United States Department of Agriculture

National Soil Health Study Progress Report – Year 1

Effect of Mixed Species Cover Crops on Soil Health

Natural Resources Conservation Service
Norman A. Berg National Plant Materials Center
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Introduction

The Norman a Berg National Plant Materials Center (NPMC) is participating in a national study to evaluate the effect of different cover crop mixes and seeding rates on soil health. The NPMC and six other Natural Resources Conservation Service (NRCS) Plant Materials Centers in California, Washington, Oregon, Missouri, North Dakota, and Florida are working together with the NRCS National Soil Health and Sustainability Team to expand the agency's knowledge of using cover crops to improve soil health.


Figure 1. Soil Health Study plots 225 days after seeding.

This study attempts to determine the effect of various cover crop treatments on soil health over three cycles of cover crop and commodity crop plantings. This report summarizes the first year of data at the NPMC in Beltsville, Maryland. Results are expected to change over the next two years as more data are collected and analyzed. The results of this study will help inform recommendations for using cover crops to improve soil health, reduce inputs, and improve commodity crop yield.

Methods

The NPMC is located about 10 miles north-east of the District of Columbia. The study was planted on moderately well to well-drained soil with 10 inch loamy sand topsoil, with 43 inches average precipitation per year. Tested are nine cover crop treatments and a control with no cover crop. Cover crop treatments consist of three seed mixes comprised of two, four or six species, seeded at rates of 20, 40 and 60 seeds/ft^2. Seed mix percentages by seed number, and pounds per acre seeding rates as well as costs per acre are listed in Table 1. Plots are arranged in a randomized, complete-block design with four replications.


Figure 2. Rolling cover crops and panting corn June 4, 2013.

Table 1. Cover crop mixes in Beltsville PMC Soil Health Study.

	2 Species Mix				4 Species Mix				6 Species Mix			
	% mix by seed number	lb/acre 20*	40*	60*	% mix by seed number	lb/acre 20*	40*	60*	% mix by seed number	lb/acre 20*	40*	60*
Rye	50%	24.0	48.0	72.0	45.0%	21.6	43.2	64.8	22.5%	10.8	21.6	32.4
Crimson Clover	50%	2.9	5.8	8.7	22.5%	1.3	2.6	3.9	22.5%	1.3	2.6	3.9
Hairy Vetch					22.5%	12.0	24.0	36.0	22.5%	12.0	24.0	36.0
Radish					10%	2.6	5.1	7.7	5%	1.3	2.6	3.8
Oats									22.5%	10.1	20.2	30.3
Rapeseed									5%	0.3	0.6	0.8
Total lbs/acre		26.9	53.8	80.7		37.5	74.9	112.4		35.8	71.6	107.2
Seed Cost ($/acre)		**$18.8**	**$37.6**	**$56.3**		**$53.8**	**$107.4**	**$161.2**		**$50.8**	**$101.5**	**$151.7**

***20, 40 and 60 seeds per square foot seeding rates.**
Seed costs are based on Fall 2013 quotes from seed dealers in the Mid-Atlantic region.

Each 30 by 60 foot plot was divided randomly into three subplots that are each sampled only once in the three year study period to ensure sample integrity. The sampling procedures, including timing and a brief description, are described in Table 2. Cover crop treatments were planted into a conventionally prepared seedbed on September 20, 2012 using a Truax Trillion seeder. Cover crops in year two and three will be planted with a Truax Flex2 no-till planter. To improve uniformity of the seeding, the small seeded crimson clover and rapeseed were placed in the small “legume” box of the seed drill. Chicken crumbles were mixed with the crimson clover and rapeseed to provide enough bulk for the seed drill to accommodate the low seeding rate. The cover crop was terminated and the corn planted in one pass over the field on June 4, 2013 using a tractor with a roller crimper on the front and a corn planter on the rear (Figure 2). Field corn was the commodity crop grown at this location. Glyphosate was applied 3 weeks after corn planting on June 25th, 2013. Canopy cover was recorded every 30 days unless dormant or snow covered and ceased at 100%. Corn yield samples were hand harvested September 18, 2013. Due to very dry soils after the corn harvest, it was necessary to first irrigate prior to performing the soil sampling procedures. Adequate soil moisture was especially necessary to complete the Soil Bulk Density procedure.

