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INTERNATIONAL Agrophysics
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Int. Agrophys., 2015, 29, 137-145
doi: 10.1515/intag-2015-0030

Effects of tillage, rotation and cover crop on the physical properties of a silt-loam soil**

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Received January 13, 2015; accepted April 20, 2015

A b s t r a c t. Soil and crop management practices can affect the physical properties and have a direct impact on soil sustainability and crop performance. The objective of this study was to investigate how soil physical properties were affected by three years of tillage, cover crop and crop rotation treatments in a corn and soybean field. The study was conducted on a Waldron silty-loam soil at Lincoln University of Missouri. Soil physical properties studied were soil bulk density, volumetric and gravimetric water contents, volumetric air content, total pore space, air-filled and water-filled pore space, gas diffusion coefficient and pore tortuosity factor. Results showed significant interactions ($p<0.05$) between cover crop and crop rotation for bulk density, gravimetric and total pore space in 2013. In addition, cover crop also significantly interacted ($p<0.05$) with tillage for bulk density and total pore space. All soil physical properties studied were significantly affected by the depth of sampling ($p<0.0001$), except for bulk density, the pore tortuosity factor and total pore space in 2012, and gravimetric and volumetric in 2013. Overall, soil physical properties were significantly affected by the treatments, with the effects changing from one year to another. Addition of a cover crop improved soil physical properties better in rotation than in monoculture.

K e y w o r d s: cover crop, rotation, tillage, soil physical properties, corn/soybean

INTRODUCTION

Soil and crop management practices have the potential to provide several benefits to farmers and to the ecosystem, and have been studied by many authors (Blanco-Canqui *et al*., 2011; Hill, 1990; Osunbitan *et al*., 2005; Özgöz *et al*., 2007; Radcliffe *et al*., 1988; Raper *et al*., 2000; Sharratt *et al*., 2006). However, studies on these soil management practices, especially tillage, have yielded conflicting results for soil properties in general and for soil physical properties in particular. For soil bulk density, as an example, after 14 years of tillage practice, Anken *et al*. (2004) found that tillage did not significantly affect soil bulk density. Similar results were also reported by Arshad *et al*. (1999), Logsdon *et al*. (1999) and Taboada *et al*. (1998) in much shorter studies.

In contrast, Hill (1990) and Mahboubi *et al*. (1993) found greater soil bulk density in no-tillage compared with conventional tillage. Other studies also reported that soil bulk density was greater in no-till in the 5-10 cm soil depth as compared to tillage (Grant and Lafond, 1993; Osunbitan *et al*., 2005; Radcliffe *et al*., 1988; Rhoton *et al*., 1993; Strudley *et al*., 2008; Wander and Bollero, 1999; Hussain *et al*., 1998).

Besides soil bulk density, other soil properties were also differently affected by soil tillage. Hussain *et al*. (1998) noted higher water content within a no-tillage system than within conventional tillage. In a 20-year study, Sharratt *et al*. (2006) reported that no-tillage had greater soil penetration resistance and water content compared to all other tillage treatments. Similar results were also reported by Hill (1990) and Mahboubi *et al*. (1993). Some authors have finally suggested that tillage practices can also alter soil physical properties and, consequently, the surface and subsurface hydrology of agricultural fields, especially when a similar tillage system has been practiced for a long period (Buschiazzo *et al*., 1998; Gómez *et al*., 1999; Hill, 1990; Özgöz *et al*., 2007; Tsegaye and Hill, 1998).

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**This work is part of a regional collaborative project supported by the USDA-NIFA, Award No. 2011-68002-30190, ‘Cropping Systems Coordinated Agricultural Project: Climate Change, Mitigation, and Adaptation in Corn-based Cropping Systems’. Project Web site: http://sustainablecorn.org

The discrepancies in the results previously reported on the effects of soil and crop management practices on soil physical properties suggest that more studies needs to be conducted. Furthermore, in many of these previous studies, the effect of one or two management practices such as tillage or cover crop or rotation on soil properties was studied. Few studies have looked at a combination of several of these soil and crop management practices on soil physical properties. The objective of this study was therefore to investigate the effects of a combination of tillage, crop rotation and cover crop on soil physical properties.

