United States Department of Agriculture

STUDY REPORT
Lockeford PMC, Lockeford, CA

Effects of Mixed Species Cover Crop on Soil Health – Year Two

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ABSTRACT

Soil health is becoming an increased focus for the agriculture industry in California. This report provides the results for the second year of a national soil health study at the Lockeford Plant Materials Center (PMC). The study is facilitated by the Plant Materials Program, and is in collaboration with six other PMCs from around the country. Three cover crop seeding rates and three mixes of six cover crop components are being evaluated for their effect on soil health. The experimental design is a randomized complete block design with four blocks and two treatment factors; species mix and seeding rate resulting in nine species mix and rate combinations. The second year of cover crops were planted in the fall of 2013 and sweet corn planted the following summer. Cereal rye dominated the cover crop mixtures during the second year of the Soil Health Study. The 4 component mixture performed the best at all seeding rates, reaching 100% canopy cover by 120 DAP. The 4-component mixtures had the least amount of bare ground and weeds, and biomass was significantly higher. Sweet corn yields did not vary significantly between treatments. Soil health, as measured by Soil Health Indicator Values, was improving over time, but these were not statistically significant and there was no difference in bulk density, soil moisture, soil resistance, and total nitrogen

INTRODUCTION

This report provides the results for the second year of a national soil health study at the Lockeford Plant Materials Center (PMC), facilitated by the Plant Materials Program, and in collaboration with six other PMCs from around the country. The Lockeford PMC is located in a Mediterranean climate in California's Central Valley. There are hot, dry summers and variable precipitation conditions throughout the rest of the year. During the first year of the study, in 2012, California farmers were beginning to see moderate (D1) and severe (D2) drought throughout the state. By the conclusion of the second year's study, exceptional (D3) and extreme (D4) drought covered most of the state's landscape.

Soil health is becoming an increased focus for the agriculture industry in California. The current drought has highlighted the use of cover crops to increase infiltration and, over time, soil water holding capacity. Cover crops are important as their use has benefits including, increasing soil organic matter and water holding capacity (Lal. 2015), increasing fertility by adding nitrogen from growth of legumes, increasing arbuscular mycorrhizae (Lehman, et al., 2012), decreasing soil salinity (Gabriel, et al., 2012), and causing weed suppression through interspecies competition (Clark, 2007). Cover crops are being increasingly used as a viable tool for generating profit indirectly through the beneficial use of fallow periods. Although cover crops have been found to be disadvantageous in specific instances such as winter rye's inability to reduce nitrate leaching in loamy sand soils in the Mid-Atlantic States (Ritter, et al., 1998), overall, the technique of cover cropping has been successful in achieving many different benefits for soil health. Cover cropping is not a new technique; the Latin poet Virgil (70-19 BCE)

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authored the tome *Georgics* around 29 BCE, which mentioned the use of alfalfa, clovers, and lupine for increased wheat yields. The Mediterranean climate of California, with dry summers and typically wet winters, is different from the continental US and makes implementation of cover cropping a challenge for farmers, especially under drought conditions.

This study evaluates three different seeding rates and mixes of six plant species to observe their impact on soil health. Cover crops planted each fall and sweet corn were to be planted each summer as an example of a commodity crop. Information gathered in this study will help us determine the effectiveness of these cover crop species to the Central Valley of California. The objectives are to determine effect of cover crop diversity and seeding rate on soil health.

MATERIALS AND METHODS

The study was established on a Vina fine sandy loam soil at the Lockeford PMC. Each year of the study, cover crops were planted in the fall and sweet corn planted the following summer. A randomized complete block design with four replications was used. Three rates (20, 40 and 60 seeds/ft^2) and three species combinations (Table 1) resulted in nine treatment plots and one control plot in each block; control plots were treated with herbicide and were not planted. Each plot was 30 ft. x 60 ft.

Table 1. Planting mixes for the soil health study at the Lockeford PMC.

