Cover Crop Diversity in No-Till Systems

Project Final Report

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NORTHEAST SARE
Sustainable Agriculture Research & Education

This project was funded by
Northeast SARE
On Farm Research/Partnership Project:
ONE13-177

UNIVERSITY OF VERMONT EXTENSION
CULTIVATING HEALTHY COMMUNITIES

COVER CROP DIVERSITY IN NO-TILL SYSTEMS

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Northeast SARE Project Number: ONE13-177
2014 Final Report

Summary

In 2013 and 2014, the UVM Extension Champlain Valley Crop, Soil and Pasture Team based in Middlebury, Vermont partnered with four farms to evaluate two cover crop mixes in winter wheat and corn silage systems, as well as Tillage Radish in a pasture system. Four replicated trials were planted and evaluated for both fall and spring performance in percent ground cover, biomass, and nutrient uptake. Our focus was primarily on the heavier clay soils; however, much of the information from this project is applicable across the Champlain Valley (and beyond).

During the project timeframe, Vermont had the wettest two consecutive months on record in May and June of 2013. As a result, it was a challenging farming year. Cash crop planting was delayed, as were mid-season fertilizer applications and weed control applications. This resulted in poor cover crop established in some locations and rendered only one research site that produced usable data.

A winter hardy cover crop mix of winter triticale, winter pea and winter rape. *Photo credit: K. Workman*

The data collected in fall 2013 showed the lower seeding rates (50 pounds per acre) of our two different mixes interseeded into corn fields, performs comparably or better than the control plots of 100 pounds of winter cereal rye in percent cover, dry matter yields, and nutrient uptake of nitrogen, phosphorus and potassium in the fall. However, the data also showed winter rye out competed other treatments in the percent cover, dry matter yields, and nutrient uptake of nitrogen, phosphorus and potassium in the spring of 2014.

As a result of this project, we increased farmer interest and adoption in utilizing cover cropping and no-till systems in corn silage production. Not only did farms who participated in the project try new farming practices, but other farmers who heard about the project through our monthly newsletter, by attending the Farmer Field Day, and who received technical assistance have showed an increasing interest and adoption of these projects. This preliminary project has led to subsequent grant projects looking at cover crops in no-till systems.

Introduction

The Lake Champlain Basin is in the midst of a water quality dilemma. Elevated phosphorus levels in the lake have been identified through the EPA's TMDL process as a problem pollutant for the lake. The Lake Champlain Basin Program (LCBP) has determined that agriculture contributes between 40 and 50 percent of the phosphorus that enters the lake. Much of the phosphorus that enters the lake from farm fields comes attached to soil particles that erode from fields as a result of tillage. When soil is left bare before crop planting or after crop harvest, the potential for erosion is high. Due to soils with high clay content and wet spring weather conditions, many farmers in the basin fall plow to avoid poor conditions in the spring, which when

plowed or tilled then can lead to difficult and unsuccessful establishment of cash crops. For these same reasons, farmers are often reluctant to establish cover crops, as it is a cost burden without a sufficiently perceived benefit. Soils that are fall plowed tend to become compacted, slowing infiltration and increasing surface runoff, making fields that are left bare all winter more susceptible to heavy rainfall and winter thawing events and exacerbating the soil erosion problem.

Algae blooms in Lake Champlain

As the price of fuel, feed, and grain continue to rise faster than the price of milk, farmers are under significant economic pressure to grow more corn, therefore increasing the acres potentially fall plowed and left bare all winter. Furthermore, the same economic pressure makes some farmers less receptive to cover crops. Many of the benefits provided by cover crops shown in research and by farmers in other parts of the country are perceived by farmers in the Lake Champlain basin to be negated by the clay soils in the area. These soils are unique and do present challenges, however, it is apparent that there are also significant psychological barriers to the adoption of cover crops, no-till, and minimum tillage practices.

Research conducted on silt loam soils at the University of Vermont (Darby, 2010) have shown neutral and positive yield responses in corn silage planted after winter annual cover crops. Winter rye killed by plow down showed a corn silage yield increase over no cover crop; while herbicide killed winter rye showed only a small decrease in corn silage yield. Also, in research done by Dr. Ray Weil at the University of Maryland (SARE project number LNE03-192) row crop yields had a positive response to cover crops including forage radishes. More recently, there has been increased interest in cover crop mixes, or "cocktails", to utilize the advantages of multiple species at once.

This project evaluated the ability to establish cover crops after wheat, after corn silage, and on pasture, while measuring ability to scavenge nutrients and provide positive crop responses while limiting the amount of fall tillage. Participating growers Ray Brands, Ashley Farr, Joe Hescock, and Roger Scholten are optimistic the right combination of cover crop species and timing will improve their soil quality and reduce erosion.

Objectives/Performance Targets

1. Identify alternative cover crop options for field crop producers (in wheat and corn silage) and determine if cover crop mixes provide increased benefits over single species winter cereal rye plantings.
As most field crop growers in Vermont have historically used winter rye (*Secale cereale*) as the sole cover crop, we set out to determine the potential benefits and basic agronomic aspects of planting mixtures of cover crops. Two different cover crop mixes were planted on three farms and evaluated in comparison to winter rye. We did find some advantages to these alternative species of cover crops in a corn silage system. This was especially true for fall biomass and nutrient uptake. However, the cost associated with these mixes may or may not make them viable options for farmers in Vermont. This project did garner lots of interest from local farmers who are looking for more locally derived data about these cover crop species, and to see them growing in our northern climate and heavier soils.

We also proved that the time-tested method of frost seeding legumes into winter cereal grains is the best way to establish a cover crop and reduce weed pressure…especially in manured dairy systems. Our plots did not establish well after wheat harvest, as weed pressure was too high. Interestingly, outside the plots where the cover crop mixes were planted into the frost-seeded sweet clover showed significant growth. In addition, the farmer noted that the corn planted the following season showed decreased yields where our cover crop plots were in comparison to the rest of the field that grew a nice crop of sweet clover between the winter wheat and corn silage.

'Planting Green' at Deer Valley Farm. No-Till planting corn into a living winter rye cover crop. *Photo: K. Workman*

2. Evaluate winter-killed cover crop mixes in comparison to winter-hardy mixes, as an option for farms with heavier soils to incorporate cover crops as part of a no-till system.
As our most successful planting site was on a Vergennes clay soil, this project provided a great opportunity to evaluate the winter-killed mixes in comparison to winter hardy mixes and straight winter rye. In addition, the participating farmer eventually decided to plant his subsequent corn crop in these plots with no-till methods. This enabled us to truly evaluate the system as it was intended. Additionally, he conventionally plowed (fall moldboard followed by spring chisel/finishing) the other half of the field for comparison. We were then able to monitor the progress of the corn crop the following summer to see the impacts of our treatments. PSNT's were taken during the summer and corn yields were measured prior to harvest this fall. One big takeaway was that proper termination of cover crops is key to making the no-till/cover cropping system work here in Vermont. The producer did not accomplish an adequate termination of the winter hardy cover crops, and as such saw reduced yields on these plots. Although not a function of the cover crop species themselves, it is an important management factor to emphasize as farmers start to adopt these more complex systems. We were able to show that a winter killed cover crop on clay soil is a feasible system for farmers hoping to utilize no-till planting. These plots did not show significant yield difference from the conventionally managed part of the field, but did require significantly less time (and money) for field operations prior to planting.

3. Determine the amount of soil coverage, nutrient uptake and biomass produced by cover crops in the fall, as most information is evaluating spring performance.
We were able to successfully measure fall biomass and nutrient uptake on the early planted plots, percent cover on all plots, and spring biomass, nutrient uptake and percent cover on all winter-hardy planted plots. We saw distinct differences in nutrient uptake and biomass from fall to spring and from earlier plantings vs. later plantings. Although spring biomass and percent cover was best accomplished by the control treatment of winter rye; fall biomass, percent cover, and nutrient uptake was better in the cover crop mixtures.

4. Evaluate the use of no-till drilled radishes to increase forage in grazing systems
We were not able to gather any usable data from this part of the project. Although all tillage radish plots were planted as proposed, challenging growing conditions during the project ended in no usable data. With record breaking wet weather early, followed by drought conditions later in the summer, the field's heavy clay soils did not have good production for the existing pasture sward or our forage radish plantings.