MATERIALS AND METHODS

The study was conducted at Lincoln University of Missouri Freeman farm in Jefferson City from 2011 to 2013. The site is located between latitude 38°58'16"N and longitude 92°10'53"W, in the bottom land of the Missouri river. The elevation is 166 m above sea level with a 2% slope (Fig. 1). The soil type is a Waldron silt loam (Fine, smectitic, calcareous, mesic Aeric Fluvaquents). It has a fine sub-angular blocky structure in the Ap horizon which extends from the surface to a depth of about 20 cm. The Ap horizon is underlain by C1 (20-35 cm), C2 (35-43 cm), Cg1 (43-71 cm), Cg2 (71-101 cm) and Cg3 (101-152 cm) horizons, all of similar structure. The mean annual precipitation between 2011 and 2013 was 990.6 mm, with the months of May and January usually receiving the highest (127 mm) and lowest (50.8 mm) precipitations, respectively. However, 2012 was a particularly dry year with an average precipitation of about 752.09 mm. Twenty four plots of each corn (*Zea mays*) and soybean (*Glycine max*) were established on a 4.05 ha field and arranged in a 3-factor factorial design with 3 replications. Each of the plots had a length and breadth of 12.2 x 21.3 m. The 3 factors (treatments) were tillage at two levels (no-tillage *vs.* conventional [mouldboard plough] tillage), cover crop at two levels (no-rye vs. rye) and rotation at four levels (continuous corn, continuous soybean, corn/soybean and soybean/corn rotations). The field was mouldboard ploughed (henceforth referred to as conventional tillage) before planting corn and soybean. Corn and soybean were planted each year in late May/early June and harvested in late October. Rye (*Secale cereale*) was planted in 12 plots of each corn and soybean immediately after corn and soybean harvest. All corn and soybean plots received 26 kg N, 67 kg P_2O_5, and 67 kg K_2O ha^{-1}. However, the corn plots received an additional 202 kg N ha^{-1} from urea.

Soil samples were taken two weeks after tillage and planting in 2011 and at the end of the growing seasons in 2012 and 2013 (after rye harvest). They were taken at points in the centre of each plot with no trafficking to avoid compaction. They were taken using cylindrical cores with a diameter of 6.3 cm at four different depths of 0-10, 10-20, 20-40, and 40-60 cm, corresponding to depths 1, 2, 3 and 4, respectively. Because of the difference in sampling depths, the cylindrical cores used were of two different heights: 10 and 20 cm for samples at: 0-10, 10-20 cm and 20-40, 40-60 cm, respectively. The volumes (V) of the cores were 311.57 and 622.98 cm^3 for 10 and 20 cm probe, respectively. The soil samples were then taken to Lincoln University Dickenson research laboratory where they were weighed (wet weight of sample, WWS), then oven dried at 105°C

