National Soil Health Study Progress Report – Year 2

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 230 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 two years of data at the NPMC in Beltsville, Maryland. Results are expected to change from year to year and as more data are collected and analyzed. The conclusions in this report on the preliminary analysis of the first two years of data may change as more data is collected. The results of this study will further expand recommendations for using cover crops to improve soil health, reduce inputs, and improve commodity crop yield.

Methods

The NPMC is located about 10 miles northeast 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 May 21, 2014.

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			% mix by seed number	lb/acre			% mix by seed number	lb/acre		
		20*	**40***	**60***		**20***	**40***	**60***		**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. Planting, Termination and Harvest Dates are listed in Table 3. For the first year only, the cover crop treatments were planted into a conventionally prepared seedbed using a Truax Trillion seeder. After the first year the cover crop plots were 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 using a tractor with a roller crimper on the front and a no-till corn planter on the rear (Figure 2). An early maturing 95 day field corn was the commodity crop grown at this location. Canopy cover was recorded every 30 days unless dormant or snow covered and ceased at 100% cover. In year 2, weed control was practiced in the control lots and therefore biomass samples were not taken from the control plots. Irrigation was required after the corn harvest in year one to achieve adequate soil moisture 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

Table 3. Planting, Termination and Harvest Dates

Year	Cover Crop Planting	Cover Crop Termination and Corn Planting	Corn Harvest
1	September 20,2012	June 4, 2013	September 18, 2013
2	September 30, 2013	May 21, 2014	September 15, 2014

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 60 days after planting (DAP) in year 1. In year 2, however, only the 4 species mixtures and 6 species at 40 and 60 seeds/ft^2 achieved 80% cover by a much later 230 DAP.
- Rye provided the greatest cover in all treatments for both years and sampling dates except at 230 DAP in year 2 where hairy vetch exceeded.
- Hairy vetch and crimson clover provided similar cover in year one with 25% and 21% cover at termination respectively. In year 2, hairy vetch greatly exceeded crimson clover with 46% cover versus crimson clover with 5% cover due to a later planting date and earlier cold temperatures.
- Oats, radish and rapeseed winterkilled both years 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 crop 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 in year 1, but only 0.7 to 1.1 t/ac dry matter biomass prior to termination in year 2.
- Differences in dry matter biomass and %N in dry matter did not show a clear trend and were statistically similar between cover crop treatments for both years.
- The overall soil health as indicated by the Soil Health Calculation number has continued to show no significant difference between treatments.

Results and Discussion

Cover and Weed Suppression

The early cold temperatures of fall 2013 and planting date that was 10 days later than in year 1 greatly affected cover crop growth, especially crimson clover. The cover crop mixes did not exceed 41% cover prior to ceasing growth for the winter (Figure 3). The 2 species mixtures at all seeding rates with only rye and crimson clover achieved less than 60% cover by termination. Seed mix species composition influenced percent cover more than seeding rate. Weed growth was greater in year 2, but consisted mostly of small short species at levels that were still acceptable.

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 except 230 DAP in year 2. 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 4). Rye and hairy vetch persisted well and contributed the most cover by termination with 33% and 46% cover respectively. In year 1 only, 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. Radish growth was limited both years, as expected, by the September 20 and 30 planting dates. 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 cover crops were successfully terminated with the roller crimper both years, with only sparse regrowth of the hairy vetch that did not affect corn growth. Herbicide was not used to assist termination of cover crops in the second year and was used but not necessary the first year.