Table 2. Sampling Procedures

Sample Procedure	Timing	Description
Soil Bulk Density	Prior to cover crop seeding	3” cylinders, 0-2” and 2-4” depths; 3 samples
Soil Resistance	Prior to cover crop seeding	Soil compaction tester (DICKEY-John Corp.)
Soil Indicators	Prior to cover crop Seeding	National Soil Survey Center
Soil Biological Assessment	Prior to cover crop seeding and prior to commodity crop seeding	Haney Test; Dr. Richard L. Haney, USDA-ARS
Soil Temperature and Moisture	Prior to cover crop seeding and prior to commodity crop seeding	Hydrosense II probe at 7” depth; 5 readings Soil thermometers; 5 readings
Cover Crop Photos	Every 15 days after planting cover crop	Each plot of one replication from fixed points
Canopy Cover and Plant Height	Every 30 days after planting cover crop	Diagonal line transect, 50 points, 1 foot apart
Biomass Yield	At cover crop termination	0.5m^2 sample, functional groups separated
Corn Yield	At corn harvest	1/1000th acre sample, dried kernels

Summary of Preliminary Results

- All mixtures at 60 seeds/ft^2 and the 2 and 4 species mixtures at 40 seeds/ft^2 reached 80% cover by 2 months after planting.
- Rye provided the greatest cover in all treatments and sampling dates. Rye averaged between 34% to 51% cover at 210 days after planting (DAP), followed by hairy vetch with 17-29% cover and crimson clover with 14-40% cover.
- Rye cover peeked by 60 DAP with 41% to 91% cover in all treatments except the 6 species 20 seeds/ft^2 treatment which was 23% cover at 60 DAP and 34% at 210 DAP. Oat cover also peaked at 60 DAP with 4% to 16% of cover. Legume cover continued to increase up to termination.
- Oats, radish and rapeseed winterkilled with the exception of a few small radish plants.
- Rapeseed and radish require earlier planting for adequate growth. Rapeseed failed to grow beyond several small leaves before being winterkilled.
- Cover crops treatments were very effective at suppressing weeds both before and after termination.
- Cover crop plots produced 2 to 3.5 t/ac dry matter biomass prior to termination compared to 0.7 t/ac in the control plots.
- Differences in dry matter biomass and %N in dry matter showed not clear trend and were statistically similar between cover crop treatments, but significantly different between the control and at least some of the cover crop treatments.
- The overall soil health as indicated by the Soil Health Calculation number increased in all treatments and the control most likely due to the transition to no-till.
- Corn Yield was not statistically different between treatments.

Results and Discussion

Cover and Weed Suppression

All three seed mixes at the 60 seeds/ft^2 seeding rate and the 2 and 4 species mixes at the 40 seeds/ft^2 seeding rate achieved over 80% cover by 60 days after planting (DAP) (Figure 3). This may indicate a minimum optimal seeding rate of 40 seeds/ft^2 for the 2 and 4 species mixes and 60 seeds/ft^2 for the 6 species mix. The cover of the 6 species mix at 20 seeds/ft^2 was well below all other mixes and rates at 30, 60 and 90 DAP. Weed growth was suppressed very well by all cover crop treatments. The highest weed cover recorded in the cover crop treatments was 12% at 210 DAP for the 2 species mix at 20 seeds/ft^2; all other cover crop treatments had very little weed cover (Figure 4).