5. Increase farmer knowledge and adoption of cover crops, cover crop mixtures, and conservation tillage.
This objective was most definitely met. The sheer act of performing a research/demonstration project looking at cover crops in Addison & Chittenden counties 'got the ball rolling' for farmers in our area. As noted in our annual report, we had great attendance by farmers at our field day hosted at the Deer Valley Farm location. Subsequently, project staff in coordination with other UVM Extension agronomy staff and faculty hosted a two -day No-Till and Cover Crop Symposium in February 2014. This event was the first of its kind in Vermont, and it was well received. One of our participating farmers, Ray Brands, was on a farmer panel describing his use of cover crops on his farm. We have seen many farmers this growing season try many new and innovative techniques, including 'planting green', traditional no-till, interseeding cover crops with sidedress nitrogen and with a helicopter, and adding new species of cover crops. As a result of this project, a new section of our newsletter is now devoted to cover cropping practices every month. The "Cover Crop Corner" section discusses all aspects of cover cropping.

MATERIALS AND METHODS

Cover Crop Mixes in Corn Silage

We designed two identical experiments on two different farms. Farr Farms is located on a sandy loam soil in the Winooski River flood plain in Richmond, Vermont. Deer Valley Farm is located in Ferrisburgh, Vermont on a clay soil between the Otter Creek and Little Otter Creek Rivers near the mouths of Lake Champlain.

2013

On August 15th and 16th, respectively at Deer Valley Farm and Farr Farm, we seeded the following treatments with over-the-shoulder broadcast spreaders.

- 100 lbs/acre winter cereal rye
- Winter Kill Mix (56% Everleaf Forage Oats/33% Cow Peas/11% Tillage Radish) seeded @50 lbs/acre
- Winter Kill Mix @ 116 lbs/acre
- Winter Hardy Mix (56% Winter Triticale/33% Austrian Winter Pea/11% Bonar Forage Rape) at 50 lbs/ acre
- Winter Hardy Mix at 116 lbs/acre

Plots were four corn rows wide (10-feet) by 100-feet long, with a row on each side of the seeded plots to allow for a buffer. See Figure 1 for a plot layout diagram. Seeds were mixed prior to seeding. All treatments were calibrated to apply the accurate pounds per acre desired for each seeding mixture. The treatments were laid out in a randomized complete block and replicated three times (on each farm). Corn was at the R1 stage at both farms. Plots were monitored for germination and growth. We saw good germination and growth at Deer Valley Farm but did not see good germination at Farr Farm.

Figure 1. Corn Silage Cover Crop Plot Layout

Plot Layouts for SARE Cover Crop Diversity in No-Till Systems Project - 2013

Cover Crop Mixes in Corn Silage

Mix 1 = Oat/Pea/Radish — *Low Rate = 50 lbs/acre*

Mix 2 = Triticale/Winter Pea/Winter Rape — *High Rate = 116 lbs/acre*

N / W E / S

	Broadcast into standing corn: 8-15-13		Drilled after corn harvest: 9-26-13
R1	Mix 1 @ 116 lbs	15	Mix 1 @ 116 lbs
	Mix 2 @ 116 lbs	14	Mix 2 @ 116 lbs
	Mix 2 @ 50 lbs	13	Mix 2 @ 50 lbs
	Control (Winter Rye @ 100 lbs)	12	Control (Winter Rye @ 100 lbs)
	Mix 1 @ 50 lbs	11	Mix 1 @ 50 lbs
R2	Mix 2 @ 116 lbs	10	Mix 2 @ 116 lbs
	Mix 2@ 50 lbs	9	Mix 2@ 50 lbs
	Control (Winter Rye @ 100 lbs)	8	Control (Winter Rye @ 100 lbs)
	Mix 1 @ 50 lbs	7	Mix 1 @ 50 lbs
	Mix 1 @ 116 lbs	6	Mix 1 @ 116 lbs
R3	Mix 2 @ 116 lbs	5	Mix 2 @ 116 lbs
	Mix 1 @ 116 lbs	4	Mix 1 @ 116 lbs
	Mix 2 @ 50 lbs	3	Mix 2 @ 50 lbs
	Mix 1 @50 lbs	2	Mix 1 @50 lbs
	Control (Winter Rye @ 100 lbs)	1	Control (Winter Rye @ 100 lbs)

First Planting Date: August 15th (simulate aerial application)

Second Planting Date: After Corn Harvest (end of September with No-Till Drill)

Corn was harvested at Deer Valley Farm on September 24th. The second planting of all treatments occurred on September 26th. Corn was harvested on October 14th at Farr Farm and the second planting of all treatments occurred on October 15th. For the second planting all plots were repeated roughly 40 feet down the field (in line with corn rows), but were planted with a 10.5-foot wide Haybuster 170C No-Till Grain Drill. All treatments were calibrated in the drill beforehand to ensure accurate seeding rates. Plots were drilled in the same direction and on the same day. We planted one additional planting at the Farr Farm, which included three replicates of Treatments 1, 3 and 5 (the higher rates of all seedings) broadcast on the surface.

As mentioned above, Deer Valley Farm saw the only measurable results from these cover crop plantings. As such, we took all fall and spring measurements from this site. On October 22, 2013, samples were collected from the earlier (August) planted plots only, as there was not enough biomass to collect a usable sample from the later, drilled plots. We collected four subsamples per plot using a 6" x 36" quadrat, for a total of 60 samples. Samples were weighed fresh in the field and then dried in a forage sample drying room at the UVM

Horticultural Research Farm. Once dry, all samples were weighed again, subsamples were combined for each plot, and then they were ground in a Wiley Mill through a 2 mm sieve. Samples were sent to the Dairy One Forage Lab in Ithaca, NY for the following analyses: percent dry matter, percent crude protein (as a measure of nitrogen), percent phosphorus, and percent potassium. All mineral extraction was done using wet chemistry methods in their lab. On October 28th and 30th, 2013, the Line Transect method (VT NRCS Agronomy Technical Note 1, http://efotg.sc.egov.usda.gov/references/public/VT/VT_AgronTN_1_LineTransectMethod.pdf) was used to measure percent residue cover for all plots in both the August and September seedings.

2014

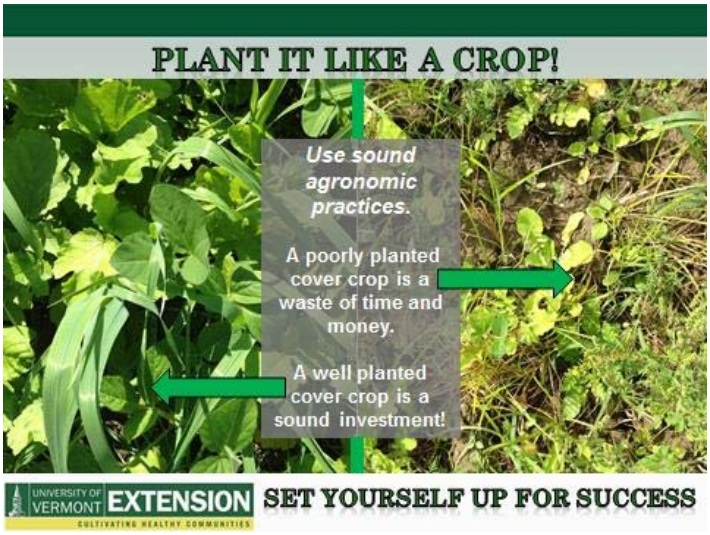
The following spring, all plots were analyzed for performance again. On April 25th visual assessments were made to determine the overwintering success of all plots at the Deer Valley Farm location. Winter rye seemed to look the best at this early spring date, there was very little winter pea survival, all of the 'winter kill' mix plots had indeed been terminated over the winter, and there was noticeable deer browsing in the 'winter hardy mix' triticale/winter pea/winter rape mix plots. On May 8th, percent cover measurements were taken on all plots, again using the Line Transect Method. On May 12th, percent soil moisture measurements were taken using a Spectrum FieldScout TDR300 Soil Moisture Meter, collecting 10 subsamples per plot and averaging. We attempted to take soil temperature measurements, but only collected seven plots worth of data before the equipment malfunctioned. However, there did not seem to be a noticeable difference between plots or treatments leading up to that. Also on May 12th, forage samples were taken on all winter rye and 'winter hardy' plots. We collected four subsamples per plot using a 6" x 36" quadrat, for a total of 72 samples. They were dried in the forage drying room at the UVM Horticultural Research Farm. Once dry, all samples were weighed, subsamples were combined for each plot, and then they were ground in a Wiley Mill through a 2 mm sieve. Samples were sent to the Dairy One Forage Lab in Ithaca, NY for the following analyses: percent dry matter, percent crude protein (as a measure of nitrogen), percent phosphorus, and percent potassium. All mineral extraction was done using wet chemistry methods in their lab.