Species Mix	Grasses	Legumes	Brassicas
2-component	50% cereal rye	50% crimson clover	
4-component	45% cereal rye	22.5% crimson clover	10% tillage radish
		22.5% hairy vetch	
6-component	22.5% cereal rye	22.5% crimson clover	5% tillage radish
	22.5% oats	22.5% hairy vetch	5% canola

Prior to the cover crop planting, nutrient levels were measured and soil health indicator values were calculated. The Soil Health Indicator Value was developed as a tool to assess soil health, factoring in the balance of soil carbon and nitrogen and its relationship to microbial activity. The values were calculated from one day's CO_2 release divided by the organic C:N ratio plus weighted organic C and N additions; these values represent the overall health of your soil system. Values are on a scale of 0 to 50, and should increase over time if the soil is being sustainably managed. Soil temperature and volumetric water content (VWC) measurements were also taken prior to cover crop seeding. Soil temperature was measured manually with a soil thermometer and soil moisture was measured with the Hydrometer II (Campbell Scientific, Logan, UT).

Plots were irrigated prior to planting the cover crops on October 23, 2013 using a Truax range drill. There was no further irrigation. Growth was slow for all treatments during December and January with cold temperatures and no rain. Rainfall amounts in November, December and January were 1.09, 0.43 and 0.1 inches, respectively. This was an exceptionally dry winter as normal annual rainfall is 19 inches between September and April. The 3.7 inches of rain in February was near average for the month, and there was an additional 1.42 inches in March. There was a period of intense cold during the first week of December, with temperatures of 20° F at night and near 40° F during the day. After this time day temperatures were normal or above normal, but the clear skies led to below average temperatures and frosts at night.

Canopy cover and plant height data were collected every 30 days post-cover crop planting. Before cover crop termination, 0.5 m^2 samples of above ground biomass were acquired from each treated plot according to the guidelines put forth by the National Plant Materials Center; botanical composition was determined by means of biomass measurements of individual species with weeds being treated as a single group.

The cover crops were terminated on April 14, 2014 using a roller crimper. Soil temperature and soil moisture were measured at cover crop termination. The area was left fallow after cover crop termination until sweet corn planting. Sweet corn was planted in the June 19, 2014 with a Monosem no-till 4-row corn planter. Sprinkler irrigation was used prior to seeding until sweet corn emergence, after which time the plots were drip irrigated.

Sweet corn was harvested on September 3, 2014, approximately 10 weeks after the mid-summer planting. Corn yield was estimated by sampling 0.5 m^2 areas from all plots. After termination of the commodity crop a second biological assessment of the soil took place. Soil resistance was measured manually with a soil resistance meter and bulk density was determined through the use of core samples from each of the plots. The plots were mowed following the sweet corn harvest.

Data sorting was performed utilizing the Microsoft Excel program and statistical analysis was executed on Statistix 8.0; one-way ANOVA and Tukey HSD comparison tests were run.

RESULTS AND DISCUSSION

Cover Crop Results – Biomass and Cover

The effect of seeding rate on canopy cover was only significant at early stages of growth (Table 2) and after 120 days there were not significant differences between seeding rates. Emergence was lowest in the 6-component mix, leading to reduced cover, and at 30 days cover was 17 and 11% for the 4- and 2-component mixes respectively, but only 4% for the 6-component mix (Figure 2, 3). The reduced biomass with the 6-species treatment was probably due to an adjustment made during planting that placed seed at a lower depth.

Two-component mix	Four-component mix	Six-component mix

Figure 1. Showing the 60 seedsft^2 seeding rate with the 2- 4-, and 6- component plantings. Images taken Jan 6 2014, (45 DAP) at the Lockeford Plant Materials Center.

Above ground biomass was highest in the plots seeded with the 4-species mix, with the differences in plot treatments of 2-species and 4-species being statistically significant (Figure 3).

The drought conditions during 2013 – 2014 reduced growth of legumes. In a separate demonstration trial at the CAPMC with several species of legumes, which included bell beans, clover, peas, and vetch cultivars all performed poorly. These legumes are widely planted as cover crops in the Central Valley and perform well in years with average precipitation.

Table 2. Canopy Cover for Cover Crop Mixes planted at the Lockeford PMC 2013 – 2014.