Rye had the fastest fall growth of all the cover crop species, and provided the most cover in all of the cover crop plots for all dates tested. The cover contributed by rye, crimson clover, hairy vetch and oats can be compared on an equal seed number basis in the 6 species mix plots as each comprised 22.5% of the seed mix (Figure 5). There was notable herbivory of rye by deer which contributed to the dip in rye cover between 60 and 90 DAP when growth and recovery of rye was minimal. The 6 species mix at the 20 and 40 seeds/ft^2 seeding rates had less cover than the other mixes at the same rates, allowing for greater weed growth at the 20 seeds/ft^2 seeding rate as shown in Figure 6. The reduced cover appeared to be largely due to the oats that replaced at least half of the better performing rye in the 6 species mix compared to the other mixes. Radish growth was limited, as expected, by the September 20 planting date. In the Maryland coastal plain it is recommended to seed radish by September 15 or at least 6 weeks before frost for the best growth, weed suppression and nutrient accumulation (Weil et al., 2009). The rape plants remained tiny, not growing beyond a few leaves, indicating that the rape required a much earlier seeding. Oats, radish and rapeseed winterkilled and subsequently decomposed, and did not contribute to above ground biomass at time of termination. The weeds in the control plots provided less than 20% cover over the winter, but rapidly grew in the spring to provide 56% cover at 210 DAP. The cover crops were successfully terminated with the roller crimper; however, the weed cover in the control plots were largely unaffected.

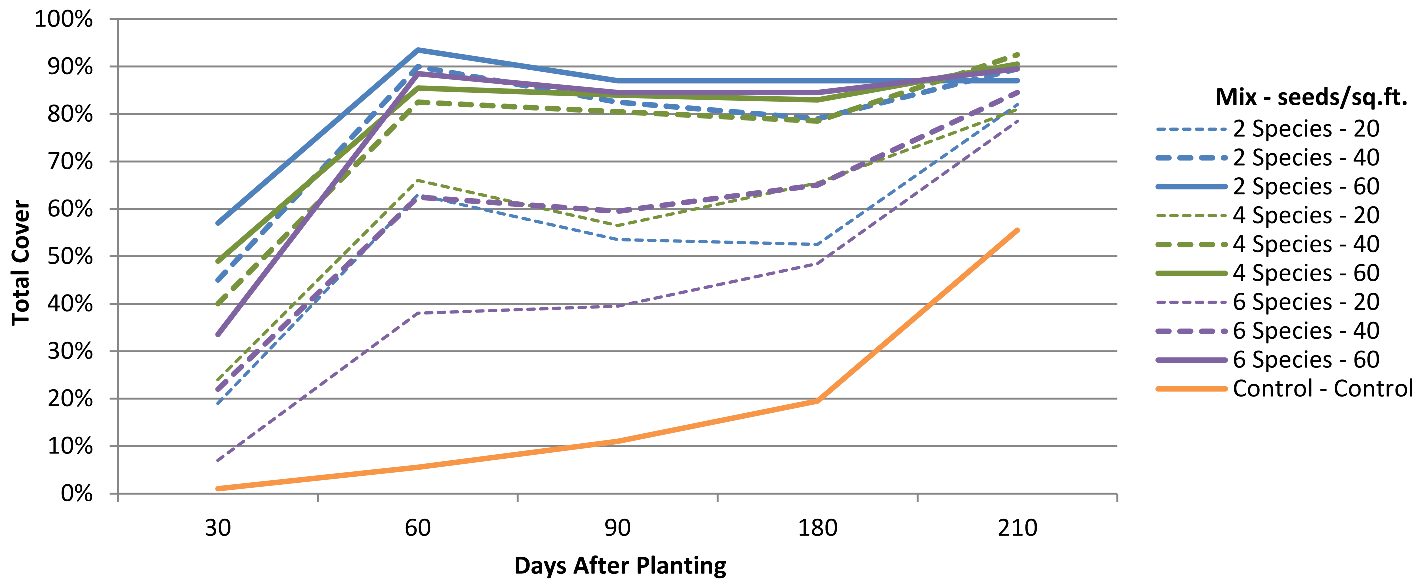

Figure 3. Effect of cover crop mix and seeding rate on percent cover from 30 to 210 days after planting.

