research from other regions (Jordan et al., 1997; Brown et al., 2003).

Conservation tillage favors greater earthworm populations than CT for several reasons. The accumulation of crop residue in ConsT systems preserves soil moisture (Veseth, 1985) and moderates soil surface temperatures (Hatten et al., 2007b), factors known to influence earthworm densities (James, 2000; Chan, 2001). Higher organic matter levels found near the soil surface in DS systems may also lead to increases in earthworm density (Hendrix et al., 1992). In turn, earthworms may increase SOC levels by incorporating surface residue and by increasing plant productivity and soil aggregation (Lee, 1985). Larger numbers of earthworms in ConsT systems may therefore enhance SOC levels above what is expected due to reduced soil disturbance alone.

Few studies on SOC storage in ConsT soils of the Palouse have been conducted. Due to its size and known level of agricultural productivity, the Palouse may represent an important, but incompletely characterized carbon sink at the regional and national scales. Additionally, it is important to understand how changes in SOC influence the density of keystone species such as earthworms, since the activity of these organisms may feedback to enhance SOC storage. Our main goals were, therefore, to (1) quantify the effects of tillage practices on SOC, TN, pH, and earthworm density, biomass, and fecundity, and (2) relate earthworm density, biomass, and fecundity to measured soil properties (SOC, TN, and pH) in commercial fields of the Palouse. Although plot studies have been conducted at a University experimental farm (Kambitsch Farm) within the study area (Hatten et al., 2007a), cultural farming practices of the region are heterogeneous and necessitate study on a regional basis. Expanding the study area to include on-farm, field-scale research was, therefore, necessary to assess regional effects of agricultural practices on soil properties and earthworms.

2. Materials and methods

2.1. Study sites

Twelve fields were sampled between late spring and early summer of 2002 and of 2003 for a total of 24 fields. Although the 12 fields were different between years, all fields were located in the high rainfall zone (i.e. southeast region) of the Palouse in Latah and Nez Perce Co., ID. Half the sampled fields were managed under CT and half under DS. Fields were defined as CT if a moldboard plow or a chisel followed by a cultipactor was used prior to seeding and defined as DS if a drill was used to deposit the seed into stubble (Hatten, 2006). All DS fields were considered ConsT since greater than 30% of the soil surface was covered with residue through planting (Veseth and Karow, 1999). All sampled fields were part of a 3-year cereal-legume crop rotation consisting of spring wheat, winter wheat, and peas (*Pisum sativum* L.) or lentils (*Lens cultinaris* L.) (Hatten, 2006), but only pea and spring wheat were sampled during the study (12 fields per crop total). In sampled fields, spring wheat always followed winter wheat while peas always followed spring wheat. Fields were usually planted in early- to mid-May. Fertilizer was applied to spring wheat prior to or during planting, while fertilizer was generally not applied to pea crops. To account for inter-field differences in management practices (Chan and Barchia, 2007) and cropping history, a detailed survey was sent out to all farmers involved in the study to gain information on field-specific crop cultural practices including fertilizer application dates and rates and this information is available (Hatten, 2006). Average annual precipitation measured between 1974 and 2003 at the Palouse Research, Education, and Extension Center, which is located within 6–29 km from the study sites, is 714 mm.

Table 1
Notable transect characteristics for each field sampled in 2002 and 2003.

Field #	Crop	Tillage	Aspect (°)	Slope (%)	Elevation (m)	Years in DS
2002						
1	W	DS	65	7	894	6
1	W	DS	202	9	917	6
2	W	DS	27	17	883	6
2	W	DS	99	6	885	6
3	W	CT	187	19	897	na
3	W	CT	54	15	911	na
4	P	CT	197	22	912	na
4	P	CT	173	11	910	na
5	W	CT	197	25	853	na
5	W	CT	7	10	853	na
6	P	CT	353	15	836	na
6	P	CT	344	10	850	na
7	W	CT	189	16	851	na
7	W	CT	298	8	832	na
8	P	DS	332	20	873	3
8	P	DS	212	18	867	3
9	P	DS	50	14	831	6
9	P	DS	125	10	849	6
10	P	CT	358	14	831	na
10	P	CT	284	6	860	na
11	P	DS	73	27	792	6
11	P	DS	53	14	809	6
12	W	DS	192	5	707	7
12	W	DS	19	34	679	7
2003						
13	P	CT	40	15	869	na
14	P	DS	39	17	845	5
15	W	DS	32	20	833	2
16	W	CT	59	13	848	na
17	P	CT	30	13	862	na
18	W	CT	48	19	767	na
19	P	DS	74	17	851	2
20	W	DS	57	12	844	2
21	W	DS	17	20	858	2
22	P	CT	15	16	869	na
23	P	DS	34	17	856	2
24	W	CT	30	21	813	na

Two transects per field were sampled in 2002 and one transect per field was sampled in 2003. W = wheat; P = pea; DS = direct-seeded; CT = conventionally tilled; na = not applicable.

To account for the influence of seasonality on earthworm populations, we blocked each sample within discrete time periods of no longer than 16 days. Blocks consisted of 4 fields with each crop and tillage treatment represented. In 2002, two transects were sampled per field with each transect consisting of 5 potential sites spaced 67 m apart. Three of the five sites per transect were selected for sampling based upon similar aspect and slope for a total of six soil pits per field. Transects were generally placed across midslopes with 3–35% slope. In 2002, both cool (north and east—315–135°) and warm (south and west—135–315°) facing aspects were sampled (Table 1). To reduce the variability, in 2003 only midslopes of cool aspects were sampled. In 2003, one transect per field was sampled with each transect consisting of 10 sampling sites spaced 33 m apart (10 pits/field). In total, 72 pits in 2002 and 120 pits in 2003 were sampled. Across fields and years, soils in this study were classified as Argialbolls, Argixerolls, or Haploxerolls (Soil Survey Staff, 2007a,b).

2.2. Earthworm and soil sampling

Sampling occurred from 17 June 2002 through 15 July 2002 and from 5 June 2003 through 26 June 2003. Sampling began when the soils were dry enough to allow access to the field but moist enough to encourage maximum earthworm activity. Pits averaging 0.2 m × 0.3 m × 0.5 m were hand dug and excavated soil was placed in buckets. Earthworms and cocoons were then separated