As a result of our experiment/demonstration, Ray Brands (owner/operator of Deer Valley Farm) decided to utilize no-till planting practices one half of this corn field, including the cover crop plots. He fall applied manure, fall plowed, and utilized conventional spring tillage and planting on the rest of the field for comparison. On the no-till side, he 'planted green' into the living cover crops and then used utilized pesticides to terminate the cover crop immediately after planting. This allowed us to continue our analysis of the site by measuring corn yields in the cover crop plots and compare them to his 'conventional' management on the rest of the field in the fall of 2014. On September 8th, we measured corn yields (three subsamples per plot) in the plots that had received Treatments 1, 3 and 5 (the higher rates of all seedings) on the earliest planting date plus three samples in the conventionally managed side of the field (for a total of 12 samples). This was decided on from a practical standpoint. The plots from the earlier planting date (August 2013) were the closest to the edge of the field. They also had the highest biomass production, and therefore we assumed the most treatment effect. We collected 1/1000th of an acre worth of fresh corn plants from each of the 9 plots. We counted total plants to calculate plant populations, weighed each sample wet and then chose three representative plants for each treatment to chop, dry and determine percent dry matter. Once dry, percent dry matter was determined and applied to fresh weight data to determine a 'silage equivalent' yield. This was done because samples were collected roughly three weeks prior to actual corn harvest.

Measuring corn yields by cover crop treatment at Deer Valley Farm.
Photo credit: K. Workman

In addition to the formal demonstration plots, we also had one farmer utilize our 'Winter Kill' cover crop mix on a 70-acre field. Senesac Farm planted 55 pounds per acre on August 9th, 2013. The mix was comprised of 25 pounds of forage oats, 25 pounds of soy bean and 5 pounds of forage radish. Cover crop height and forage samples were collected at three locations on September 3rd, September 30th and October 25th. Another thing we gained from this planting was a great example of why using sound agronomic practices is important, even when planting cover crops. The producer had broadcast his seed over the entire field. To initiate good seed to soil contact, he was rolling the field with a brillion type pulvimulcher. After rolling half the field, he had an equipment breakdown and had to stop. It then rained for a couple of days, the cover crop seed germinated, and he decided not to roll the second half to avoid damaging newly emerged seedlings. Later that fall, you could visually see the differences between the two halves of the field with cover crop biomass, weed pressure, etc.. This made for a great educational opportunity and we have used this in many presentations since then (see Figure 2). In addition Mr. Senesac offered to let us use this same field to do some reduced tillage comparison plots the following spring. Unfortunately, field conditions in the spring prohibited this from happening. However, he has stayed engaged and will continue to work with us on demonstration projects.

Figure 2. Plant it Like a Crop Slide



Cover Crop Mixes in Organic Winter Wheat

One trial was planted on an organic winter field operated by Elysian Fields Dairy in Shoreham, Vermont. Winter wheat was drilled in the fall of 2012. In April 2013, our test plot perimeters were established just prior to the farmer frost-seeding yellow sweet clover into the rest of the winter wheat field. Wheat was combined, straw harvested, and manure applied in late July. Our plots were 10-feet by 58-feet. At this site, we planted three replications of the following 10 treatments, for a total 30 plots, on August 12, 2013:

- 100 lbs/acre winter rye
- Winter Kill Mix (56% Everleaf Forage Oats/33% Cow Peas/11% Tillage Radish) at 30 lbs/acre
- Winter Kill Mix at 50 lbs/acre
- Winter Kill Mix at 80 lbs/acre
- Winter Kill Mix at 116 lbs/acre
- Winter Hardy Mix (56% Winter Triticale/33% Austrian Winter Pea/11% Bonar Forage Rape) at 16 lbs/acre (this was a mistake on the first replication, so we repeated for all three reps)
- Winter Hardy Mix at 30 lbs/acre
- Winter Hardy Mix at 50 lbs/acre
- Winter Hardy Mix at 80 lbs/acre
- Winter Hardy Mix at 116 lbs/acre

We monitored plots for growth through the fall of 2013. Our observations were that we had little cover crop growth in our plots. The seeded cover crops were out competed by weeds. In fact, the only place we saw cover crop growth was outside the plots where we had drilled into the frost seeded sweet clover. We did not collect any further data from this site. The farmer's method of frost seeding clover was concluded to be a preferable strategy.

Weeds out compete cover crops in organic winter wheat, farmer frost-seeded sweet clover thrives beyond the plots.

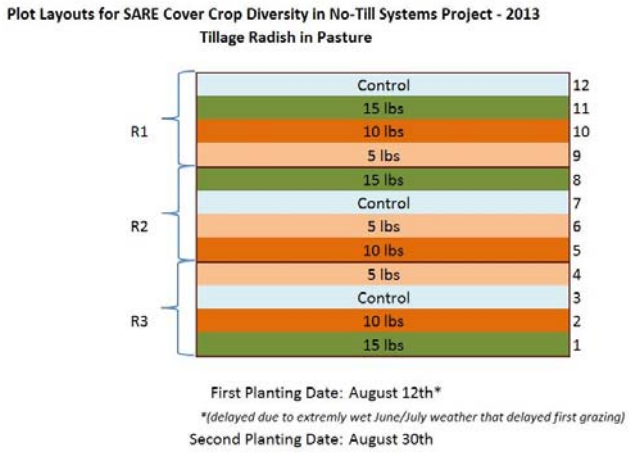
Tillage Radish in Pasture

One trial was planted into an existing organic dairy pasture on Scholten Family Farm in Weybridge, Vermont. We used a Haybuster 170C No-Till Grain Drill to seed Tillage Radish at three different rates on two different dates. Our plots were 10 by 100 feet wide. Our 'early' planting date was delayed by wet field conditions created by our extremely wet spring and the heavy clay soils on this farm. We seeded the following treatments in three replications on both August 12 and August 30, 2013 (See Figure 3 for a plot layout diagram).

- Control (no radish)
- Tillage Radish at 5 lbs/acre
- Tillage Radish at 10 lbs/acre
- Tillage Radish at 15 lbs/acre

In addition to the treatments, we seeded a high rate of 20 pounds per acre around the perimeter of the plots. We fenced off the plots (as the farmer would be grazing the remainder of the pasture later in the season). We checked back often, but did not see any measurable results. However, this pasture also did not show much growth in total, even from the cool season grasses. We had also drilled some radish along with other brassicas and summer annuals in a few other demonstration sites throughout the valley as a part of another project on varying soil types and saw similar results. We did not collect forage samples.

Figure 3. Tillage Radish in Pasture Plot Layout



Drilling Tillage Radish into Pasture at Scholten Farms in Weybridge, Vt. *Photo credit: K. Workman*

RESULTS AND DISCUSSION

Although we were not able to gather data from all of the sites or studies that were part of this project, the data we did gather has been very useful and given us a lot of insight as we move forward and design future studies. Some of the challenges we encountered were unavoidable due to the very wet early growing season of 2013. That said, this project has been a great catalyst for many farmers around the Champlain Valley, particularly those on heavier soils. At the one site where we were able to capture plentiful data (Deer Valley Farm, Ferrisburgh), we measured the following parameters for the cover crop mixes: percent cover (as a measure of erosion protection), Biomass production (measured in dry matter yield per acre), and nutrient uptake (measured in pounds of nitrogen, phosphorus and potassium per acre). In addition, we were also able to measure cash crop performance following the cover crop treametns by measuring plant population and silage equivalent yield of a corn silage crop. A description of the results from the Deer Valley Farm site are as follows:

Percent Cover

One measure of a cover crop's performance is its ability to cover the bare soil and protect it from sheet and rill erosion. The higher percent cover we can achieve from the cover crop in the fall and the spring, the northeast's highest erosion potential seasons, the better off we are from an environmental standpoint and from an overall farm sustainability standpoint. As discussed in the Methods section above, we utilized a Line Transect Method to estimate the percent of the ground surface covered by plant residue. We did this for all plots on October 22, 2013 as a report card measurement for fall and on May 8, 2014 just prior to termination. Refer to Figure 4A and corresponding table to see the results of these fall 2013 measurements.