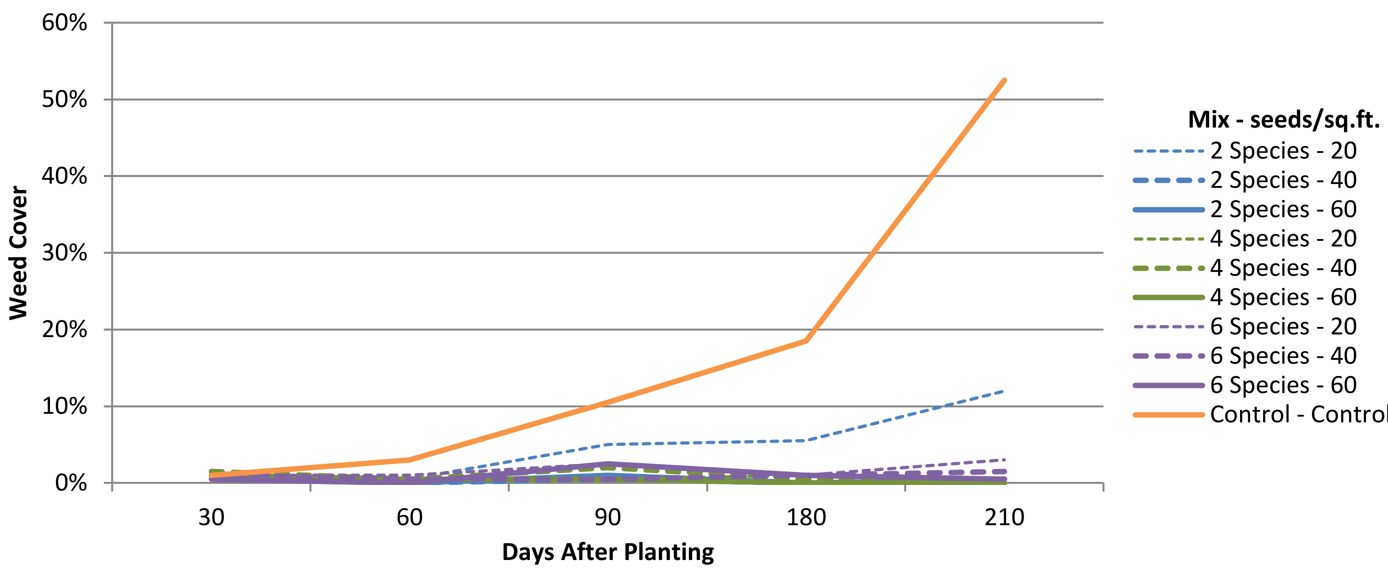

Figure 4. Effect of cover crop mix and seeding rate on weed percent cover from 30 to 210 days after planting.