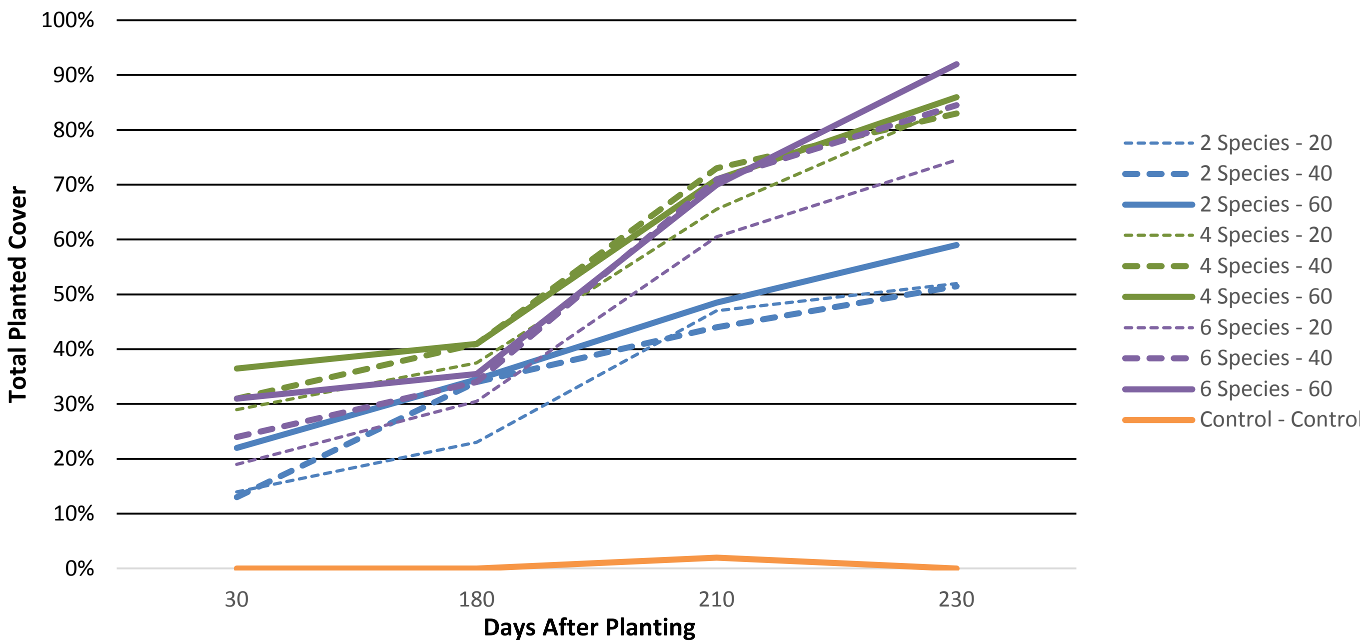

Figure 3. Effect of cover crop mix and seeding rate on Total Planted Percent Cover from 30 to 230 days after planting. (2013-2014)