Figure 4A. Percent Cover for Broadcast and Drill Treatments for Fall 2013

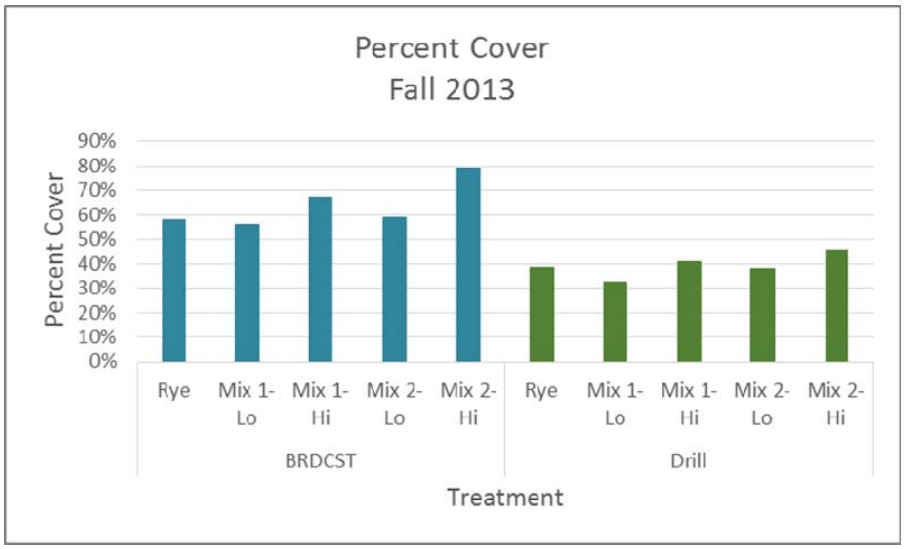


Table 4A. Fall 2013 *(measured 10-22-13)*

	Broadcast (planted 8-15-13)	Drill (planted 9-26-13)
Winter Rye	58%	38%
Mix 1-Lo	56%	33%
Mix 1-Hi	67%	41%
Mix 2-Lo	59%	38%
Mix 2-Hi	79%	46%

Figure 4B. Percent Cover for Broadcast and Drill Treatments for Spring 2014

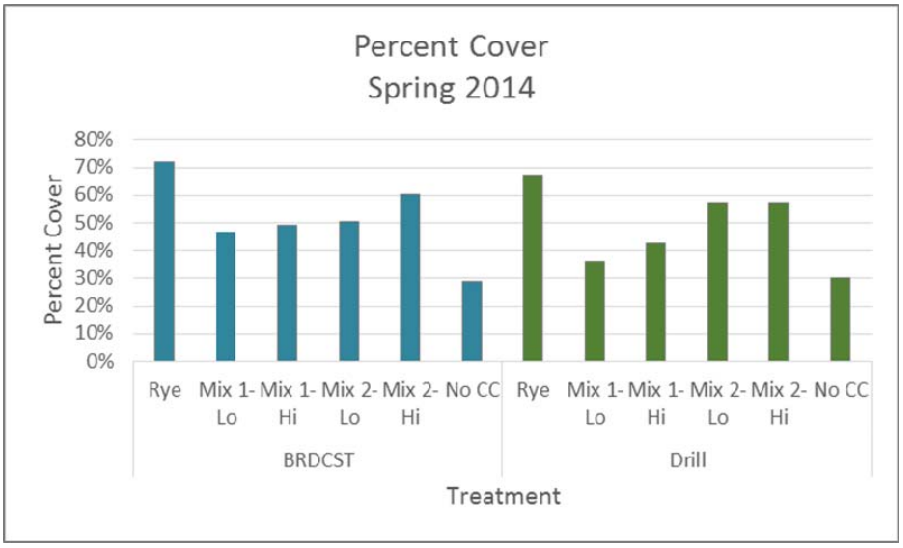


Table 4B. Spring 2014 *(measured 05-08-14)*

	Broadcast (planted 8-15-13)	Drill (planted 9-26-13)
Winter Rye	72%	67%
Mix 1-Lo	47%	36%
Mix 1-Hi	49%	43%
Mix 2-Lo	50%	57%
Mix 2-Hi	60%	57%
No Cover	29%	30%

In summary, we saw that both cover crop mixes were comparable to our winter rye control in percent cover at the lower seeding rates or exceeded the winter rye control at the higher seeding rates. This was true for the earlier seeded broadcast treatments and the later drilled treatments. In the spring, however, winter rye outperformed all the cover crop mix treatments. Refer to Figure 4B and corresponding table to see the results of these spring 2014 measurements.

While the winter rye control plots increased significantly in percent cover from fall to spring, many of the cover crop mix treatments decreased in percent cover from fall to spring. This was expected from the winter kill plots, as the plants died over the winter and left only decayed residue in the spring. However, we also saw this from our early planted winter hardy mix as well. We believe this was due to a lack of winter survival from the winter peas in the mixture and to some extent the winter rape. The later planted (drilled) plots of this mix did increase in percent cover, but never in excess of the fall measurements of the broadcast plots. For example, the higher seeding rate of the winter hardy mix drilled on September 26th, increased from 46 percent cover in the fall to 57 percent cover in the spring. However, the broadcast planting of that same mix planted on August 15th had 79 percent cover when measured in the fall. In both the spring and fall, the earlier seeded (broadcast) treatments outperformed the later planted (drilled) treatments (with one exception, the low rate of the winter hardy mix measured in the spring). All cover crop treatments exceeded the baseline field conditions, which measured around 30 percent cover without a cover crop (this included corn silage stubble, weeds, etc).

Biomass/Dry Matter Yield

Biomass was measured in dry matter yield (tons per acre dry matter) in the fall of 2013 and the Spring of 2014 just prior to termination. In the fall, the later planted drilled seedings did not generate enough biomass to collect adequate samples; therefore only the earlier seeded broadcast plots were measured. The lower seeding rate of Mix 1 (oat/pea/radish) yielded the highest at half a ton per acre dry matter. The winter rye control yielded the lowest with 0.27 tons per acre dry matter. See Figure 5A and Table 5A for results by treatment for fall 2013.

Figure 5A. Average Dry Matter Yield (in tons/acre) for Broadcast Treatments for Fall 2013

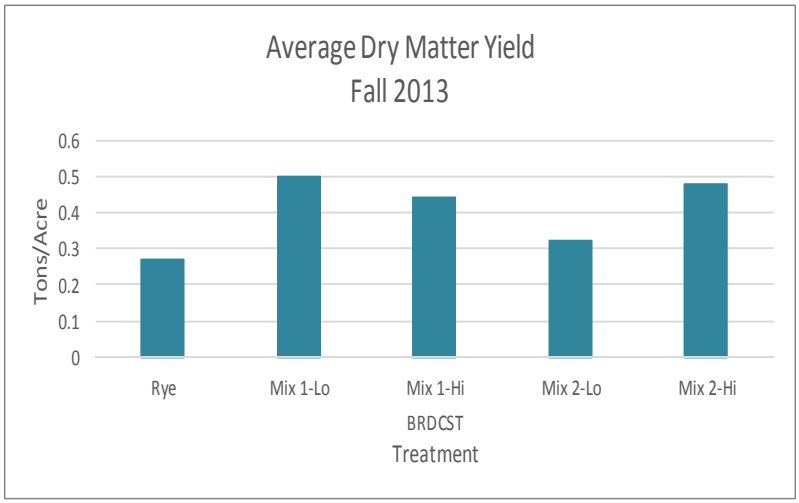


Table 5A. Fall 2013 Dry Matter Ton/Acre

	BRDCST
Winter Rye	0.27
Mix 1-Lo	0.50
Mix 1-Hi	0.44
Mix 2-Lo	0.32
Mix 2-Hi	0.48

In the spring of 2014, just prior to termination, biomass was measured again. This time samples were collected from both planting dates (August and September), but as the winter killed cover crop mix had died, only the winter rye and winter hardy mix treatments were measured. Spring biomass of the early broadcast winter rye was highest at 0.57 tons per acre dry matter, and the low rate of the later planted (drilled) winter hardy mix was the lowest at 0.27 tons per acre dry matter. See Figure 5B and Table 5B for results by treatment from spring 2014 . Interestingly, the lower seeding rate of the early planted winter kill mix produced almost the same biomass in the fall as the highest producing winter rye treatment in the spring. It did this by the first sampling date in the fall 2013, a full 7 months before the winter rye produced as much. We have seen similar results from fall planted oats in subsequent projects.