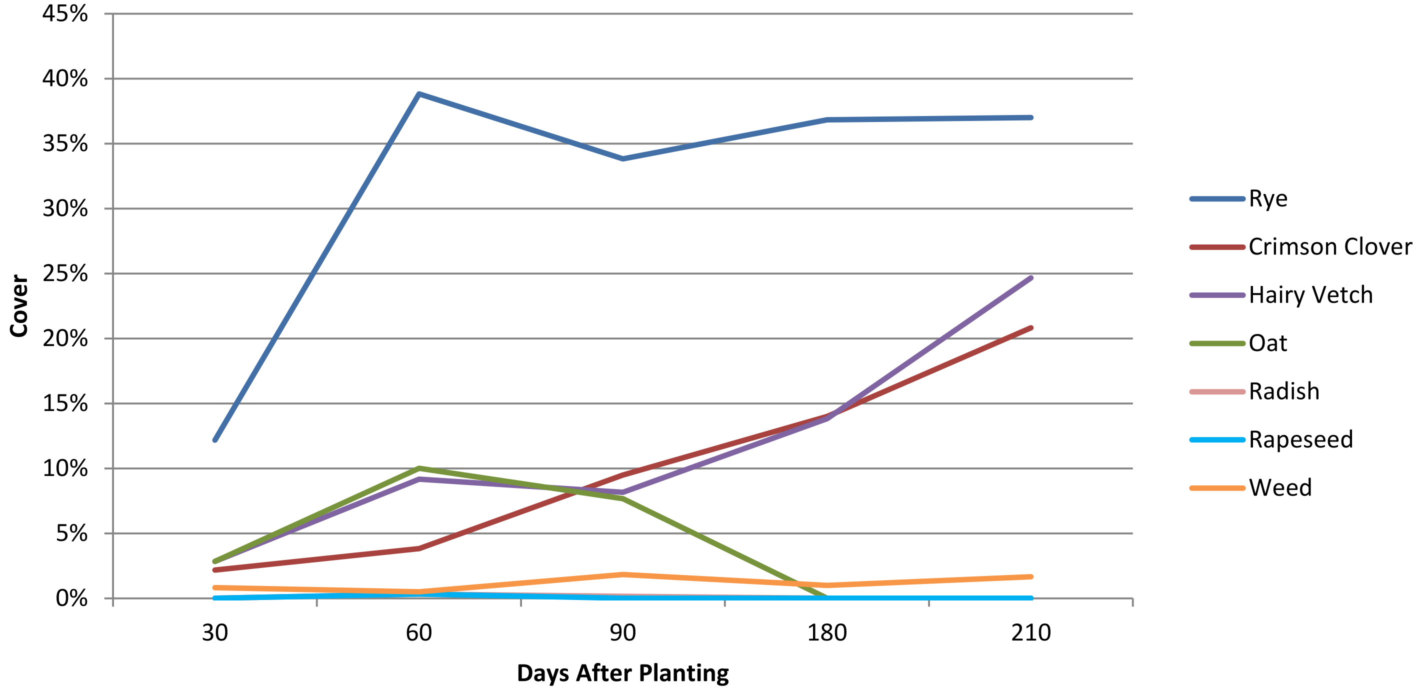

Figure 5. Comparison of average percent cover of cover crop species in 6 species mix plots from 30 to 210 days after planting. Contributions to cover on an equal seed number basis can be compared for rye, crimson clover, hairy vetch and oat; each was 22.5% of the seed mix by seed number.

Biomass and Nitrogen from Cover Crops

Dry matter (DM) biomass at termination in all seeded plots consisted primarily of grasses and legumes (Figure 6). Rye was the only grass component at termination and contributed the most to total DM biomass for all cover crop treatments. The legumes in the control plot consisted of volunteer crimson clover as well as common vetch (*Vicia sativa*), black medic (*Medicago lupulina*) and rabbitfoot clover (*Trifolium arvense*). All of the cover crop treatments had from 2.9 to 5.2 times the biomass of the control, however only the two treatments with at least 4.9 times the biomass of the control were significant. Substantial variation in the soils and prior year management of the plot area were likely factors in limiting statistical sensitivity. The continuation of the same cover crop treatments over three years should reduce this variation while increasing the response to the cover crops. The species mixtures or seeding rate had no effect on biomass production in this first year of the study.