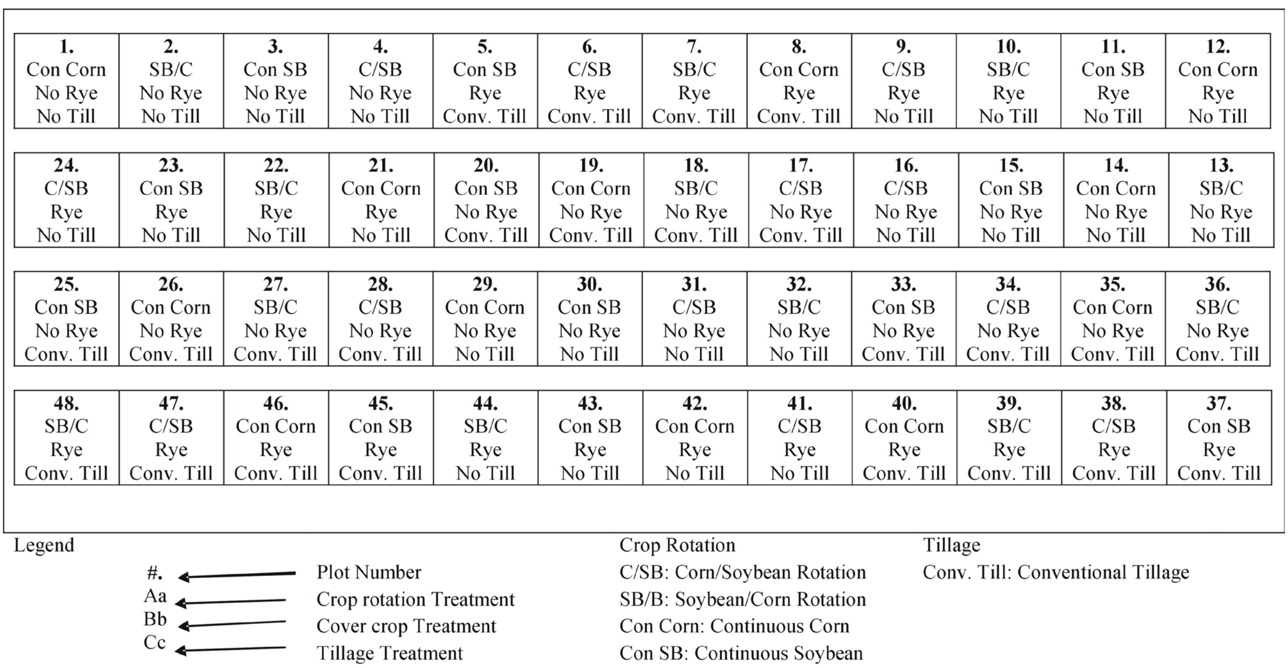

Fig. 1. Experimental set up.

for 72 h. Soil physical properties were calculated as follows: BDY was calculated as a ratio of the oven dry soil weight to the total soil volume. Volumetric water content (VWC) was estimated by subtracting DWS from WWS and dividing by the total soil volume. Gravimetric water content (GWC) was calculated by subtracting DWS from WWS and dividing it by the DWS. Total pore space (TPS) was analysed by subtracting the ratio of BDY to particle density (taken as 2.65 g cm^{-3}) and subtracting it from 1 (the number one). Volmetric air content (VAC) was calculated by subtracting VWC from TPS. Water-filled (WFPS) and air-filled pore space (AFPS) were calculated as a percent of the ratio of VAC to TPS and as a percent of the ratio of VAC to TPS, respectively. The gas diffusion coefficient (Ds/Do) was estimated by squaring the AFPS, while pore tortuosity factor (Tort) was calculated as the reciprocal of VAC (Nkongolo *et al*., 2010).

Soil texture was determined by the sieve and pipette method (Smith and Mullins, 1991). After the soil physical properties were calculated, the data was transferred to Minitab version 16.2 for statistical analysis. Analysis was done on the data with respect to moments (the shape of the sample statistical distribution: skewness, kurtosis, mean and standard deviation), and coefficient of variation (CV) at the four sampled depths for each of the plots in all the years of study (results no showed). Because the effects of some of the treatments (cover crop and crop rotation) could only be felt in the second year (2012), analysis of variance differed in 2011 as compared to 2012 and 2013.

RESULTS AND DISCUSSION

The means for soil texture at the four depths are shown in Table 1. The soil contained more silt than clay and sand in all the depths. The amount of silt slightly decreased in depth 2 (10-20 cm) and depth 3 (20-40 cm) as compared to depth 1 (0-10 cm). Sand, in opposite, was the lowest in depth 1, while clay increased and decreased as we moved deeper into the soil. On the field, sand had the highest variation while silt showed the least variation.

This study began in 2011 and the effect of cover crop and crop rotation treatments on soil physical properties could be felt only in subsequent years. Therefore, the 2011 analysis focused only on the effects of tillage and depth on soil physical properties (Table 2). The analysis of variance showed significant Tillage x Depth interactions for AFPS, Ds/Do, Tort, VAC and WFPS. AFPS was the greatest in the 0-10 cm depth of conventionally tilled plots and the least in the 10-20 cm depth of no-till plots. The difference between the highest AFPS and the least AFPS was about 25%. Ds/Do was greater in the upper 10 cm of conventionally tilled plots, but lower in the 40-60 cm depth of no-till plots. This can be explained by the fact that tillage exposes the soil to sunlight, which increases evaporation of soil moisture therefore increasing the percentage of pore space filled with air. In addition, loose and fluffy soils offer less restriction to gas diffusion compared with a compacted soil. The pore tortuosity factor (Tort) was greater in the 10-20 cm and the lowest in the 20-40 cm depth of no-till plots as expected. Volumetric air content had its highest values in the upper 10 cm of conventionally tilled plots and lowest in the 40-60 cm depth of conventionally tilled plot. Finally, there were more WFPS in the 10-20 cm depth of no-till plots and less in the upper 10 cm of tilled plots. All the soil physical properties studied were significantly affected by depth of sampling ($p<0.001$), as shown in Table 2. However, only GWC and VWC were significantly affected by tillage ($p<0.05$). GWC and VWC were 8% and 10% greater under no-till compared with conventional tillage treatment, respectively.