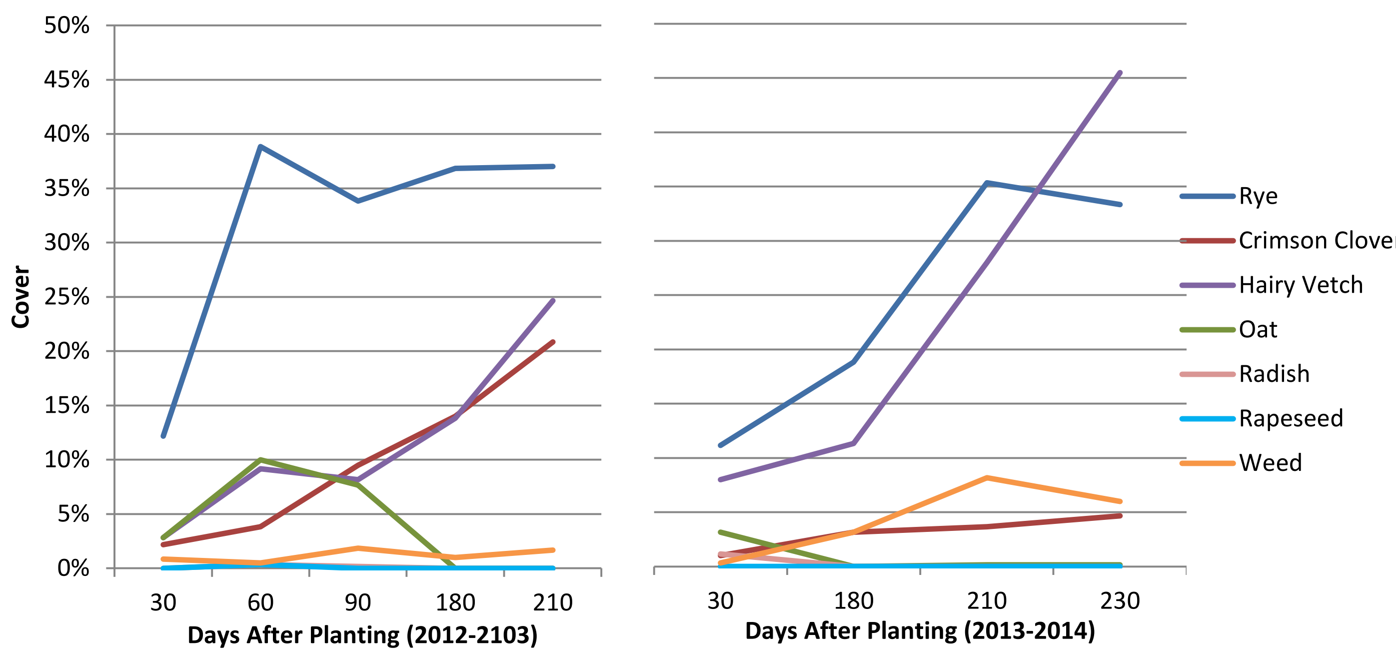

Figure 4. Comparison of average percent cover of cover crop species in 6 species mix plots from 30 to 210 days after planting in 2012-2013 and 30 to 230 days after planting in 2013-2014. Contributions to cover on an equal seed number basis can be compared for rye, crimson clover, hairy vetch and oat; each was 22.5% of the seed mix by seed number.

Biomass and Nitrogen from Cover Crops

The species mixtures or seeding rate had no statistically significant effect on biomass production in the first 2 years of the study. 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 (Figure 5). Rye was the only grass component at termination and contributed the most to total DM biomass for all cover crop treatments in both years. There was no statistical difference in biomass DM production between cover crop treatments for both years. 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.

