Final Report: Using Cover Crops after Wheat to Improve Soil Health
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Project justification

The fallow period between wheat harvest and corn planting in Michigan crop rotations offers a prime opportunity for double-cropping. This time could be used to grow cover crops (CC) to improve soil quality, fix nitrogen for the next row crop in the rotation, and provide a harvestable forage double crop. However, growers often believe that harvest of a cover crop will negatively affect ecosystem services and future crop productivity. They also lack information on which cover crops would be most suitable for such a double-cropping system.

Objectives

1. Characterize specific soil benefits imparted by individual cover crop species.
2. Quantify consequences of partial removal of cover crop biomass.

Materials and Methods

The trial was conducted in 2013-2015 and 2014-2016 on adjacent sites in East Lansing. The system was managed using no-till best management practices for wheat and corn in Michigan. Winter wheat was planted in the first autumn and harvested in the second summer. We compared nine cover crops [frost-seeded red clover control (RCL), nondormant alfalfa, oat/field pea mix, cowpea, sunn hemp, sudangrass, sorghum x sudangrass hybrid (sudex), teffgrass, and oilseed radish) to fallow in a wheat-corn rotation. The experimented was conducted twice to provide a range of weather conditions. The RCL control was frostseeded into wheat in spring and the remaining CC treatments were drilled immediately after wheat harvest. Wheat straw was not removed and no fertilizer was applied directly to cover crops. Half of the cover crop plots were harvested for haylage eight weeks after planting, and then allowed to regrow. Ground cover was evaluated before and after cover crop harvest. Overwintering potential of covers was evaluated the third spring before termination of surviving covers and weeds using glyphosate. Soil samples were taken from each plot after cover crop harvest. Roundup-Ready corn was planted in the third spring and harvested for grain in the last autumn. The first winter was severe and resulted in some wheat stand loss and reduced yields. Growing degree day accumulation was relatively low during the cover crop phase which probably reduced growth of warm season cover crop species. A summer drought period affected corn growth in 2016. Single degree of freedom contrasts were used to separate treatment group effects and LSD was used to separate simple pairs of treatments.

Results.

Objective 1. *Characterize specific soil benefits imparted by individual cover crop species.*

Objective 1 addressed the traditional cover crop potential of the test species, using fallow (no cover crop) as a negative control and frostseeded RCL as a positive control. In general, performance of summer-seeded covers was less than expected. Possible contributing factors included competition from volunteer wheat, cool weather after cover seeding, and the decision to not apply starter fertilizer to CC. Non-legume CC displayed yellowing consistent with N deficiency throughout most of the growth cycle and harvested forage was relatively low in crude protein (CP, Table 1). Frostseeded RCL consistently provided the most ground cover among CC, followed by oat/pea, sudex, and sudangrass. Nondormant alfalfa, teffgrass, and radish did not consistently contribute to ground cover due to poor establishment, and cowpea and sunn hemp failed to establish in either year.

Combined action of CC and volunteer wheat successfully suppressed weeds to negligible levels throughout the study (data not shown). Some oilseed radish was observed in corn plots at harvest, probably a result of hard seed surviving from the previous year. Frostseeded RCL did not affect wheat yields (mean 77 bu DM/acre, $P > 0.05$). All CC except RCL and alfalfa winterkilled as planned. Spring glyphosate application was ineffective at terminating RCL, which was not completely killed until the post-corn planting glyphosate application. This contributed to a 4% reduction in corn grain yield with use of RCL compared to fallow (Table 2, $P < 0.06$). Summer-planted CC did not affect corn grain or stover yields ($P > 0.10$).

In regard to soil improvement, one use of frostseeded RCL and summer-planted covers between wheat and corn had little discernable impact on soil quality in this trial. This is consistent with current belief that it takes several years of cover cropping to detect improvements in soil and underscores the importance of long-term funding sources for rotation trials. Covers did not affect total soil carbon, active soil carbon, or total soil N under cover crops, nor did they affect soil penetration resistance the following spring ($P > 0.10$, data not shown). Using harvested forage chemical composition (Table 2) as a proxy for the C:N ratio of cover crop residues, the only cover with a C:N < 24 was RCL, and therefore all summer-seeded CC would promote soil N immobilization. Frostseeded RCL tended to increase N content of corn grain and stover ($P < 0.10$) without increasing corn yield. This suggests something other than N was limiting corn yields. In 2016, this was likely drought.

Based on 2017 seed prices and equipment operation prices, estimated planting costs of sudangrass, red clover, sudex, and oat/pea mix were $52, $68, $69, and $87/acre, respectively. In addition to being ineffective, the other CC species were more expensive ($93-157/acre). After harvest costs were added, production cost per ton of forage harvested was $51, $87, and $100/ton for red clover, sudangrass, and oat/pea mix, with forage production cost of other species ranging from $118 to $264/ton. Cost of producing the latter group was more than the value of the harvested forage.

Objective 2. *Quantify consequences of partial removal of cover crop biomass.*

Harvesting CC in early October produced 0.5 to 2.0 ton/acre of forage dry matter (Table 1). None of the summer-planted covers yielded as much forage or matched nutritive value of the frostseeded RCL control. Better nutritive value in frostseeded RCL is indicated by reduced neutral detergent fiber (NDF) and greater crude protein (CP) compared to summer-planted covers. Harvested forage NDF and CP concentrations were similar among summer-planted covers. Nutritive value was adequate for livestock with low nutrient needs, such as growing heifers, dry cows, or beef cows.