Figure 5B. Average Dry Matter Yield (in tons/acre) for Winter Hardy Broadcast and Drilled Treatments for Spring 2014

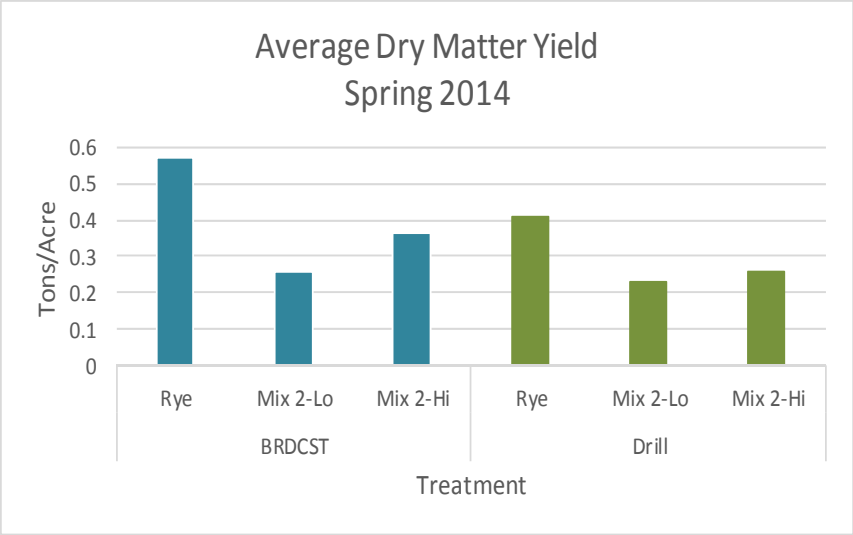


Table 5B. Spring 2014 Dry Matter Ton/Acre

	BRDCST	Drill
Winter Rye	0.57	0.41
Mix 2-Lo	0.26	0.23
Mix 2-Hi	0.37	0.26

Nutrient Uptake

Nutrient uptake was calculated by measuring biomass and percent nitrogen, phosphorus and potassium of forage samples in the fall and the spring. Calculations were then done to figure pounds per acre of all three of these nutrients. This is important as a measure of reduction of nutrient losses to the environment and nutrient cycling for subsequent cash crops when these cover crops are terminated.

In the fall 2013 measurements (which only included the early planted broadcast treatments), the low rate of the winter kill mix (oat/pea/radish) performed the best with 35.73 pounds of nitrogen, 3.64 pounds of phosphorus and 33.90 pounds of potassium per acre. All of the cover crop mixes (high and low seeding rates planted early) outperformed the winter rye control treatment in the fall. See Figure 6A and Table 6A for fall results by treatment.

Although there were no measurements collected for the later planted drilled plots in the fall, it is safe to assume that they would have been significantly lower in pounds per acre of all the nutrients based on the very small amount of biomass accumulated at the time of sampling. In the spring 2014 measurements (which only included winter hardy treatments), winter rye broadcast at the early date performed the best with 31.39 pounds of nitrogen, 5.68 pounds of phosphorus and 36.52 pounds of potassium per acre. For all winter hardy treatments, the early planted broadcast plots outperformed the later planted plots for all nutrients. See Figure 6B and Table 6B for spring results by treatment (attached). Interestingly, the early planted winter kill mix had the most nitrogen in pounds per acre of all treatments for both planting dates and sampling dates, despite the fact that it was lower in biomass overall than the early planted winter rye cover crop (See Figure 6C). One question this raises is that with a cover crop that is made up entirely of winter killed species, what happens to those nutrients during the early spring when soils warm up and there is no living crop there to take up those nutrients until the subsequent cash crop is planted. This is in contrast with winter rye, which has comparable nutrient content, but isn't terminated until just prior (or even after) the cash crop is planted. We have two new research projects which will look into this, as we have planted several cover crop plots that combine winter killed and winter hardy species this last fall (2014) and we will measure results in spring 2015.

Figure 6A. Nutrient Uptake in pounds per acre by treatment for Fall 2013

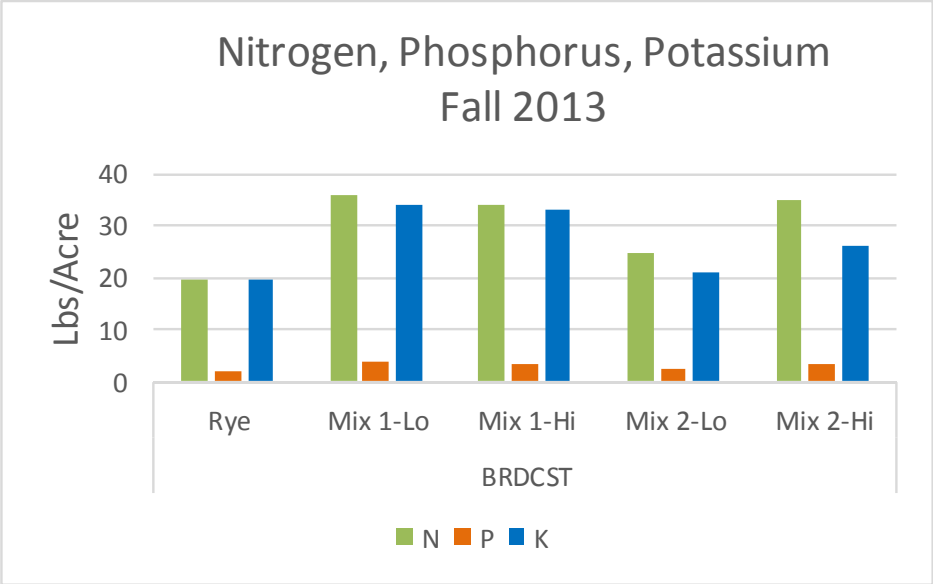


Table 6A: Fall 2013 Nutrient Uptake (Broadcast plots, seeded August 15, 2013)

Lbs/acre	**Nitrogen**	**Phosphorus**	**Potassium**
Rye	19.62	2.03	19.66
Mix 1-Lo	35.73	3.64	33.90
Mix1-Hi	33.91	3.57	33.33
Mix 2-Lo	24.96	2.39	20.94
Mix 2-Hi	31.98	3.52	26.22

Figure 6B. Nutrient Uptake in pounds per acre by treatment for Spring 2013

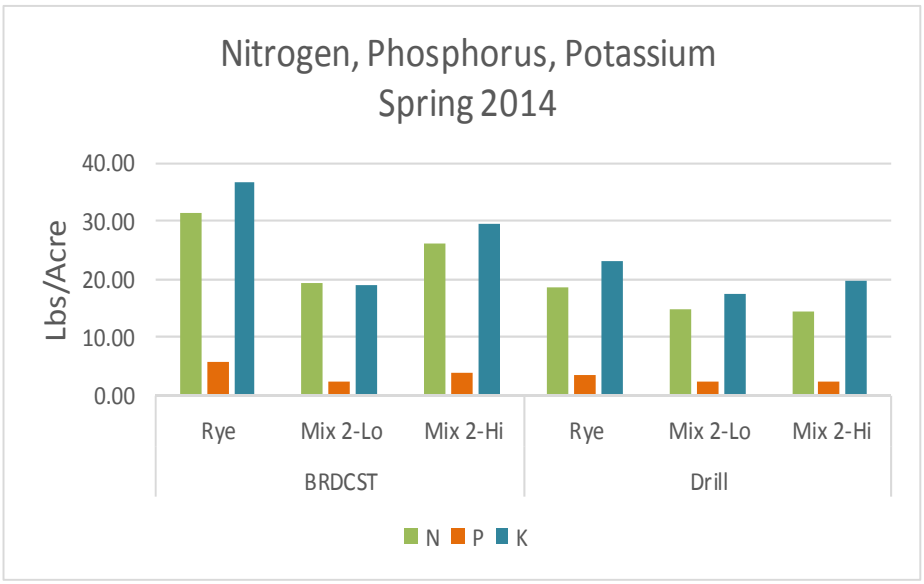
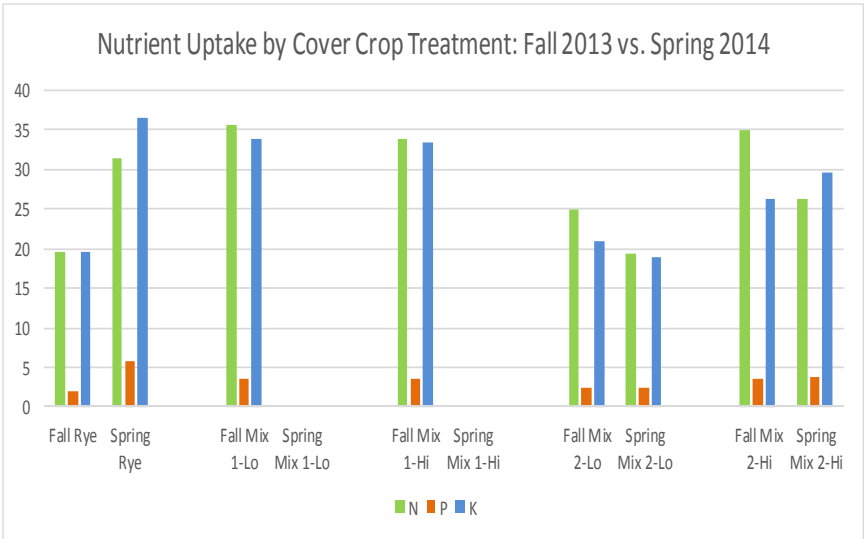