SPECIES Mix	**% Canopy Cover[1]**				
2-component	**30 DAP**	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
20 seed ft²	6	19 a[2]	25 a	73a	89 a
40 seed ft²	7	32 a	34 a	82 a	88 a
60 seed ft²	20	64 b	68 b	91 a	92 a
Mean	11	38	42	89	89
4 Component					
20 seed ft²	9 a	40 a	73 a	97 a	95 a
40 seed ft²	15 a	49 a	83 ab	98 a	97 a
60 seed ft²	28 b	79 b	92 b	100 a	99 a
Mean	17	56	82	98	97
6 Component					
20 seed ft²	.05 a	4	13 a	38 a	71 a
40 seed ft²	3 b	11	19 a	49 a	80 a
60 seed ft²	8 b	12	40 b	80 b	94 a
Mean	3	9	24	55	81

[1] Percent canopy cover determined by line transect method 30, 60, 90, 120 and 150 days after planting (DAP) (16 November 2013)

[2] Means in columns for mixes planted at 20, 40 and 60 seeds/ft^2, respectively, followed by the same letters are not significantly different according to LSD test ($p<0.05$)

[3] 2 component mix: Cereal rye + crimson clover

[4] 4 component mix: 2 component + hairy vetch + tillage radish

[5] 6 component mix: 4 component + oats + canola

The least amount of bare ground, dead plant material, and weed cover was found in the 4-component treatments. These plots had the highest amount of cereal rye cover at 95%. The legume cover in these plots was only 2% , but that was the highest level of legume cover attained this year (Figure 4). Cereal rye residue when present will increase the nitrogen requirement for decay of organic matter.

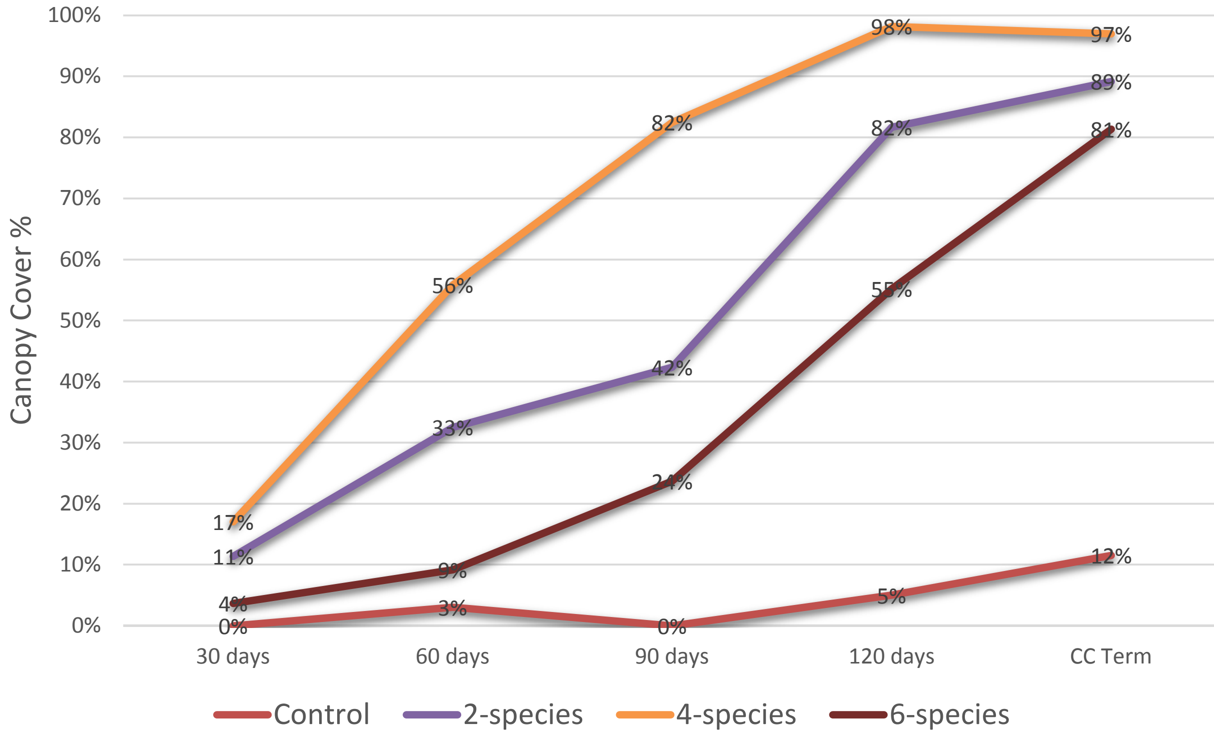
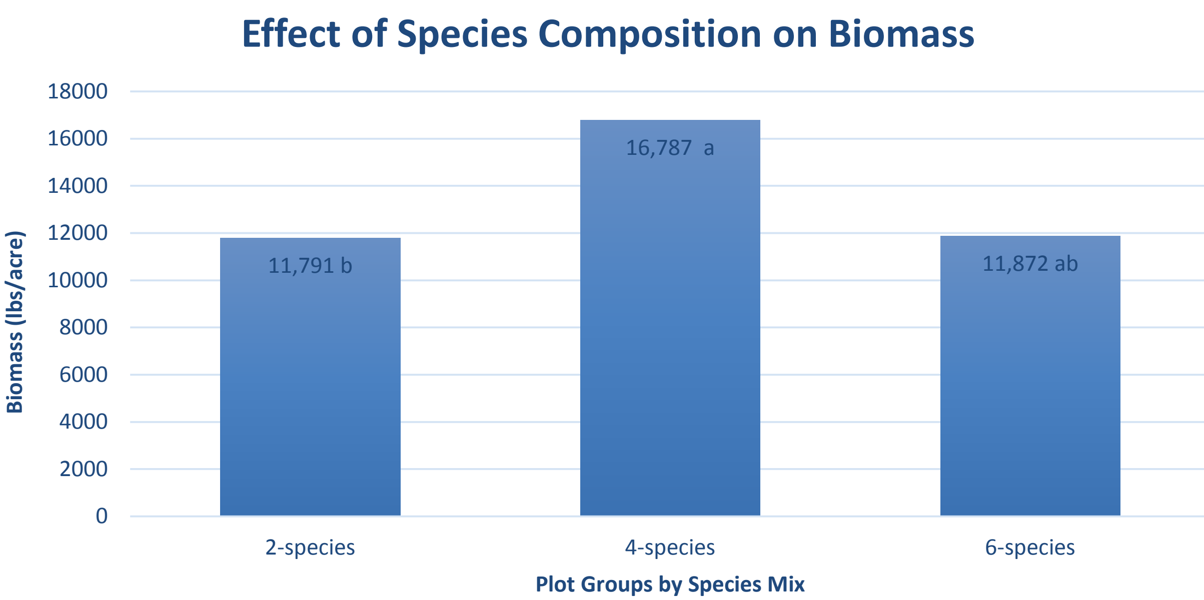