Cover crop harvest did not affect corn grain or stover yields or CP concentrations (Table 2, $P > 0.10$). Harvesting covers decreased the total N removal by the corn crop ($P < 0.01$) for most covers, with a the greatest reduction exhibited by harvesting RCL (34%). The reduction in corn N removal after RCL harvest was 175% times greater than the amount of N removed in the forage harvest, which suggests substantial reduction of below ground N fixation after RCL harvest. In contrast to all other treatments, harvest of radish increased total N removal in corn by 8%.

While harvesting CC did reduce total ground cover on average by 10 percentage points compared to no harvest (Table 1), all CC treatment had at least 85% ground cover going into winter and there was no difference in ground cover by harvest treatment the following spring.

Summary of Impacts

- Frostseeded RCL in wheat may reduce subsequent corn yields by 4% in a no-till system if chemical termination of the RCL is ineffective before corn planting.
- Growing and harvesting summer-seeded CC after wheat had no negative impacts on subsequent corn yields.
- Harvesting forage from frost-seeded RCL or summer-seeded oats/peas, sudangrass, or sudex planted after wheat can provide up to 2.0 ton/acre of forage with moderate nutritive quality while maintaining 85% or more ground cover. Forage quality is suitable for feeding beef or dry dairy cows, or dairy heifers.
- Nondormant alfalfa, teffgrass, and oilseed radish provided ground cover but little harvested forage in this system.
- Cowpea and sunn hemp did not establish reliably and are not recommended cover crops for a wheat-corn rotation in Michigan
- Volunteer wheat from shattered heads at harvest can be a significant source of "cover crop", contributing ground cover and harvested forage, and competing with planted cover crops.
- RCL added nitrogen to the production system, but harvesting it reduced the nitrogen benefit by 34%.
- Summer-seeded cover crops doubled-cropped after wheat can be harvested as forage with no negative impact on subsequent corn grain yields.

Table 1. Total forage and cover crop (CC) harvested dry matter yield (DMY), harvested forage chemical composition, and total ground cover percentage (live and residue) pre-harvest (PH), after 4 weeks of regrowth (RG) and the following spring (SPR).

	Dry matter yield		Forage composition				Total Ground Cover (%)			
	Total (ton/A)	CC (% of total)	DM%	NDF %	CP %	C:N ratio	PH mean	RG H*	RG NH*	SPR mean
fallow	-	-	-	-	-	-	59.3	-	71.7	87
red clover	1.95	86.0	24.8	58.6	14.1	20.6	99.7	99.3	77.5	92.2
alfalfa	0.69	7.6	36.1	63.9	10.6	29.8	97.7	98.5	90.4	95.6
cowpea	0.60	4.3	37.1	64.2	8.9	27.6	99.5	94.4	90.4	94.8
sunn hemp	0.54	3.5	37.3	65.3	9.8	30.8	98.6	91.2	87.9	92.6
radish	0.52	29.6	30.5	63.8	9.0	31.1	99.4	98.1	90.5	96.0
oat/pea	1.10	75.2	22.8	61.2	10.5	27.5	99.3	97.1	85.0	93.8
sudangrass	0.83	68.1	28.2	64.8	8.8	31.6	99.5	92.1	71.0	87.5
sudex	0.74	51.6	31.1	66.8	7.8	36.1	98.3	93.7	86.3	92.8
teff	0.56	17.6	34.6	63.4	10.5	27.5	99.3	95.7	89.0	94.6
MEAN	**0.84**	**38.2**	**31.4**	**63.5**	**10.0**	**29.2**	**99.0**	**95.6**	**85.3**	**90.5**
LSD	**0.786**	**54.00**	**9.65**	**13.42**	**5.96**	**24.9**	**0.50**	**43**	**43**	**10.5**

All means reported as least square means. LSD (P < 0.05).
* H = cover crop harvested, NH=not harvested.

Table 2. Yield, N concentration, and N removal in corn grain and stover after harvest (H) or no harvest (NH) of cover crops from 2014 to 2016 in East Lansing.

	Corn		Stover		Corn N		Stover N		N removal	
Cover Crop	NH	H	NH	H	NH	H	NH	H	NH	H
	bu DM/acre		ton DM/acre		-------- % of DM ----------				-- lb/acre --	
fallow	223	-	6.50	-	1.43	-	0.94	-	293	-
red clover	188	182	6.17	5.80	1.91	1.65	1.11	1.02	446	293
alfalfa	207	207	6.80	6.54	1.50	1.51	0.93	0.91	374	324
cowpea	202	204	5.74	5.91	1.44	1.31	0.97	0.95	308	280
sunn hemp	201	193	6.03	5.68	1.73	1.60	0.93	0.95	323	331
radish	199	200	5.43	6.23	1.35	1.68	0.94	0.93	318	343
oat/pea	209	210	6.52	6.21	1.44	1.46	0.94	0.90	335	322
sudangrass	200	205	6.04	5.84	1.59	1.59	0.93	0.93	365	327
sudex	196	202	6.21	6.20	1.47	1.45	0.91	0.92	304	294
teff	209	202	6.18	6.54	1.73	1.54	0.93	0.92	335	310
MEAN	**201**	**200**	**6.12**	**6.11**	**1.57**	**1.53**	**0.95**	**0.94**	**345**	**314**
LSD	**70**	**70**	**3.14**	**3.14**	**0.18**	**0.18**	**0.10**	**0.10**	**65**	**65**

All means reported as least square means. LSD (P < 0.05).

Clockwise from top left: frost-seeded red clover growing in wheat stubble in August; preparing to harvest oat-pea and sudex cover crops as forage in October; oat-pea cover crop in October; and graduate student Sabra Gerdes sampling corn in October.