Table 6B: Spring 2014 Nutrient Uptake (lbs/ac)

BDCST	**Nitrogen**	**Phosphorus**	**Potassium**
Rye	31.39	5.68	36.52
Mix 2-Lo	19.29	2.44	18.88
Mix2-Hi	26.27	3.75	29.55
Drilled	**Nitrogen**	**Phosphorus**	**Potassium**
Rye	18.46	3.56	23.10
Mix2-Lo	14.95	2.20	17.40
Mix2-Hi	14.41	2.47	19.61

Figure 6C. Nutrient Uptake Comparison by Treatment: Fall 2013 vs. Spring 2014



Additional Results

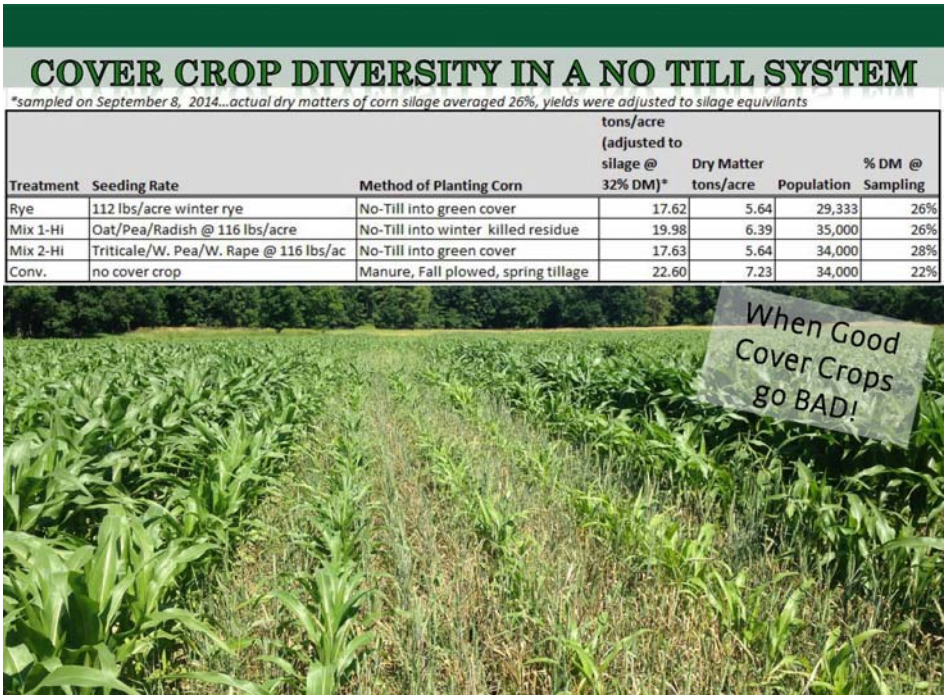
Although many of our plots did not yield data, we were able to collect additional data outside the formal research/demonstration plots as a part of this project. Circumstances arose that led to an additional producer (Jeff Senesac) to plant an entire 70 acre field with a cover crop mix very similar to our Mix 1/Winter Kill Mix. Due to the very wet spring/summer conditions in 2013, Mr. Senesac had a field that was unable to be planted to its intended soybean grain crop. He had already prepared the field for planting (tillage, fertilizer, etc) and did not want to leave it fallow. Knowing of our project, he consulted with project staff and planted 55 pounds per acre as follows: 25 pounds soybeans, 25 pounds forage oats and 5 pounds of forage radish. This was planted on August 9th, roughly a week before our first planting date at our other project sites. It also did not have competition from a growing cash crop. That said, we were able to collect forage analysis and biomass data (See Figure 7). Overall, this cover crop performed well. It had almost double the biomass of our similar mix, but did not correspond with double the nutrient uptake. This is not statistically significant, as it was planted on a completely different farm with different soils and cropping systems. It did, however, provide us with another opportunity to measure cover crop performance. It did illustrate the potential forage value of cover crops as well, as we saw relative feed values from all three of our forage samples averaged RFV values of 147. It would have made a great grazing/ pasture crop for livestock.

Figure 7. Forage Analysis from Senesac Cover Crop

Oat/Soybean/Tillage Radish Cover Crop…Forage Value				
Sample Date	*9/3/2013*	*9/30/2013*	*10/25/2013*	*Average*
Yield (DM Ton/ac)	**0.58**	**0.80**	**0.95**	
%DM	11.60	12.50	17.10	
% Crude Protein	22.90	15.10	15.60	17.87
%ADF	28.20	28.50	30.80	29.17
%NDF	36.40	43.30	47.60	42.43
%TDN	61.00	63.00	62.00	62.00
NEL	0.65	0.65	0.63	0.64
RFV	171	143	127	147
lbs N/acre	42.25	38.76	47.66	42.89
lbs P/acre	4.73	4.97	5.92	5.21
lbs K/acre	30.79	42.67	35.71	36.39

As a result of our project being hosted at his farm, Ray Brands (Deer Valley Farm, Ferrisburgh) elected to no-till plant corn in the half of the field with our trials after our cover crop data collection was completed in May 2014. He managed the remaining half of the field conventionally: fall applied manure incorporated with moldboard plow, spring field prep with chisel plow and land finisher implements. In the spring, he utilized the same White corn planter (with no-till retrofit) to plant the entire field the same day. The only difference in the planter was he raised the planting population from 34,000 seeds per acre to 35,000 seeds per acre to account for potential germination issues on the no-till side. He planted into the winter-killed residue and living cover crops directly on the no-till side then had the cover crop sprayed with pesticide. This side of the field did not receive a manure application. This allowed us to compare the cover cropped, no-tilled management to his conventional management. Unfortunately, he did not receive effective termination on his cover crop, which likely reduced yields on the no-till side of the field. Weather conditions stayed cool and wet after spraying, which delayed the termination of the cover crops and allowed them to continue maturing and increasing carbon to nitrogen ratios. We measured corn populations and yields in September 2014, prior to actual silage harvest and then adjusted yield results to silage equivalents. We measured by treatment (winter rye, winter killed mix high seeding rate, winter hardy mix high seeding rate, and the conventionally managed portion of the field). See the Methods section for a description of our sampling methods. The conventionally managed portion of the field had the highest yields at 22.60 tons per acre corn silage (adjusted to 32 percent dry matter). The winter rye plot yielded the lowest with 17.62 tons per acre corn silage. This stands to reason as it had the highest cover crop biomass prior to termination. That coupled with the difficulties terminating the cover crop impacted subsequent corn yields. Populations were all good except in the winter rye plots where populations were below 30,000 plants per acre (compared to 34,000 or higher in the other plots). The winter killed cover crop plots, which obviously did not suffer from the spring termination issues of the winter hardy cover crops, performed quite well. Corn silage yielded 19.98 tons per acre and populations were 35,000 plants per acre. If you take into account that these plots did not receive manure as the conventionally managed portion of the

Figure 8. Corn Yields After Cover Crop Treatments at Deer Valley Farm



field, this could be considered a success. Even without manure, the farmer would have gained savings in time and money from the reduced field operations required from no tilling into the winter killed residue and not having to do any tillage. He would also realize the soil health benefits of reduced tillage and cover crops. Even though cover crop termination challenges did not allow us to compare all the cover crops equally from a subsequent yield standpoint, it did allow us to emphasize the importance of proper termination and helped us demonstrate the benefits of the winter killed cover crop in a no-till system. See Figure 8 for a slide illustrating the yield data information and a picture of the impacts of improper cover crop termination in these plots.

