USDA NRCS Vermont State Conservation Innovation Grant Final Report

# Better Cover Crop Mixes in Vermont

December 2016

**Organization Name:** University of Vermont and State Agricultural College
**Project Name:** Better Cover Crop Mixes in Vermont
**NRCS Agreement Number:** 69-1644-13-5
**Start/End Date:** 09/27/13 - 09/30/16

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**Deliverables Identified in the Grant Agreement:**

**1. Cover Crop Demonstrations -** A Series of ten different cover crop mixes will be planted in side-by-side demonstration s trips on five different farms in the Champlain Valley of Vermont Crop fields will be selected that represent soil types that range from well-drained sandy loam to poorly-drained clay soils. Crop situations will include two crop fields with corn silage production, one with corn grain, one field with soybeans and one with winter wheat. Each sequence of crop and cover crop scenario will be repeated for two years to demonstrate repeatability of cover crop establishment. Cover crop mixes will include three-way mixes of one grass or cereal grain, plus one legume, plus one brassica or forb species to enhance biomass production, nitrogen fixation, deep taproot penetration and soil nutrient scavenging. Cover Crops will be planted with two methods, broadcast seeding into the standing crop as a companion crop that continues to grow after crop harvest, and direct seeded using a no-till grain drill immediately after crop harvest.

**2. Farmer Outreach -** Demonstration field days will be offered to farmers in the region to view the cover crops at the five farm sites. Transfer of information will include articles and project updates distributed to 950 farmers and agriculture professionals in Vermont through our monthly Champlain Valley Crop, Soil and Pasture Team newsletters. In addition, we will periodically post updated Information on our Facebook page, Blog and YouTube sites for farmer and public outreach. Project results will be presented at regional Extension farmer meetings.

**3. Information Transfer -** Evaluations of each cover crop mix for establishment and cover, biomass production and nutrient uptake will be used to enhance printed guidelines for seeding mixes in the Cover Crop (340), Vermont State Supplement, Soil Quality Enhancement Activity - SQL04-Use of Cover Crop Mixes. Information about seed mixes cost and returns, planting recommendations and production management will be used in UVM Extension cover crop guide for farmers.

**4. Reporting -** Written quarterly performance progress reports and a final report submitted to the Vermont State CIG Program Manager will highlight success of cover crop mix practices. All reports will contain a summary of work performed, significant achievements and a comparison of actual accomplishments to project goals.

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**Executive Summary**


Water quality in Lake Champlain and soil health are major priorities for Vermont NRCS, UVM Extension agronomy professionals and farmers in Vermont. This project was designed to demonstrate and investigate an innovative approach to cover cropping, a known practice to improve water quality and increase soil health. Winter rye is by far the most common cover crop grown in Vermont. While it is reliable and effective, many farmers are looking for information on other species of cover crops and mixtures of cover crops as an alternative to winter rye. This project entailed planting a series of cover crop mixes in side-by-side demonstration plots on farm fields from Richmond to Orwell in the Lake Champlain watershed in Vermont. These mixes included grasses/grains, legumes and brassicas and were planted into corn silage and soybean fields at two or three different times, including interseeding into standing crops and planting after harvest.

The goal of this project was to provide local information about the use of alternative cover crop species and mixtures, from both agronomic and ecosystem service standpoints, thereby increasing cover crop adoption on Vermont farms by providing alternatives to monoculture winter rye cover cropping.

In order to accomplish this, several objectives were outlined.

1. Establish cover crop demonstration plots on multiple farms in dairy/field crop situations over the course of two years to evaluate cover crop mixtures that include a grass or grain, a legume and a brassica.
2. Demonstrate this practice throughout the southern half of the Lake Champlain basin on varying soil types, landscape positions and microclimates.
3. Share results of these demonstrations with farmers, agronomists, and service providers directly and through educational resources.
4. Inform current NRCS practice standards to include more specific guidance on cover crop mixtures.

This project accomplished the following over the course of two growing seasons:

- 15 different three-way cover crop mixtures (and wintery rye monoculture) were planted and evaluated. This equated to 29 different planting events and a total of 319 different plots.
- These cover crop mixtures were evaluated for 11 different parameters: percent cover (fall), percent cover (spring), height (fall), height (spring), biomass (fall), biomass (spring), Nutrient (N, P, K) content (fall), Nutrient (N, P, K) content (spring), soil temperature, soil moisture, and soil compaction.
- 10 farms participated as demonstration partners, allowing the use of 13 different fields as demonstration sites in 7 Vermont towns.

- At least 12 different field days and 6 presentations directly contacted 829 people with information generated from this project. In addition, seven newsletter articles and 5 *Across the Fence* episodes indirectly reached thousands more.
- Valuable data was collected assessing cover crop performance in Vermont
- A new fact sheet was developed and an existing fact sheet was updated
- Recommendations were made to improve existing NRCS practice guidance

The goals and objectives of this project were met in full. All work was completed on time and mostly as planned. We did adjust some of the initial project design by omitting plantings on cereal grain and corn grain fields in order to focus on crops that are more prevalent, namely corn silage and soybeans. However, we were able to involve more farmers and actually add a third planting date in some cases, augmenting our original goal of five farms and two plantings. We had good response from farmers and service providers to the project, as was evidenced by good attendance at field days and positive responses to conference/workshop presentations. Cover cropped acres in Vermont have increased from an estimated 5,000 acres to over 25,000 acres since 2013. While those numbers cannot be directly tied to this project, it is safe to say this project contributed to that accelerated increase in acres. A multi-year project in highly visible areas, with signage and flagging definitely caught the eye of farmers and the public. One farmer recounted having folks just pull into his field and 'check out' the plots and ask questions about the project. It was an excellent way to spread the word about cover cropping and engage people in the topic. The project was designed in response to areas farmers had requested assistance or identified as gaps information they were looking for. This information was gathered through surveys, evaluations, and focus groups prior to and during the project.