Table 1. Means for soil texture at four depths in a silt-loam soil

Depth of sampling (DS) (cm)	Clay	Silt	Sand
0-10	20.11±1.02	65.06±1.47	14.83±1.97
10-20	20.85±1.02	63.30±1.50	15.85±2.03
20-40	19.85±0.91	63.12±1.30	17.03±1.79
40-60	20.97±0.87	63.84±1.61	15.19±2.04

The effects of tillage, crop rotation, cover crop and depth of sampling on soil physical properties for the second year (2012) are shown in Table 3. Significant cover crop x depth of sampling interactions ($p<0.05$) were found for BDY, Ds/Do, GWC and TPS. In addition, there was a significant crop rotation x depth of sampling interaction for GWC ($p<0.05$). The interaction between cover crop and depth of sampling is presented in Fig. 2 for BDY and TPS, respectively. They suggest that the benefits of the cover crop (rye) roots in decreasing soil bulk density (reducing soil compaction) and increasing total porosity were more prominent in the top 10 cm of the soil. At deeper depths (20-60 cm), the influence of rye is no longer felt since BDY and TPS were higher in rye planted plots as compared to no-rye plots. This is understandable, since most rye roots were concentrated in the 0-10 cm depth. Our results agree with those by Villamil *et al*. (2006) who reported similar findings. The cover crop x depth of sampling interaction showed that Ds/Do was 25% (0-10 cm) and 14% (10-20 cm) greater in plots planted to rye as compared with plots with no cover crop. This same interaction also showed that GWC was 10% greater in cover crop compared with no cover crop plots in the 10 cm layer of the soil. Blanco-Canqui *et al*. (2011) also reported a 4% increase in soil water content with cover crop. These results suggest an improvement in bio-pores which have been reported to increase water retention and infiltration (Bruce *et al*., 1992; Joyce *et al.,* 2002; Wilson *et al*., 1982) and to reduce runoff and soil loss. However,

T a b l e 2. Effects of tillage and depth of sampling on selected soil physical properties in 2011

Treatment	AFPS	BDY	Ds/Do	GWC	Tort	TPS	VAC	VWC	WFPS
Tillage (TL)					Means				
No-till	42.06a	1.28a	0.06a	0.25a	5.14a	0.52a	0.23a	0.30a	57.94a
Conventional tillage	43.08a	1.26a	0.06a	0.23b	5.20a	0.53a	0.24a	0.27b	56.92a
Depth of sampling (DS) (cm)									
0-10	47.48a	1.25b	0.07a	0.22b	4.62b	0.53b	0.26a	0.27b	52.52c
10-20	37.42c	1.44a	0.04c	0.20c	6.67a	0.46c	0.18b	0.28b	62.58a
20-40	43.73ab	1.20c	0.06ab	0.26a	4.72b	0.55ab	0.24a	0.30a	56.27bc
40-60	41.65b	1.18c	0.05b	0.27a	4.67b	0.56a	0.23a	0.32a	58.35b

Analysis of variance

Sources of variation	df	AFPS	BDY	Ds/Do	GWC	Tort	TPS	VAC	VWC	WFPS
Blocks	2					p-values				
Tillage (TL)	1	0.3366	0.1441	0.8876	0.0259	0.7858	0.1621	0.7966	0.0391	0.3366
Depth of sampling (DS)	3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
					Interaction					
DS x TL	3	0.0075	0.1036	0.0097	0.5963	0.0157	0.1183	0.0066	0.0600	0.0075
Error (MS)	182	53.3230	0.0101	0.0007	0.0010	2.1814	0.0015	0.0025	0.0011	53.3230
Total	191									

Means followed by different alphabet in the same treatment and depth of sampling are statistically significant at the 0.05 probability level. p-values < 0.05 are statistically significant. AFPS – air filled pore space (%); BDY – soil bulk density (g cm^{-3}); Ds/Do – relative gas diffusion coefficient ($m^2 s^{-1} m^{-2} s$); GWC – gravimetric water content of soil (g g^{-1}); TPS – total pore spaces ($cm^3 cm^{-3}$); Tort: pore tortuosity factor (m m^{-1}); VAC – volumetric air content ($cm^3 cm^{-3}$); VWC – volumetric water content ($cm^3 cm^{-3}$); WFPS – water filled pore space (%).

