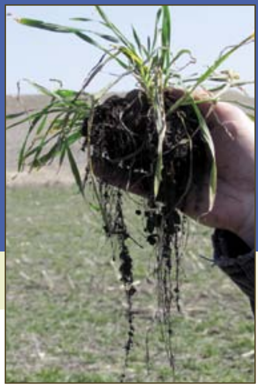
Winter Rye Cover Crop Effects on Soil



Iowa Learning Farms and Practical Farmers of Iowa

Project Timeline

Fall 2008-Spring 2013

Cooperators

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Definitions

Water infiltration describes the rate and volume of water that can flow into the soil profile. The measurement of runoff, conversely, reflects the volume of water running off the surface and potentially carrying soil with it.

Sorptivity is the ability of a soil to take up water based solely on small pore space connectivity and continuity; a larger value indicates greater soil water uptake and is desirable.

Soil bulk density is the dry mass of soil contained in a given volume, and indicates the level of compaction; a compacted soil will have a greater bulk density than a noncompacted soil.

Background

Research has demonstrated that maintaining vegetation on crop fields during the off-season through cover cropping has benefits for farmers and soil. Cover crops hold soil in place, preventing erosion and the concomitant loss of phosphorus (Villamil et al. 2006); cover crops also take up residual nitrates, so less leach from the field (Strock et al. 2004, Villamil et al. 2006, Kaspar et al. 2007). Soil temperature is greater in early spring under cover crops, and some cash crop yield increases have been observed (Patrick et al. 1957, Liebl et al. 1992). Some evidence suggests that cover crops may help alleviate compaction in the soil through the growth of cover crop roots (Williams and Weil 2004), and the macropores created by these roots may decrease compaction and improve soil structure, seen in increased water infiltration rates and decreased soil bulk densities (Patrick et al. 1957, Steele et al. 2012). The decomposition of terminated cover crop roots and biomass also contributes organic material to the soil, improving soil organic matter and quality (Villamil et al. 2006). A five-year trial was initiated to quantify the changes in soil properties due to cover crop use over time.

Materials and Methods

A cover crop trial was established on three farmers' fields in the fall of 2008 (Table 1). Test plots were set up within their existing corn-soybean rotation fields; within each block, half were seeded with winter rye each fall and half were left uncovered. Plots received the same treatment each year (2008-2013).

Table 1. Farmer cooperators in the 5-year cover crop trial.

Cooperator	Cash Crop					Cover Crop Planting Method
	2009	2010	2011	2012	2013	
Whiterock	soy	corn	soy	corn	soy	drilled; no-till drilled fall 2012
Funcke	corn	soy	corn	soy	corn	drilled
Juchems	soy	corn silage	soy	corn	soy	drilled

A Cornell University sprinkle infiltrometer was used to measure water infiltration rates of the soil, at two replications on each plot, both at the beginning and end of the trial (spring 2009 and 2013; van Es and Schindelbeck). At the same sites, three soil cores were taken with a 0.75 in. (1.9 cm) diameter push probe to a depth of 12 in. (30.5 cm), and divided into 0–6 in. (0–15.2 cm) and 6–12 in. (15.2–30.5 cm) subsamples. Subsamples were combined for each depth at each sampling site. The samples were analyzed at the Iowa State University Soil Testing Lab in Ames, Iowa, for total carbon and nitrogen concentration. In 2013 only, a single 3 in. (7.6 cm) diameter core was taken to a depth of 6 in. (15.2 cm) at each site and split into 0–3 in. (0–7.6 cm) and 3–6 in. (7.6–15.2 cm) subsamples, which were analyzed for soil bulk density.

Data were analyzed with Statistical Analysis System (SAS) software, using a mixed model. Because of variability between sites in terms of soil type and plot size, locations are analyzed separately. Year, replication, and treatment were used as variables, as well as depth of sample for some soil tests. Values reported are least-squares means, unless otherwise specified; differences were considered significant at the $P = 0.05$ level, with tendencies noted if $P < 0.10$.