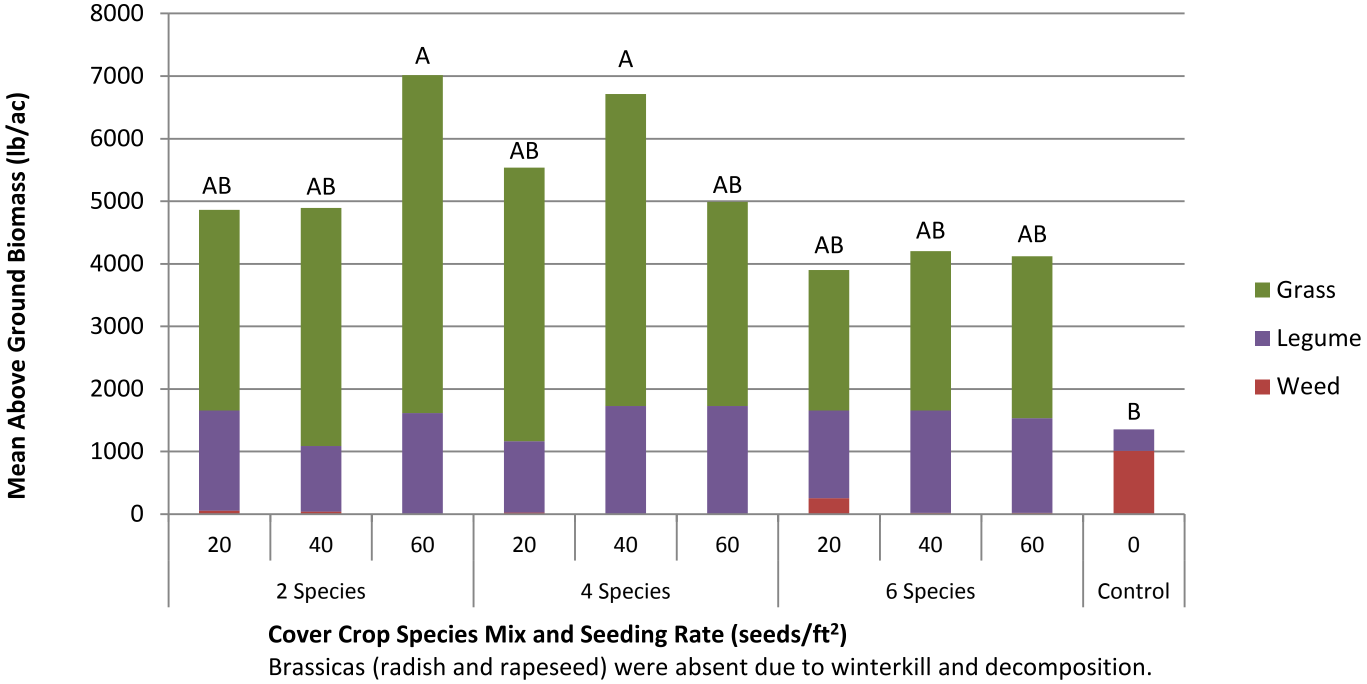

Figure 6. Above ground biomass of cover crop species at termination. Means with the same letter above the bar are not significantly different in Tukey HSD comparisons at α=0.05 for total mean above ground biomass.

Cover crops have the ability to provide nutrients to subsequent commodity crops through nutrient capture and as well through the production of plant-available nitrogen (PAN) by leguminous cover crops. Planting cover crops earlier in the fall results in greater biomass and nutrient scavenging, however University of Maryland research has shown that radish planted late (September 24) still scavenges significant nutrients due to a lower C:N ratio in the younger plants (Dean et al., 2009). The biomass and resulting organic matter provided by cover crops also improves soil fertility through erosion protection, improved soil structure, increased infiltration and water holding capacity, increased cation exchange capacity and the more efficient long-term storage of nutrients (Clark, 2007).

The nitrogen (N) content of above ground biomass dry matter (DM) was below 2% for all cover crop treatments but 2.5% for the control (Table 3). Grasses comprised over 58% of the biomass in all cover crop treatments and the control was comprised of 0% grasses and 25% weed and volunteer legumes which can explain these differences in percent N. Legumes at flowering typically contain 3 to 3.5 percent N compared to 1.5 to 2.5 percent for small grains, with these percentages dropping rapidly after flowering (Clark, 2007). Percent N is strongly related to the amount of plant available nitrogen (PAN) released to the following crop, with little to no PAN provided by crops with less than 1.5% N in DM (Sullivan et al., 2012). Percent N in DM for the cover crop treatments ranged from 1.3 to 1.8 percent and therefore little to no PAN is expected to be provided to the following corn crop. However, much of this N content will be used to decompose biomass and build soil organic matter which can release between 10 and 40 lb. N/A for each 1 percent soil organic matter; with warm, well drained soils at the higher end of this range (Clark, 2007) (Sullivan et al., 2012). Since the cover crop was rolled and not incorporated, the release of PAN is expected to gradually be released as the residue slowly decomposes. Soil fertility is also expected to improve with increases in soil organic matter from continued cover cropping in this study.