in contrast, Ewing *et al*. (1991) suggested that cover crop lowered soil moisture and reduced the productivity of subsequent cash crops. Finally, the interaction between crop rotation and depth of sampling suggested that GWC was 42% greater in corn/soybean rotation compared with continuous soybean treatment where GWC was the lowest. This is understandable, as after harvest corn residues were left on the soil and therefore helped to reduce evapotranspiration. Fewer residues were left in a soybean monoculture. The cover crop alone also significantly affected BDY and TPS ($p<0.05$). Although not significant, we did notice an increase in AFPS, Ds/Do and VAC in plots with cover crop (Rye), confirming a potential increase of bio-pores, which improved infiltration as suggested by Joyce *et al.* (2002).

The effects of tillage, cover crop, crop rotation, and depth of sampling on soil physical properties after the three-year study (2013) are shown in Table 4. In contrast to the previous assessments, this analysis focused only on the first two depths (0-10 and 10-20 cm) where the effect of cover crop would be more felt, given its short rooting system. In comparison to the first two years of this study, soil physical properties responded differently to tillage, crop rotation, cover crop, and depth of sampling. In fact, the analysis of variance showed that none of the interactions reported in 2012 were present in 2013, suggesting that the interactions between various soil and crop management practices are complex in nature and their effects on soil physical properties may not be easily predictable.

Bulk density was significantly affected by cover crop x crop rotation and cover crop x tillage interactions. These interactions are presented in Figs 3 and 4. Figure 3 suggests that the addition of a cover crop to monocultures of soybean and corn increased soil bulk density in comparison to no cover crop plots. However, in rotation plots the addition

Table 3. Effects of tillage, crop rotation, cover crop and depth of sampling on selected soil physical properties in 2012

Treatment		AFPS	BDY	Ds/Do	GWC	Tort	TPS	VAC	VWC	WFPS
Tillage (TL)						Means				
No-till		46.77a	1.37a	0.06a	0.19a	5.24a	0.48a	0.23a	0.25a	53.23a
Conventional tillage		47.04a	1.40a	0.07a	0.18a	5.41a	0.47a	0.23a	0.24a	52.96a
Crop rotation (CR)										
Continuous corn		46.81a	0.25a	0.07a	0.20a	5.18a	0.49a	0.24a	0.25a	53.81a
Continuous soybean		47.02a	0.23a	0.06a	0.17a	5.58a	0.45a	0.22a	0.23a	52.98a
Corn-soybean rotation		46.19a	0.26a	0.06a	0.20a	5.19a	0.49a	0.23a	0.26a	53.81a
Soybean-corn rotation		47.60a	0.24a	0.07a	0.19a	5.18a	0.48a	0.23a	0.24a	52.40a
					Cover crop (CC)					
No-rye		46.76a	1.48a	0.06a	0.21a	5.33a	0.43b	0.24a	0.25a	53.24a
Rye		47.05a	1.34b	0.07a	0.18a	5.31a	0.49a	0.22a	0.24a	52.95a
Depth of sampling (DS) (cm)										
0-10		44.10b	1.39b	0.05b	0.20a	5.35a	0.47b	0.21bc	0.26a	55.90a
10-20		42.10b	1.53a	0.03b	0.17a	6.34a	0.42c	0.18c	0.25a	57.90a
20-40		46.22b	1.36bc	0.06b	0.20a	5.44a	0.49ab	0.23b	0.26a	53.78a
40-60		55.21a	1.25c	0.11a	0.19a	4.16b	0.53a	0.30a	0.23a	44.79b
					Analysis of variance					
Sources of variation	df	AFPS	BDY	Ds/Do	GWC	Tort	TPS	VAC	VWC	WFPS
Blocks	2					p-values				
Tillage (TL)	1	0.8989	0.3578	0.8926	0.2737	0.6034	0.3687	0.9394	0.3077	0.8989
Crop rotation (CR)	3	0.9731	0.2325	0.8373	0.0742	0.8117	0.2358	0.8505	0.3425	0.9731
Cover crop (CC)	1	0.8919	0.0507	0.1029	0.0632	0.9547	0.0504	0.2669	0.3278	0.8919
Depth of sampling (DS)	3	0.0001	0.0000	0.0000	0.1412	0.0001	0.0000	0.0000	0.0667	0.0001
					Interactions					
CC x DS	3	0.3189	0.0509	0.0486	0.0243	0.2442	0.0501	0.2024	0.1491	0.3189
CR x DS	9	0.7846	0.2575	0.9244	0.0501	0.7971	0.2756	0.8787	0.1573	0.7876
Lack of fit	48									
Error (MS)	135	214.55	0.0615	0.0037	0.0048	5.1028	0.0088	0.0109	0.0048	214.55
Total	191									

Explanations as in Table 2.