Two plots at the Whiterock site were excluded from final statistical analysis due to cropping changes at the plot site.

Results: Water infiltration, runoff, and sorptivity

In general, presence of winter rye cover crops did not affect water runoff (Table 2), infiltration (Table 2), or sorptivity (data not shown). More often than cover, year affected measured values, suggesting that climate and environmental conditions rather than treatment can influence soil characteristics. At Whiterock, 2013 steady-state infiltration values tended to be greater than 2009 ($P = 0.09$). At Funcke, 2013 steady-state runoff was lower and infiltration greater than in 2009.

Table 2. Soil water characteristics with and without cover crop.
Within each column, values followed by different letters (a,b) are different ($P < 0.05$); and values followed by different letters (x,y) tend to differ ($0.05 < P < 0.10$).

		Steady-state runoff (in/h)	Steady-state infiltration (in/h)	Steady-state runoff (in/h)	Steady-state infiltration (in/h)	Steady-state runoff (in/h)	Steady-state infiltration (in/h)
		Whiterock		Funcke		Juchems	
2009	No cover	0.13	0.06	0.16	0.05	0.16	0.03
	Cover	0.14	0.05	0.17	0.04	0.16	0.04
2013	No cover	0.12	0.10	0.08	0.13	0.13	0.10
	Cover	0.10	0.14	0.05	0.10	0.15	0.04
Year	2009	0.13	0.06 x	0.17 a	0.04 b	0.16	0.04
	2013	0.11	0.12 y	0.06 b	0.12 a	0.14	0.07
Cover	No cover	0.12	0.08	0.12	0.09	0.15	0.07
	Cover	0.12	0.09	0.11	0.07	0.15	0.04

Results: Soil carbon and nitrogen concentration and soil pH

Total carbon, total nitrogen, and pH of soil samples from 0–6 in. (0–15.2 cm) and 6–12 in. (15.2–30.5 cm) depths were analyzed by the Iowa State University Soil Testing Lab (Table 3). Total carbon concentration across treatments was greater from 0–6 in. (0–15.2 cm) than from 6–12 in. (15.2–30.5 cm) at Whiterock and Juchems, differed among replications at Whiterock and Funcke (data not shown), and was lower in 2013 than 2009 at Funcke. Total nitrogen concentration was lower across treatments in 2013 compared to 2009 at Funcke and Juchems, and was greater in the upper compared to lower depths at all locations. There were differences among replications at Whiterock and Funcke, but not at Juchems. Soil pH was lower in 2009 than 2013 at Whiterock; 2009 cover plots had lower pH than all other covers and years (year *x* cover, $P = 0.03$). This led to an overall lower average pH for cover plots than no cover plots at Whiterock. At Funcke, a particularly high pH in 2009 samples from 6–12 in. (15.2–30.5 cm) caused a year *x* depth interaction ($P = 0.02$), leading to greater pH in 2009 than 2013, and at lower compared to higher sample depths. At Juchems, 2009 cover plots had higher pH than did 2009 no cover plots or 2013 cover plots (year *x* cover, $P = 0.04$).

Table 3. Soil chemical properties with and without cover crop.
Within each column, values followed by different letters (a,b) are different ($P < 0.05$); and values followed by different letters (x,y) tend to differ ($0.05 < P < 0.10$).

		Total carbon (%)	Total nitrogen (%)	pH	Total carbon (%)	Total nitrogen (%)	pH	Total carbon (%)	Total nitrogen (%)	pH
		Whiterock			Funcke			Juchems		
2009	No cover	3.33	0.27	6.76 a	2.79	0.23	5.86	1.75	0.18	6.62 b
	Cover	3.51	0.30	6.28 b	2.80	0.23	5.97	1.64	0.17	6.83 a
2013	No cover	3.26	0.29	6.88 a	1.63	0.16	5.48	1.52	0.15	6.68 ab
	Cover	3.26	0.30	6.90 a	1.51	0.15	5.44	1.67	0.16	6.49 b
Year	2009	3.42	0.28	6.52 b	2.79 a	0.23 a	5.92 a	1.69	0.17 x	6.73
	2013	3.26	0.29	6.89 a	1.57 b	0.15 b	5.46 b	1.60	0.16 y	6.58
Cover	No cover	3.29	0.28	6.82 a	2.21	0.19	5.67	1.63	0.16	6.65
	Cover	3.38	0.30	6.59 b	2.15	0.19	5.71	1.65	0.16	6.66
Depth	0-15.2 cm	3.75 a	0.35 a	6.63	2.27	0.20 a	5.39 b	1.92 a	0.19 a	6.55
	15.2-30.5 cm	2.92 b	0.23 b	6.78	2.10	0.18 b	5.99 a	1.36 b	0.13 b	6.76