In summary, this project demonstrated that there are several factors that go into a successful cropping system. We did demonstrate that by adding to the diversity of cover crop species can enhance many of the ecosystem services provided by the cover crop. By selecting species like oats and brassicas especially, you can enhance your fall cover crop performance in terms of fall biomass production and nutrient uptake. We would like to see the performance of cover crops that include both winter hardy and winter killed species to determine if we could get the fall and spring benefits of a mixture like that. We also felt like the lower seeding rates make the most practical sense from a cost/benefit analysis (see Economic Analysis). This project also demonstrated that cover crops can work in a no till cropping system, even on heavy clay soils that are found throughout the Champlain Valley. We felt a fall application of manure could be a win-win for these systems. They will increase fall performance, while providing a more sustainable way of utilizing the nutrients from a fall manure application that is often necessary for New England dairy producers. We also demonstrated that the earlier you can establish your cover crop, the better success you will have. Whether that is getting the cash crop off in a timely manner or interseeeding into the standing crop, early establishment is especially important when adding alternative cover crop species like oats, annual ryegrass, legumes and brassicas. Another important result of this project was demonstrating the importance of having a solid strategy or strategies for cover crop termination. Although cover crops undoubtedly have great benefits to a cropping system, they most definitely can make it more complicated. Including cover crops in your cropping system only emphasizes the importance of basic agronomic principles.

Impact of Results/Outcomes

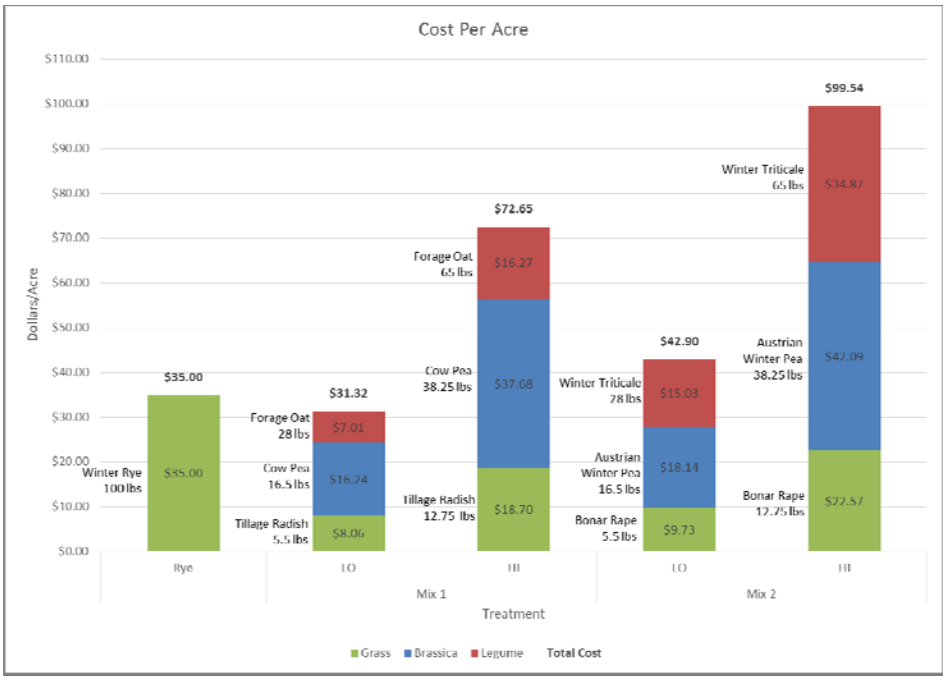
At the very beginning of this project (July 2013) we convened a small focus group of 14 farmers to discuss issues around cover crops. Many of their responses indicated they were interested in cover crop mixtures, early interseeding of cover crops, manure and cover crops, and seeing demonstrations on real farms with similar soil types and being able to talk to farmers who are implementing these practices. Similarly, we also implemented a cover crop survey in early 2014 that elicited 85 responses from farmers of all types. These responses were very similar to the focus group. You can see a summary of the survey results here (http://archive.constantcontact.com/fs158/1104770033503/archive/1117860751104.html). This survey will be implemented again in 2015, allowing us to measure changes in practice adoption and knowledge change.

This project directly addressed the issues that rose to the top in these assessments of local farmers. This project has been a great catalyst to get farmers in our area truly engaged in discussions and experiments with cover crops and reduced tillage. In fact, it has really begun a new phase of emphasis not only on single practices for sustainability, but integrative approaches to soil health and whole-farm sustainability. It also opened the door for the Champlain Valley Crop, Soil & Pasture Team to move forward with additional projects on multiple farms throughout the Champlain Valley. Having data that is on clay soil in Vermont, and being able to share those results is very powerful for us in our everyday work with farmers. We now see the farmers we have worked with on this and other projects being the ones 'spreading the word' about these practices with their fellow farmers. Since this project began, we initiated an annual No-Till and Cover Crop Symposium. In its first year (2014) it became a powerful forum for farmers to learn and share information. Results from this project will be shared at the 2015 event. We will also share information from this project with other Extension professionals, NRCS personnel, Vermont Agency of Agriculture personnel, and agricultural service providers. It will likely be useful as they develop standards, specifications and recommendations for cost share programs, nutrient management and general technical service for these practices.

Economic Analysis

As this was a research/demonstration project, we did not calculate changes in individual farm income or profitability. We did quantify the seed costs of our different treatments. The least expensive cover crop was our winter killed mixture (Mix 1) at the lower seeding rate at $31.32 per acre. Winter rye at a typical 100 pound per acre rate was comparable at $35.00 per acre. The most expensive treatment was the higher seeding rate of the winter hardy mix (Mix 2), coming in at almost $100 per acre just for the seed. For the two mixtures, there was a significant difference in seed cost between the high and low seeding rates, roughly $50 on average. See Figure 9 and corresponding tables for a detailed cost breakdown of each cover crop treatment.

Figure 9. Seed Cost per Acre



Winter-Kill Mix (Oat/Pea/Radish)

	Forage Oat	Cow Pea	Tillage Radish	Total
Mix 1-Lo	$16.24	$7.01	$8.06	$31.32
Mix 1-Hi	$37.68	$16.27	$18.70	$72.65

Winter-Hardy Mix(Triticale/Winter Pea/Winter Rape)

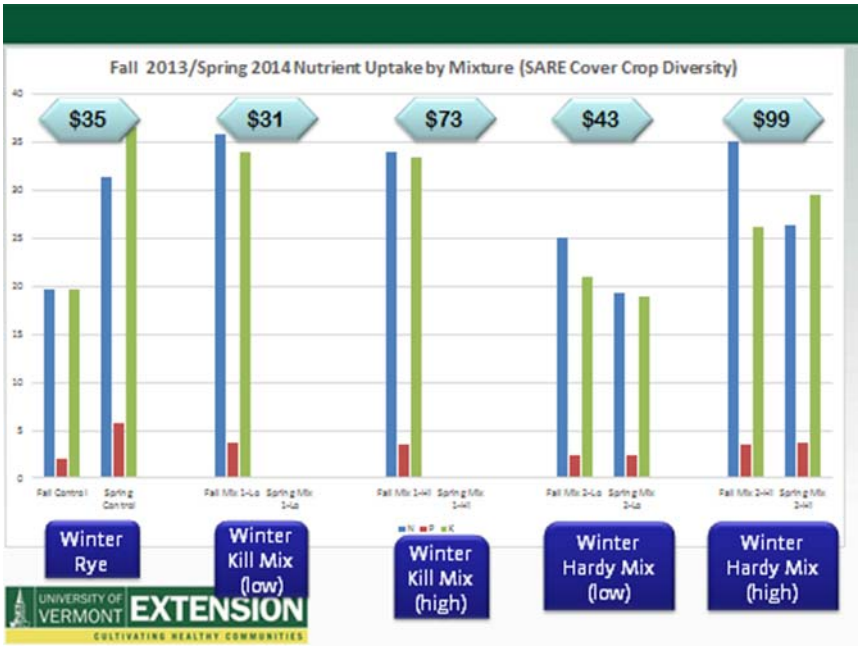
	Bonar Rape	Aust. Winter Pea	Winter Triticale	Total
Mix 2-Lo	$18.14	$15.03	$9.73	$42.90
Mix 2-Hi	$42.09	$34.87	$22.57	$99.54