Figure 2. Mean canopy cover (%) from 30 days after-planting to termination at the Lockeford PMC.



Values followed by the same letter are not significantly different according to the LSD comparison with a significance level of $\alpha = 0.05$.

Figure 3. Mean above ground biomass, organized by species composition mix, collected at cover crop termination.

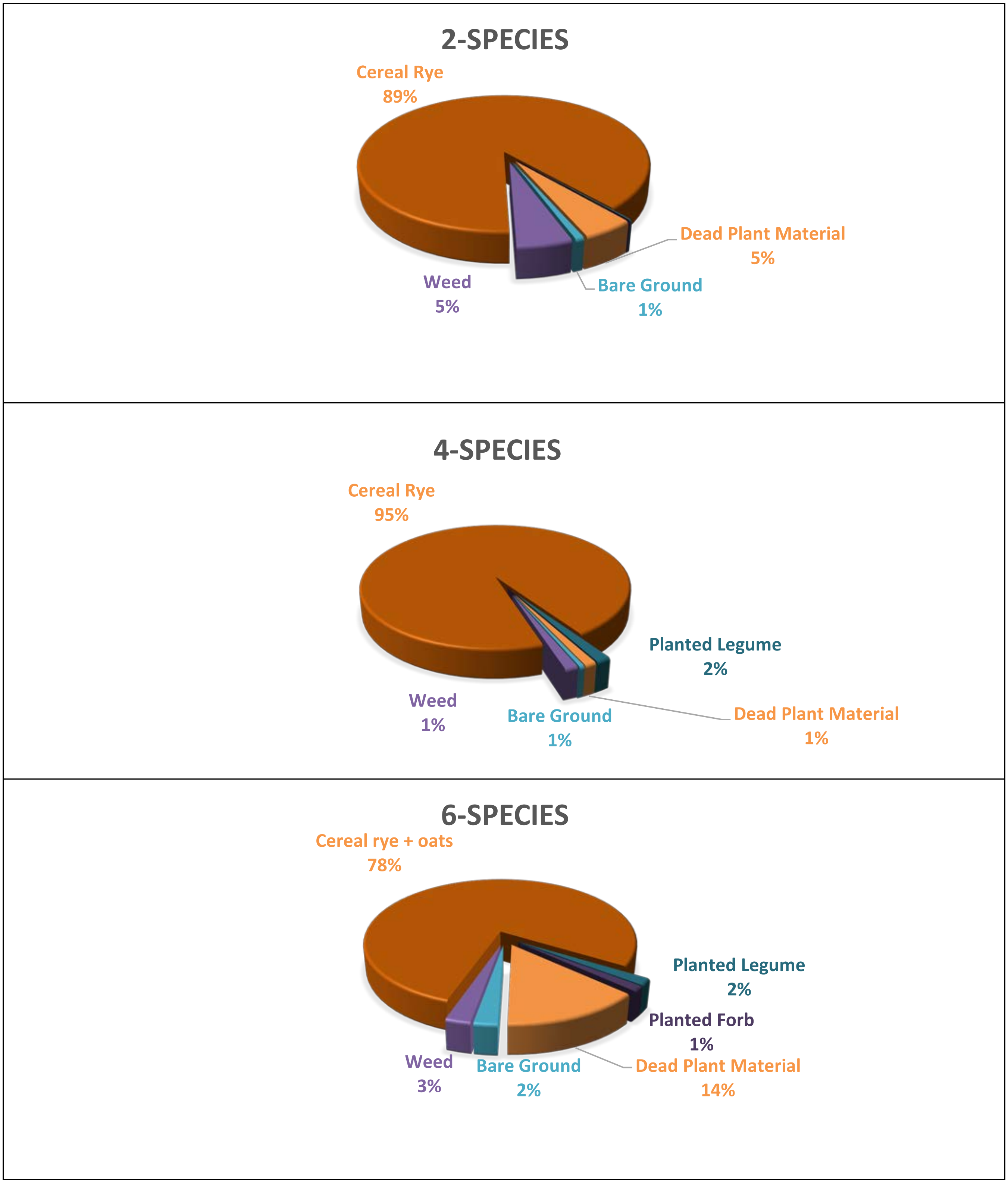


Figure 4. Canopy cover of plots at termination of cover crops, grouped by species mix at the Lockeford PMC.

The competitive nature of cereal rye in this trial, which was close to a monoculture in all treatments, reducing the presence of legumes and the loss of their nitrogen contribution to the system. A study conducted over two season in Michigan comparing different combination seeding levels of rye and vetch found tradeoffs as increased rye suppressed weeds more efficiently, but higher seeding rates of vetch increased nitrogen levels (Hayden et al. 2014). Nitrogen cycling was linked with high levels of organic carbon to provide available nitrogen in commercial organic tomato processing operations in the Central Valley of California (Bowles, et al. 2015)

Sweet Corn Yields

Sweet corn yields were not statistically different due to either species composition or seeding rates (Table 3). Yields in 2014 were much lower than the previous year and is likely the result of low soil nitrogen level from poor legume growth. Living roots were maintained in the soil over the summer, which was the aim of the trial.

Table 3. Sweet corn yield during 2013 and 2014 of the Soil Health Study at the Lockeford PMC.