Table 3. Comparisons of average aboveground biomass dry matter, % N in dry matter, and percent composition of three cover crop mixes and three seeding rates. Values within the same column followed by the same letter are not significantly different in Tukey HSD means comparisons at α=0.05.

Mix	Rate(seeds/ft2)	Dry Matter (tons/acre)	N in Dry Matter	Cover Crop Biomass Composition Grasses	Legumes	Brassicas	Weeds
2 Species	20	2.43 ab	1.6% b	66% a	33% a	0% a	1% b
	40	2.45 ab	1.3% b	78% a	22% a	0% a	1% b
	60	3.51 a	1.3% b	77% a	23% a	0% a	0% b
4 Species	20	2.77 ab	1.5% b	79% a	21% a	0% a	1% b
	40	3.35 a	1.6% b	74% a	26% a	0% a	0% b
	60	2.49 ab	1.6% b	65% a	35% a	0% a	0% b
6 Species	20	1.95 ab	1.8% ab	58% a	36% a	0% a	7% b
	40	2.10 ab	1.6% b	61% a	39% a	0% a	0% b
	60	2.06 ab	1.7% ab	63% a	37% a	0% a	1% b
Control	Control	0.68 b	2.5% a	0% b	25% a	0% a	75% a

Soil Moisture and Temperature

Despite differences in biomass, all the cover crop treatments and control plots had similar low soil moisture, which suggests the planted cover crops had little effect on soil moisture at corn planting. We also observed very little difference between the seeding rates or the control plots, with all of the plots between about 75 and 77 degrees. Canopy cover and biomass, did not substantially affect soil temperature and our soil temperatures were well above the minimum temperature for corn germination. The corn germinated quickly in all of the treatments.

Commodity Crop Yield

There were no significant differences in corn yield between treatments (Figure 8). Corn growth and yield appeared to be greatly affected by substantial variation in the soils and prior year management, potentially influencing corn yields more than the cover crop treatments. Delayed termination of the cover crops and subsequent low PAN may have limited the corn yield response to the cover crop treatments. The cover crop treatments are expected to have a cumulative effect over the 3 years of this study that may overcome the initial field variations.

Figure 7. Soil health study plots 77 days after seeding corn.

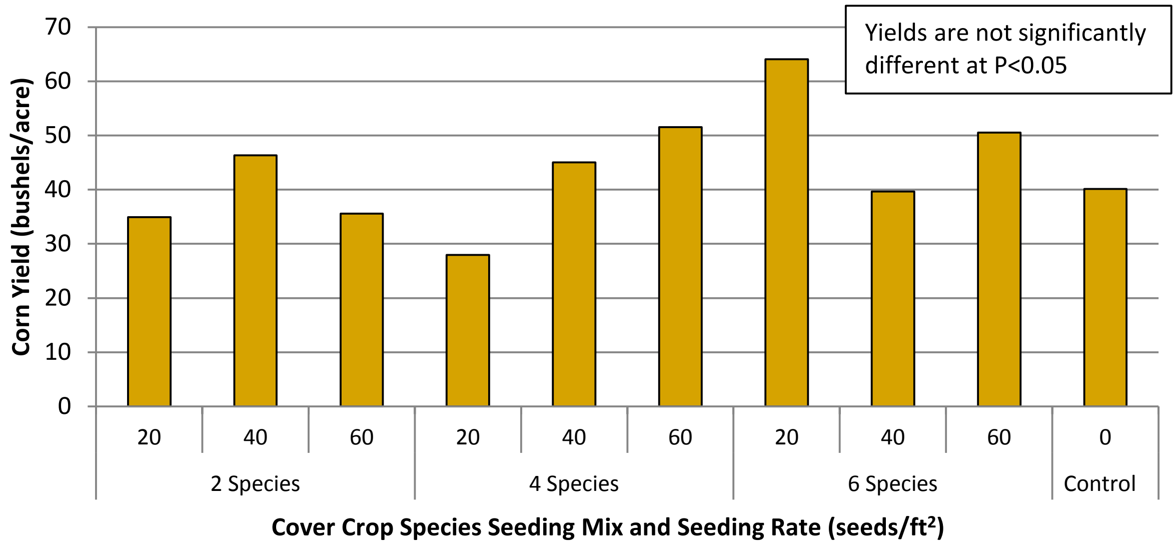

Figure 8. Field corn yield following one season of cover cropping.