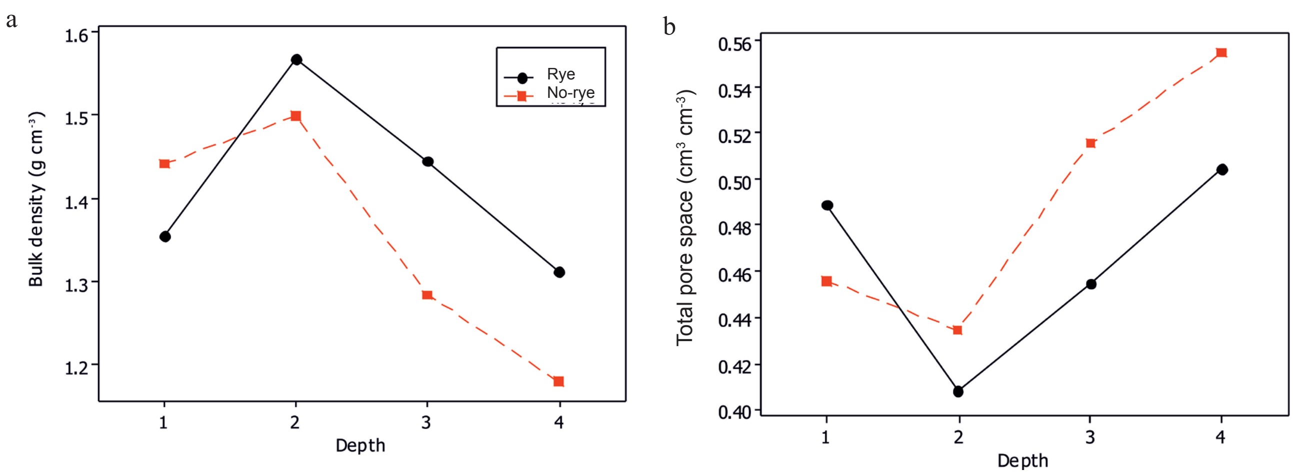

Fig. 2. Effect of cover crop x depth of sampling interaction on: a – bulk density, b – total pore spaces in 2012; 1 – 0-10, 2 – 10-20, 3 – 20-40, 4 – 40-60 cm.

of a cover crop reduced soil bulk density. The exact reason for this is still unclear but we can speculate that the various rooting systems of the crops in the rotation cycle coupled with the rye roots are responsible for reducing BDY.

The tillage x cover crop interaction (Fig. 4) shows that under no-till management, planting rye caused a 3% reduction in BDY compared with when rye was not planted. Blanco-Canqui *et al*. (2011) reported similar findings. However, in tilled plots, BDY was increased when rye was added. In fact, annual tillage causes soils to settle and later increases BDY, and planting a cover crop may not be able to immediately alleviate this problem, especially if tillage is practiced continuously, year after year.

Soil total pore space (TPS) was significantly affected by cover crop x crop rotation and cover crop x tillage interactions. A similar but opposite trend as for BDY was observed for TPS (Fig. 5). TPS was the lowest in corn and soybean monocultures although rye was added. However, TPS increased in rotation plots with the addition of rye. This suggests that bio-pores contributed by microbial movement in undisturbed soils (Reeleder *et al*., 2006) and cover crop roots may have improved soil porosity. The cover crop x tillage interaction showed that TPS was generally greater with no-till management with rye (Fig. 6).