Decomposing roots and biomass from cover crops should increase the carbon content of soil, particularly near the surface. This was not observed in the current trial; however, it often takes many years for stable carbon content fractions to noticeably change. In a 10-year winter rye cover crop study in central Iowa, Moore (2012) observed 15% greater soil organic matter and 44% greater particulate organic matter in rye cover crop treatment compared to treatment with no cover crops. Weather events that flood or dry out the soil can affect microbial activity; increased anaerobic microbial activity causes carbon to be released as CO_2 instead of incorporated into the soil. These weather effects may overshadow any effects of cover crops. Over the time of this study, some years were notably wet while others were hot and dry. Burke et al. (1989) reported a negative correlation between annual temperature and soil carbon in US plains grasslands, and a positive correlation between precipitation and soil carbon.

Results: Soil bulk density

Soil bulk density was evaluated in 2013 only, and results are shown in Table 4. As with other parameters, cover did not have a significant effect on mean bulk density across depths. However, at lower depths, soil bulk density was greater at all locations. One replication at the Funcke site was also significantly lower than the others (data not shown).

Table 4. Soil bulk density with and without cover crop. Within each column, values followed by different letters (a,b) are different (*P* < 0.05); and values followed by different letters (x,y) tend to differ (0.05 < *P* < 0.10).

		Soil bulk density (g/cm³)		
		Whiterock	Funcke	Juchems
Cover	No Cover	1.22	1.44	1.43
	Cover	1.26	1.46	1.47
Depth	0-3 in (0-7.6 cm)	1.15 x	1.40 b	1.36 b
	3-6 in (7.6-15.2 cm)	1.33 y	1.50 a	1.55 a

Reduced soil bulk density following cover crops has been reported (Patrick et al. 1957). Considering the lack of effect of cover on other parameters and the significant effect of year, it is likely that variable weather conditions influenced bulk density more than treatment. Whiterock had the lowest bulk density, and also had greater carbon and nitrogen concentrations – a correlation also noted by Patrick et al. (1957). Steele et al. (2012) found that cover crops decreased soil bulk density in only some soils and mostly during the cover crop growing season, not the subsequent crop season. In the current trial, while soils were sampled before spring planting, when cover crops were present, this was not observed. Greater bulk density with increasing depth was noted by Villamil et al. (2006). However, that study also reported that cover crops further reduced bulk density towards the surface compared to plots with no cover crops, whereas no depth *x* cover interactions were observed in the present trial. It is possible that cover crop growth was insufficient to cause any observable change.

Results: Cover crop biomass yield

Cover crop yield will depend on the timing and method of seeding, soil moisture, and temperature and precipitation following seeding (Strock et al. 2004). Across the three sites, cover crop biomass in the spring following fall planting differed greatly (*P* < 0.01), and differed among years (*P* < 0.01, Table 5). All plots were seeded with a drill, not broadcast, so planting method should not affect results. At Whiterock, greater cover crop yields were observed towards the end of the study period; this trend was not observed at the other locations. All three locations had one of the higher yields at that location in 2012, perhaps due to statewide weather patterns.

Table 5. Cover crop (dry matter) biomass. Within each column, values followed by different lower-case letters (a,b) are different (*P* < 0.05). Within each row, values followed by different upper-case letters (A,B) are different (*P* < 0.05).