Control

	Total
Rye	$35.00

It seems that most farmers are more comfortable in the $30 to $40 per acre range for cover crops, not including the cost of establishment. When you look at nutrient uptake in comparison to seed cost (See Figure 10), the two treatments (winter rye and the lower seeding rate of Mix 1) that cost the least realized the most nutrient uptake per acre. The only parameter that the most expensive treatment (higher seeding rate of Mix 2) outperformed other treatments was in fall measured percent cover. It did not perform the best for nutrient uptake (fall/spring), biomass (fall/spring) or spring percent cover. In fact for spring biomass, it produced roughly half the dry matter per acre as the winter rye control, but cost almost three times as much. This is

Figure 10. Seed Cost Compared to Nutrient Uptake by Cover Crop Treatment



important information as farmers look at diversifying their cover cropping systems, while working under tight margins for profitability.

Publications/Outreach

The Champlain Valley Crop, Soil, and Pasture Team publishes a monthly newsletter that is distributed to more than 700 people electronically and mailed to another 400. As a result of this project, the "Cover Crop Corner" section has been added and three publications specifically mention this SARE project. The newsletter archive is accessible by the link below: http://archive.constantcontact.com/fs019/1104770033503/archive/1110165034202.html.

The project is also highlighted on The Crop, Soil, and Pasture Team Facebook page: http://www.facebook.com/champlaincropsoilpasture.

The results of this study will be included in a publication in development, "Cover Crops in Corn Silage in the Champlain Valley: A Guide for Farmers." In addition information gathered with this project has been used at several farmer meetings and presentations, including the 2014 Vermont Grazing Conference, the 2014 No-Till and Cover Crop Symposium (VT), 2014 New England Certified Crop Advisor In-Service, UNH Extension Soil Health Workshop (December 2014), and others.

Farmers checking out cover crop plots at the field day at Deer Valley Farm. *Photo credit: K.* Workman

On November 8th, 2014 we hosted a farmer field day at Deer Valley Farm in Ferrisburgh, Vermont. More than 50 people attended, at least half of which were local farmers. There were also agency people (NRCS, Dept. of Agriculture, Lake Champlain Basin Program), representatives from two seed companies, and a group of agriculture students from a local vocational school. The Crops, Soil, and Pasture Team facilitated a very fruitful and lively discussion about cover crops and conservation tillage on clay soils. Because manure was spread on some parts of the field at Deer Valley Farm, discussion also included what the interface of dairy manure is in these systems.

The information we gathered from the corn silage field has proved to be very useful. As was hoped, the sheer action of planting the plots and talking about our efforts has been a catalyst for farmer adoption and additional projects. We have had several producers interested in our work and volunteering to participate in future projects. We were recently awarded a Vermont NRCS CIG grant to do more research/demonstration with cover crop mixes, and this project has enabled us to really focus what we want to do in the future with this grant and other grants to come. We will use the data collected with this research to make some conclusions and recommendations for farmers interested in cover crop mixes as part of a no-till system.

Farmer Adoption

In general over the last two years, we have seen noticeably higher rates of adoption from local dairy producers and other forage crop growers for cover crops and reduced tillage on their farms. This is a result of a multipronged effort on the behalf of UVM Extension, NRCS, local Conservation Districts, and the Vermont Agency of Agriculture Food & Markets promoting these practices and providing technical and financial assistance to increase adoption. However, we have seen many farmers trying new things on their farms after seeing the results of this project. Most obviously the participating farms were able to learn directly and adopt practices. Deer Valley Farm is a prime example. As a result of our research plots, Ray Brands of Deer Valley Farm decided to plant the entire half of the field that included our plots using no-till methods the subsequent season (the remainder of the field was moldboard plowed to incorporate manure), which enabled us to further evaluate the practical applications of cover mixes in no-till systems. Jeff Senesac, who was not part of the original project, planted 70 acres of the winter kill cover crop mix. He also volunteered to do a tillage trial in the spring, splitting the field with conventional tillage, reduced tillage, and no-till methods when planting his corn crop. An organic beef producer purchased a broadcast seeder and mounted it to his field cultivator in order to establish red clover into his organic corn silage at last cultivation on very heavy clay soils. Another farm in Vergennes, Vermont has started trying their own cover crop mix of oats, winter rye/wheat and forage radish. They liked to fall biomass and erosion protection they saw on our plots, but wanted to see some green in the spring. They have very heavy clay soil, and wanted less spring biomass than a typical 'full rate' of winter rye. They also tried several different methods of manure application in conjunction with this cover crop mix. We also have had several producers inquire about cover crops in no-till soybean systems as a result of our work with this project. In particular, we had four soybean growers partner with us to plant cover crop demonstration strips into their soybeans. One of these growers also tried no-till soybeans for the first time on clay soil with great success. All of these farmers attended the field day associated with this project and receive our outreach materials.

Areas Needing Additional Study

This project enabled us to take a preliminary look at how cover crop mixes perform in several different forage cropping systems in Vermont. Our mixes, however, were either winter hardy or winter killed. One area that we will look into further, as farmers and other agriculture service providers have expressed interest in, is the combination of winter hardy and winter killed species in the same mix. As a result of this project, we determined that many of the fall brassicas and fall-planted oats can provide great erosion protection and biomass production with early establishment. However, we are interested in finding out if we can maximize fall and spring performance of these cover crops by mixing the two types of species. Since the culmination of this project, we have started two more research/demonstration projects with multispecies cover crop mixes. Both projects combine winter hardy species with winter killed species. We are interested to see if the winter hardy species can better utilize the nutrients retained by the winter killed species than the alternative of having nothing growing in the spring prior to cash crop planting at the end of May or beginning of June. In addition, future research will focus on even earlier interseeding dates that coincide with sidedress nitrogen applications in corn in addition to the aerial interseeding timing. Also, we will be looking at interseeding into soybeans prior to harvest. We have added Annual Ryegrass as a species of cover crop that we will be looking at, especially in these interseeded scenarios. Another area that needs more work in Vermont is the herbicide interactions with interseeded cover crops and alternative cover crop species. We suspect that often the normal herbicide programs being utilized in corn and soybean cropping systems (especially in continuous corn systems) prohibits the success of early planted cover crops in many cases. As more and more farmers show interest in adopting cover cropping and reduced tillage systems, it will be important to understand this in order to give growers the appropriate guidance. Another area that cannot be ignored is promoting adoption of shorter-season annual crops. Whether it be shorter day (relative maturity) corn or even alternative summer annuals like sorghum or other cereal grains; this opens up a more successful window for high performing cover crops in our northern climate. We will continue to do these projects on working farms, as we have seen local farmers really engage with these projects and 'buy in' to the results. We are also including manure and its role in the cover cropping system in future studies. So many of our producers have livestock manure as an integral part of their farming system, we want to be sure and not 'ignore' that part of the system.

ACKNOWLEDGEMENTS

UVM Extension Champlain Valley Crop, Soil & Pasture team would like to thank the participating farmers, without whom this project could not have happened.

Ray Brands—Deer Valley Farm, Ferrisburgh
Ashely Farr—Farr Farms, Richmond
Joseph Hescock—Elysian Fields Dairy, Shoreham
Roger Scholten & Mike Compagna—Scholten Family Farm, Weybridge
Jeff Senesac—Senesac Farm/Cottonwood Stables, Colchester

We would also like to acknowledge John Roberts and Jonathan Kuehne for their assistance with field work and data entry and collection. This project was funded by a Northeast SARE Partnership Grant (Project ONE13-177). This information is presented with the understanding that no product discrimination is intended and no endorsement of any product mentioned, nor criticism of unnamed products is implied.

View this publication and other useful resources at:

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