Soil gravimetric water content (GWC) was significantly affected by cover crop x crop rotation x depth of sampling and cover crop x depth of sampling x tillage interactions (Table 4). The first interaction (figure not showed) suggested that in the top 10 cm of the soil, planting rye in continuous corn and soybean-corn rotations was beneficial for soil moisture compared with no rye. In the soybean/corn rotation particularly, the moisture content when rye was previously planted was 16% greater compared with no previous rye. The cover crop x depth of sampling x tillage interaction for GWC showed that, in the first depth, soil moisture was generally greater under no-till management. However, under conventional tillage management, soil moisture was 6% greater when rye was planted. The opposite was observed in the second depth. At this depth, the greatest moisture content was noticed under no-till and cover crop managements.

Finally, AFPS, Ds/Do, GWC,VAC, VWC and WFPS were all significantly affected by depth of sampling (Table 4). VAC was 4% greater in the second depth compared with the first depth, and it corresponded with what was found for AFPS and Ds/Do. VWC and WFPS were both greater in the first depth of sampling. VWC and WFPS were 14% and 16% greater in the first depth compared with the second depth, respectively.

CONCLUSIONS

1. In the first year of this study, gravimetric and volumetric were 8 and 10% greater under no-till treatment compared with conventional tillage treatment, respectively.

2. In the second year, we noted that planting rye reduced bulk density by 9% and increased total pore space by 12%.

3. In the third year of the study, tillage x cover crop interaction showed that under no-till management, planting rye caused a 3% reduction in bulk density compared with when rye was not planted, suggesting that the improvement of bulk density by cover crop roots is enhanced with no-till management since there was no main effect of cover crop on bulk density.

4. The cover crop x crop rotation interaction suggested that the effect of cover crop in improving soil physical properties (bulk density, total pore space) was more apparent in rotation than in monoculture (continuous cropping) plots.

5. The interactions between various agricultural management treatments are complex in nature and their effects on soil physical properties may not be easily predictable.

T a b l e 4. Effects of tillage, crop rotation, cover crop and depth of sampling on selected soil physical properties in 2013

Treatment		AFPS	BDY	Ds/Do	GWC	Tort	TPS	VAC	VWC	WFPS
Tillage (TL)						Means				
No-till		46.75a	1.26a	0.08a	0.21a	5.01a	0.52a	0.25a	0.27a	53.25a
Conventional tillage		46.17a	1.29a	0.07a	0.20a	5.98a	0.51a	0.24a	0.26a	53.82a
Crop rotation (CR)										
Continuous corn		46.81a	1.26a	0.07a	0.22a	5.15a	0.52a	0.25a	0.27a	53.15a
Continuous soybean		44.72a	1.30a	0.06a	0.21a	5.69a	0.51a	0.24a	0.27a	55.28a
Corn-soybean rotation		45.98a	1.28a	0.07a	0.21a	5.92a	0.52a	0.25a	0.27a	54.02a
Soybean-corn rotation		48.34a	1.25a	0.08a	0.21a	5.20a	0.53a	0.26a	0.26a	51.66a
					Cover crop (CC)					
No-rye		46.93a	1.28a	0.07a	0.26a	5.50a	0.51a	0.25a	0.26a	53.07a
Rye		46.00a	1.27a	0.08a	0.27a	5.48a	0.52a	0.25a	0.27a	54.00a
Depth of sampling (DS) (cm)										
0-10		41.95b	1.26a	0.06b	0.24a	5.96a	0.51a	0.22b	0.29a	58.05a
10-20		50.98a	1.29a	0.09a	0.22b	5.02a	0.51a	0.23a	0.25b	49.02b
					Analysis of variance					
Sources of variation	df	AFPS	BDY	Ds/Do	GWC	Tort	TPS	VAC	VWC	WFPS
Blocks	2					p-values				
Depth of sampling (DS)	3	0.0000	0.1869	0.0000	0.0000	0.1294	0.1859	0.0000	0.0000	0.0000
					Interactions					
CC x CR	3	0.3578	0.0469	0.6001	0.0251	0.1249	0.0391	0.3278	0.4328	0.3578
CC x TL	1	0.3152	0.0506	0.1671	0.7432	0.6414	0.0424	0.1971	0.5514	0.3152
CC x CR x DS	3	0.8162	0.6156	0.9661	0.0486	0.3601	0.6378	0.9107	0.5482	0.8163
CC x DS x TL	1	0.5287	0.5088	0.7423	0.0358	0.1442	0.5087	0.7991	0.1677	0.5287
Lack of fit	31									
Error (MS)	253	245.74	0.0295	0.0034	0.0014	27.799	0.0042	0.0114	0.0030	245.74
Total	287									

Explanations as in Table 2.