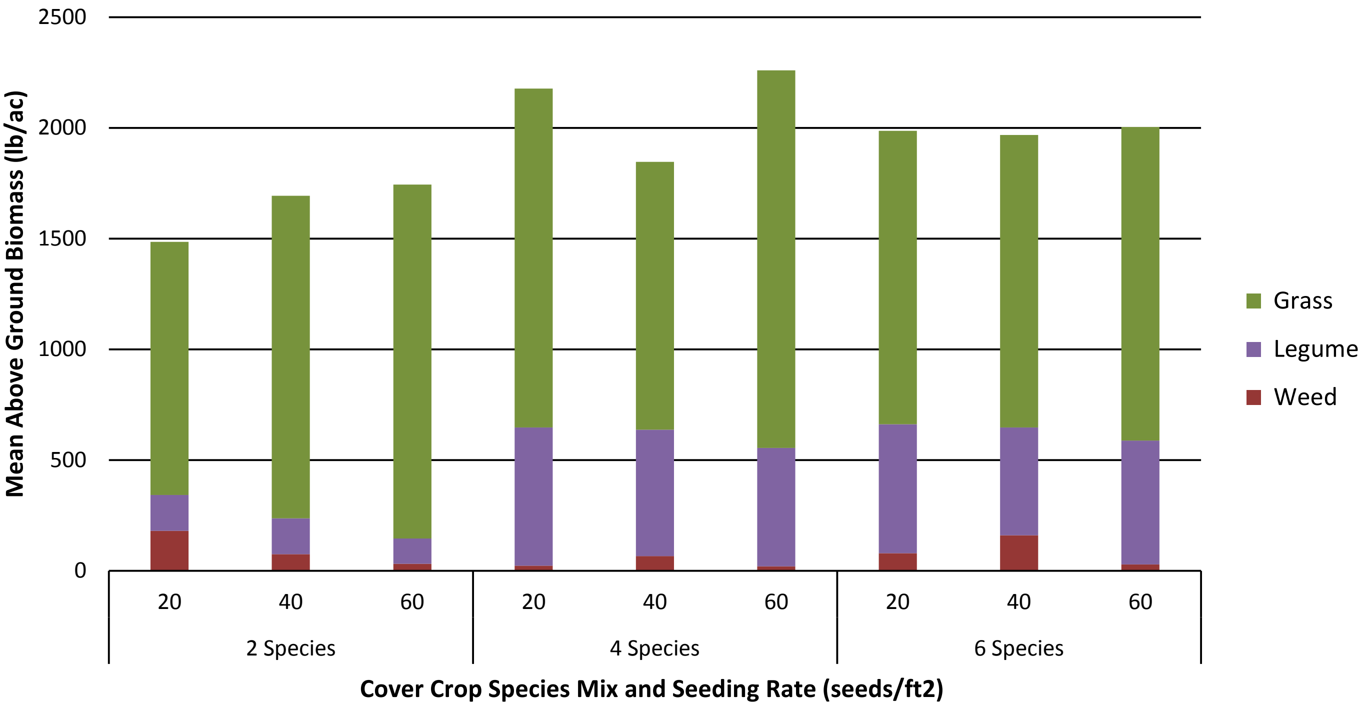

Figure 5. Above ground biomass of cover crop species at termination. Brassicas (radish and rapeseed) were absent due to winterkill.

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 in year 2 (Table 4) as well as year 1. Grasses comprised over 58% in year 1 and over 66% in year 2 of the biomass in all cover crop treatments. 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 both years 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 4. 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	0.74 a	1.4 bcd	78% a	9% a	0% a	13% a
	40	0.85 a	1.3 cd	84% a	11% a	0% a	5% a
	60	0.87 a	1.3 d	91% a	6% a	0% a	2% a
4 Species	20	0.89 a	1.6 abcd	71% a	27% a	0% a	1% a
	40	0.92 a	1.8 a	66% a	29% a	0% a	5% a
	60	1.13 a	1.5 bcd	73% a	26% a	0% a	1% a
6 Species	20	0.99 a	1.7 ab	67% a	30% a	0% a	4% a
	40	0.98 a	1.6 abc	67% a	23% a	0% a	10% a
	60	1.00 a	1.6 abc	71% a	28% a	0% a	1% a

Soil Moisture and Temperature

Despite differences in biomass, all the cover crop treatments and control plots had similar soil moisture, which suggests the planted cover crops had little effect on soil moisture at corn planting in this climate. 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 for both years. Corn yield in the second year was 22% less than the first year yield. Corn growth and yield in the first year 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. 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.

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 have increased from fall 2012 to fall 2013. Soil Health values decreased in two treatments in spring 2014 and all

Soil Health values decreased in Fall 2014 (Figure 6). There was no clear trend due to treatment and no significant difference between cover crop treatments (Table 5). The 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, a treatment effect on the Soil Health Calculation may become apparent.