Soil Health

A useful assessment of the overall health of soil was developed by Dr. Rick Haney of USDA-ARS, (Temple TX), which combines 5 measurements of soil biological and chemical properties into one Soil Health Calculation number. The soil health calculation number can range from 1 to over 50, with higher numbers indicating better soil health. The soil health calculation numbers for all cover crop and control treatments increased by a minimum of 0.75 and maximum of 1.66 from fall 2012 to spring 2013, with no clear trend due to treatment (Figure 9). This increase in the soil health calculation number in all the treatments may be due to the transition to no-till. As cover cropping continues in this study in years 2 and 3, a treatment effect on the Soil Health Calculation may become apparent.

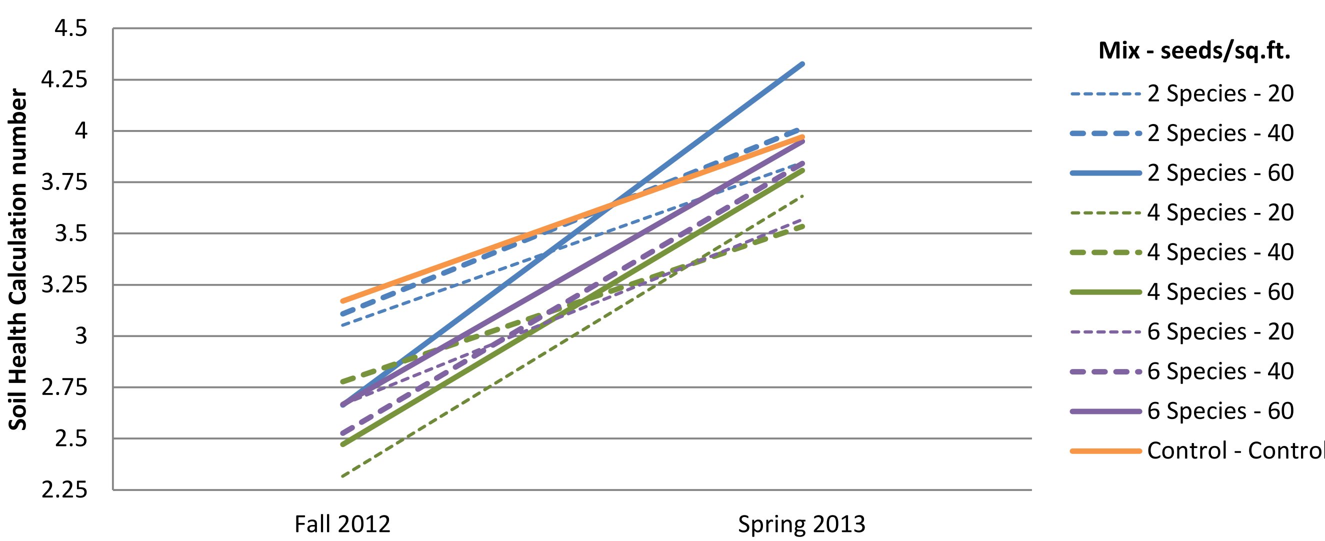

Figure 9. Change in average Soil Health Calculation number of cover crop treatments and control from time of cover crop planting (fall 2012) to the time of termination (spring 2013).

Conclusions

One year of cover crops in this study were very effective in suppressing weeds, but not in improving soil health or commodity crop yield compared to the control. Earlier cover crop termination should improve PAN and corn yield response to cover crops. Continued cover cropping should accumulate benefits to soil and commodity crop yield. Rapeseed was not well adapted for growing in the short period of time between corn harvest and killing frost in this study. All cover crop species, especially rape, radish and oats would benefit from earlier planting.

Literature Cited

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