Mix	Seeding Rate	2013 (bushels/acre)	2014 (bushels/acre)
2-species	20 seeds/ft^2	78 c[1]	28.09 a
	40 seeds/ft^2	99 bc	32.28 a
	60 seeds/ft^2	71 c	13.34 a
4-species	20 seeds/ft^2	194 a	35.03 a
	40 seeds/ft^2	165 ab	36.26 a
	60 seeds/ft^2	183 a	32.89 a
6-species	20 seeds/ft^2	176 ab	70.69 a
	40 seeds/ft^2	165 abc	62.90 a
	60 seeds/ft^2	170 ab	55.84 a
Control	0 seeds/ft^2	52.64 c	50.59 a

[1]Means in columns for mixes planted at 20, 40 and 60 seeds/ft^2 followed by the same letters are not significantly different according to LSD test ($p<0.05$)

Soil Health

Measurements were taken for bulk density, soil moisture, soil resistance, and total nitrogen. There were no significant treatment differences for any of these measurements. Soil Health Indicator calculations do not show any significant differences. To date, the highest means were found in the 4-species mix plots, at seeding rates of 20 seeds/ft^2 and 60 seeds/ft^2. The 4-species mix plots seeded at a rate of 60 seeds/ft^2 scored approximately three points higher (20.2 as opposed to 17.4) than those at the rate of 20 seeds/ft^2 (Table 4).

Table 4. Soil Health Indicator Values for from the beginning of the first year of the study to the termination of the second year.

Cover Crop Mix	Seeding Rate (seeds/ft^2)	Soil Health Indicator Values[1]			
		2012 pre-CC[1]planting	2013 (post-corn harvest)	2013 (pre-CC planting)	2014 (post-corn harvest)
2-species	20	12.7	9.6	10.2	12.5
	40	12.5	8.9	8.9	10.1
	60	11.9	8.8	8.8	14.8
4-species	20	11.4	8.9	8.7	17.4
	40	15.1	9.0	9.1	14.9
	60	10.4	8.9	9.5	20.2
6-species	20	12.7	10.3	9.6	13.7
	40	14.6	10.2	10.0	13.0
	60	13.8	9.5	10.5	13.3
Control	0	13.5	10.5	9.1	14.7

[1] Soil Health Calculation from tool developed by Dr. Rick Haney USDA-ARS calculated from one day's CO_2 release divided by the organic C: N ratio plus weighted organic C and N additions.

[2]CC represents cover crop.