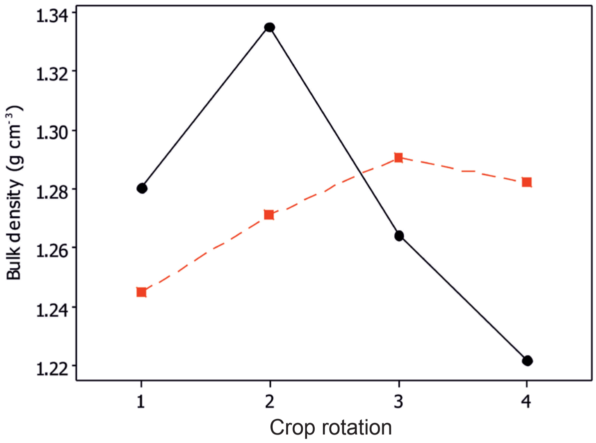

Fig. 3. Effect of cover crop x crop rotation interaction on soil bulk density in 2013. 1 – continuous corn, 2 – continuous soybean, 3 – corn/soybean rotation, 4 – soybean/corn rotation. Legend as in Fig. 2.

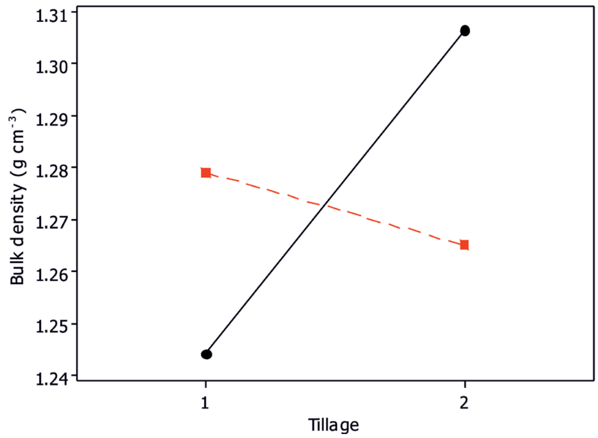

Fig. 4. Effect of tillage x cover crop interaction on soil bulk density in 2013. 1 – no till, 2 – conventional tillage. Legend as in Fig. 2.

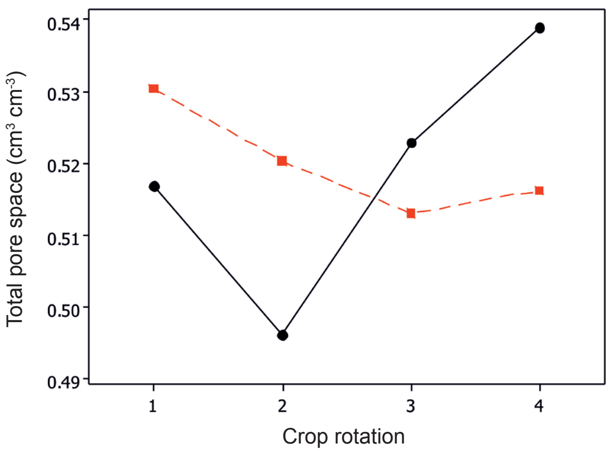

Fig. 5. Effect of cover crop x crop rotation interaction on total pore space in 2013. Explanations as in Fig. 3. Legend as in Fig. 2.

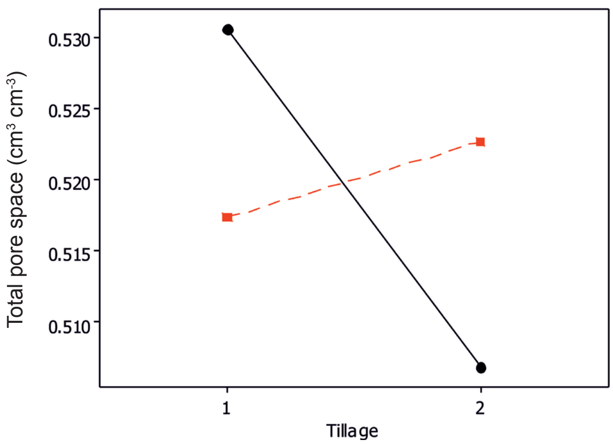

Fig. 6. Effect of tillage x cover crop interaction on total pore space in 2013. Explanations as in Fig. 4. Legend as in Fig. 2.

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