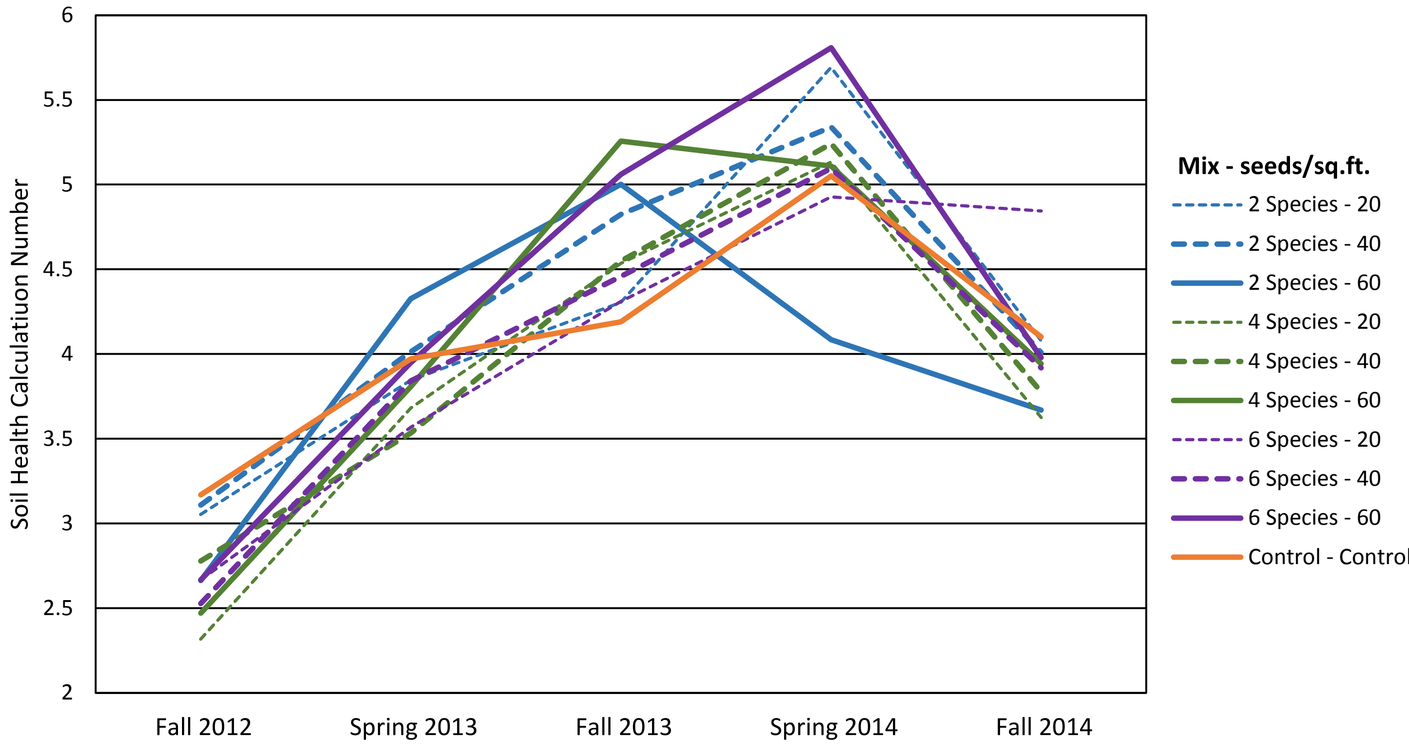

Figure 6. Change in average Soil Health Calculation number of cover crop treatments and control from fall 2012 to fall 2014.

Table 5. Soil Health Calculation numbers of cover crop treatments and control from fall 2012 to fall 2014. Values within the same column followed by the same letter are not significantly different in Tukey HSD means comparisons at α=0.05.

		Soil Health Calculation Number				
Mix	Rate(seeds/ft2)	Fall 2012	Spring 2013	Fall 2013	Spring 2014	Fall 2014
2 Species	20	3.1 a	3.8 a	4.3 a	5.7 a	4.1 a
	40	3.1 a	4.0 a	4.8 a	5.3 a	4.0 a
	60	2.7 a	4.3 a	5.0 a	4.1 a	3.7 a
4 Species	20	2.3 a	3.7 a	4.5 a	5.1 a	3.6 a
	40	2.8 a	3.5 a	4.5 a	5.2 a	3.8 a
	60	2.5 a	3.8 a	5.3 a	5.1 a	3.9 a
6 Species	20	2.7 a	3.6 a	4.3 a	4.9 a	4.8 a
	40	2.5 a	3.8 a	4.5 a	5.1 a	3.9 a
	60	2.7 a	3.9 a	5.1 a	5.8 a	4.0 a
Control	Control	3.2 a	4.0 a	4.2 a	5.1 a	4.1 a

Conclusions

Two years 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. Continued cover cropping for several more years should benefit soil health compared to the control. 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 and are probably not appropriate for use in rotation with 95 day field corn in Maryland. An earlier maturing corn or other crop would allow for greater flexibility in selecting more diverse cover crop mixes that would have greater soil health benefits and adaptability to varying weather conditions.

Literature Cited

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