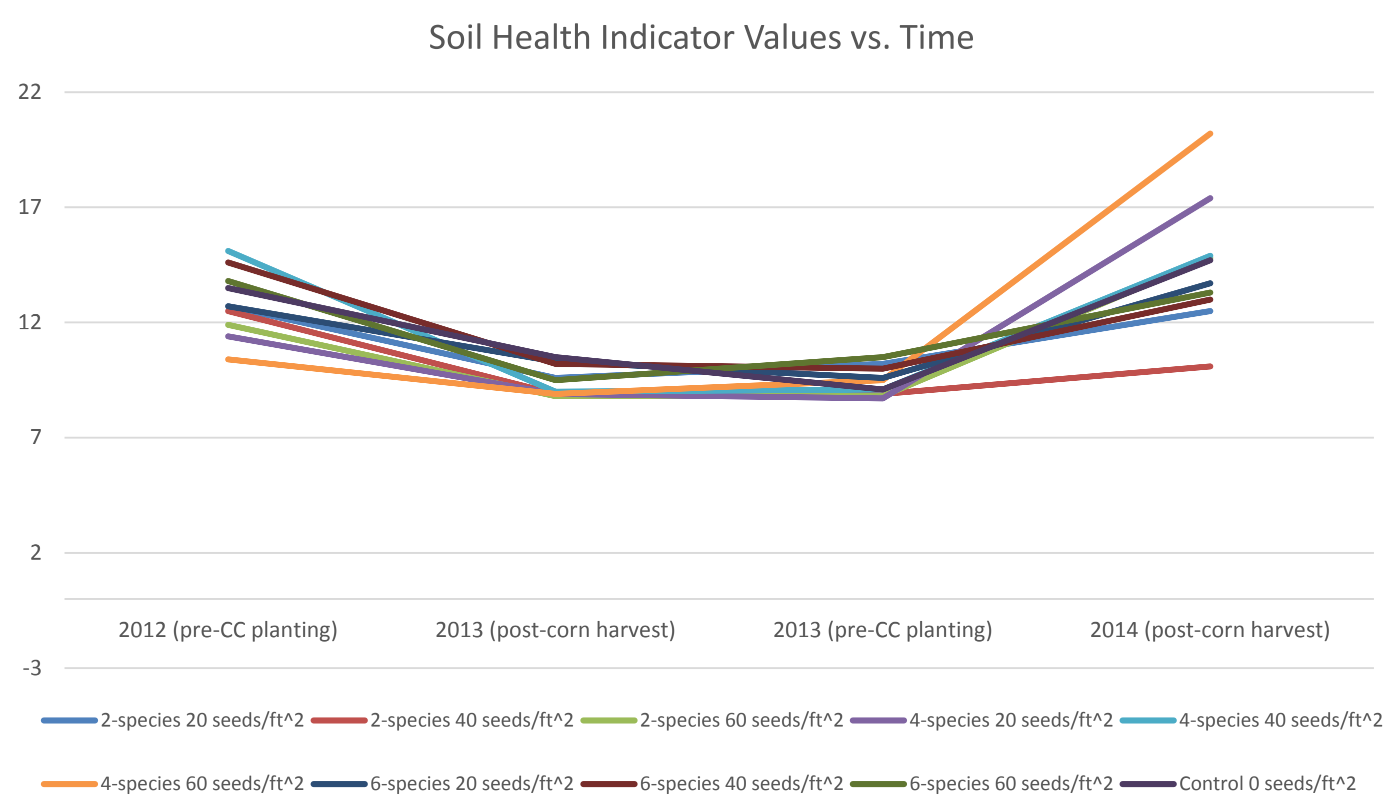


Figure 5. Soil Health Indicator Values for the Soil Health Study at Lockeford PMC 2012 - 2014.

A comparison of Soil Health Indicator Values over the two years of the trial indicates that there could be some recovery over time (Figure 5), although two years is a short period to see improvements in soil health. The greatest response was with the 4-component mix at the 60 and 20 seeds/ft^2 rates.

Results from canopy cover and biomass at termination indicate that a lower seeding rate will provide cost savings without reducing effectiveness. The exception to this would be when weed control is the most important need for a cover crop, and a higher seeding rate perhaps with an increased grass component would be recommended to provide early weed control.

CONCLUSION

Cereal rye dominated the cover crop mixtures during the second year of the Soil Health Study. The 4 component mixture performed the best as all seeding rates reached 100% canopy cover by 120 DAP. The 4-component mixtures had the least amount of bare ground, and weeds. Biomass was significantly higher in these treatments. Sweet corn yields did not vary significantly between treatments. There was an indication that soil health, as measured by Soil Health Indicator Values, was improving over time, but these were not statistically significant and there was no difference in bulk density, soil moisture, soil resistance, and total nitrogen.

LITERATURE CITED

Bowles T.M., Hollander A.D., Steenwerth K., Jackson L.E. (2015) Tightly-Coupled Plant-Soil Nitrogen Cycling: Comparison of Organic Farms across an Agricultural Landscape. PLoS ONE 10(6):e0131888. doi:10.1371/journal.pone.0131888

Clark, A. (ed.) 2007. Managing Cover Crops Profitably, 3rd ed. *Sustainable Agriculture Network.* Beltsville, MD.

Gabriel, J.L., Almendros, P., Hontoria, C., Quemada, M. 2012. The role of cover crops in irrigated systems: Soil salinity and salt leaching. *Agriculture Ecosystems & the Environment* 155: 50-61.

Hayden, Z.D., Mgouajio, M., and Brainard, D.C. 2014. Rye-vetch mixture proportion tradeoffs: cover crop productivity, nitrogen accumulation, and Weed suppression. Agronomy J. 106: 904-914.

Lal, R. 2015. Sequestering carbon and increasing productivity by conservation agriculture J. Soil and Water Conservation. 70(3):55-62.

Lehman, R.M., Taheri, W.I., Osborne, S.L, Buyer, J.S., Douds Jr., D.D. 2012. Fall cover cropping can increase arbuscular mycorrhizae in soils supporting intensive agricultural production. *Applied Soil Ecology* 61: 300-304.

Ritter, W.F., Scarborough, R.W., Chirnside, A.E.M. 1998. Winter cover crops as a best management practice for reducing nitrogen leaching. *Journal of Contaminant Hydrology* 34: 1-15.