Year	Cover crop biomass (lb/ac)		
	Whiterock	Funcke	Juchems
2009	580.5 c	122.5 c	704.3 b
2010	1068.5 b	1881.0 a	134.7 b
2011	328.0 c	184.0 c	879.7 b
2012	1855.0 a	1183.8 b	1961.3 a
2013	1679.0 a	0.0 c	383.8 b
Location average	1102.2 A	674.3 B	812.8 B

Results: Cash crop yield

Cash crop yields were reported for the first four years of the trial (2009-2012) and analyzed by location (Table 6). Year differences were common; corn grain yields were far lower in 2012 compared to 2010 at Whiterock (*P* < 0.01) and were greater in 2011 compared to 2009 at Funcke (*P* < 0.01). In contrast, soybean yield was greater in 2010 than 2012 at Funcke (*P* < 0.01). Cover crops only affected yields of corn grain at the Funcke farm; in 2009, plots with no cover crops had higher yields than did those with cover; yields in 2011 were lower and did not differ between treatments (year *x* cover *P* < 0.01). Corn silage was only produced in one year at one location, and no differences were observed between treatments.

Table 6. Cash crop yields with and without cover crop. Within each column, values followed by different letters (a,b) are different ($P < 0.05$).

Effect		Corn grain yield (bu/ac)			Soybean yield (bu/ac)			Corn silage yield (tons/ac)
		Whiterock	Funcke	Juchems	Whiterock	Funcke	Juchems	Juchems
2009	No Cover	--	193.8 a	--	50.7	--	65.4	--
	Cover	--	155.3* c	--	49.3	--	62.9	--
2010	No Cover	158.3 a	--	--	--	56.4 a	--	16.2
	Cover	113.1 a	--	--	--	56.4 a	--	15.3
2011	No Cover	--	184.5 b	--	--	--	65.6	--
	Cover	--	182.5 b	--	--	--	66.5	--
2012	No Cover	58.2 b	--	114.6	--	36.1 b	--	--
	Cover	43.2 b	--	113.9	--	36.4 b	--	--
Year	2009	--	174.5 b	--	50.0	--	64.2	--
	2010	135.7 a	--	--	--	56.4 a	--	15.8
	2011	--	183.5 a	--	--	--	66.0	--
	2012	50.7 b	--	114.3	--	36.2 b	--	--
Cover	No Cover	108.2	189.1 a	114.6	50.7	46.2	65.5	16.2
	Cover	78.2	168.9 b	113.9	49.3	46.4	64.7	15.3

In 2009 at Funcke corn yield was reduced due to herbicide failure to control the cover crop.

Improved crop yields following cover crops have been reported (Williams and Weil 2004), but not always. Several four-year trials found no difference in yields following cover or no cover (Liebl et al. 1992, Strock et al. 2004, Kaspar et al. 2007). Corn following rye is associated with yield reductions under certain conditions, mainly when cover crop yield is high and termination and incorporation is near to corn planting (Kaspar et al. 2007), which may explain the low corn yield at Funcke in 2009.

Conclusions

Results from this trial suggest that weather variability may affect soil properties such as water infiltration and carbon and nitrogen concentration more strongly than cover crop usage. While year significantly affected many measured parameters, cover crop treatment did not appear to result in any changes. Some sites had poor cover crop establishment and germination, essentially nullifying the treatment effect in those cases. This may have contributed to the lack of response to cover crop use.

Many soil changes take years to become noticeable or significant. A 10-year winter rye trial in central Iowa found differences between rye cover and no cover treatments, attributed to increased organic matter and soil nitrogen cycling (Moore 2012). In contrast, Steele et al. (2012) did not find any changes in organic matter content in Maryland soils after 13 years, though some other parameters like aggregate stability did change, and some seasonal differences were observed. A four-year trial by Liebl et al. (1992) in Illinois found fewer significant changes in soil properties, and no differences in soil organic matter. Increased organic matter after five years of cover cropping in Illinois (Villamil et al. 2006) was attributed to high cover crop biomass and a relatively high N concentration of the biomass through the inclusion of vetches as well as rye.

Resources

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