Our primary focus of this project was to inform and benefit local farmers by providing them with local data on cover crop mixes to help them make the wisest decisions when implementing this conservation practice. However, we directly contacted as many agriculture businesses and service providers (consultants, agency staff, and university/extension professionals) as we did farmers. This was equally as important, as many of those people are vital in the process of farmers adopting and implementing cover cropping as a practice.

Project funds were spent as anticipated, and we were able to leverage the committed in-kind cost share support from farmers who supported this project with their time/labor, land, equipment and willingness to share their experiences with other farmers and service providers. The results of this project showed us that is indeed feasible to plant alternative species and mixtures of cover crops with good results. The biggest conclusion is that getting corn off in early September and drilling cover crop plantings provides the most consistent and reliable results. However, we can reach similar results with interseeding if conditions are conducive. In addition, we were able to quantify where mixtures may or may not outperform a monoculture of winter rye and definitely help producers identify which species and mixtures might be most appropriate depending on their management goals. In addition, we were able to 'troubleshoot' where farmers may run into problems to help them get the most out of their cover cropping and quantify some of the economic considerations in terms of the cost of implementing cover crop mixtures on their farms. Another major result was to provide NRCS with technical information to add to their Cover Crop (340) guidance documents. This is especially important, as NRCS EQIP programs fund a large portion of the cover crop activity in Vermont.

## Introduction

The goal of this project was to show that cover crop mixes are a viable alternative to fall plowing the Champlain Valley by demonstrating different methods and timing of establishing cover crops and let farmers choose the right system for their farm. The mixes used in the trial were composed of three-way mixes of grass/cereal grain, legume and brassica species. The combination of these plant species were chosen to enhance biomass production, nitrogen fixation, deep taproot penetration, weed suppression and soil nutrient scavenging. Demonstration strips of several cover crop mixes planted at different times on several soil types at several farm sites were used to show farmers alternative cover crop production practices that they can adopt on their own farms. The overarching goal was to enable farmers in the Champlain Valley to be more receptive to cover cropping by demonstrating how these mixes can improve overall soil health, increase crop yields in the long run and prove to be economical and practical. These field demonstrations will provide information to enhance the NRCS cover crop conservation practice standard (340) recommendations on seeding rates and species mixes. The results from this project will provide a solid foundation for the continuing promotion of cover crops in Vermont.

This project could not have happened without the support of and relationships with farmers and agricultural businesses. The UVM Extension CV Crop Team involved a total of ten farms (three of those participated in both years of the project) as host sites for research/demonstration plots. These farms provided in-kind support of their time, labor, equipment, fuel and use of their land. All farmers involved were EQIP eligible producers, and were tremendous partners in this project. In addition, another five farms hosted related field days on their farms. We also leveraged the expertise and services of local agricultural businesses including seed suppliers and manure applicators.

The UVM Extension Champlain Valley Crop, Soil and Pasture Team of faculty and staff located in the Middlebury Extension office has evolved into a synergistic team that work well together to assist farms in this region right in the heart of the Champlain Valley. The response from farmers we have worked with has been very positive and they are eager to be involved with several projects including no-till planting, manure incorporation, cover crops, nutrient management, starting a local non-profit farmer coalition, and using precision agriculture methods including GPS guidance for planting and field applications. The Champlain Valley Crop, Soil and Pasture Team is a group of UVM Extension professionals and partners working to provide technical assistance to Vermont Farmers in the Lake Champlain Watershed. We strive to bring research-based knowledge that has practical applications on farm, and address many production-related issues associated with water quality and farm profitability. Further information is available at our website [http://www.uvm.edu/extension/cvcrops](http://www.uvm.edu/extension/cvcrops).

Project personnel included:

*Jeffrey Carter, UVM Extension Agronomy Specialist,*
Jeff has over 30 years' experience with field crop research, grant management and education programs for farmers on crop and pasture production, water quality, and nutrient management. As Project Director, he provided program leadership, team coordination, financial oversight and compliance reporting for the project.

*Kirsten Workman, Agronomy Outreach Professional*
Kirsten operated as the Project Manager under the guidance and supervision of the Project Director, Jeff Carter. Kirsten coordinated all communication with farmers, oversaw the procurement of supplies and equipment, laid out and planted demonstration/research plots, coordinated field sample/data collection, contributed to and/or wrote Quarterly Progress Reports, coordinated workshops and field days and presented information at workshops and conferences. She also wrote newsletter articles, recorded a webinar and filmed television episodes for "Across the Fence."

*Kristin Williams, Agronomy Outreach Professional*
Kristin assisted with all field activities including layout and planting, field sample/data collection and lab sample preparation. She took the lead on compiling data, running statistical analysis and preparing charts and graphs to interpret and analyze data. She contributed to quarterly reports and designed fact sheets and other outreach tools.

*Daniel Infurna, Research Field Technician*
Dan operated the no-till drill, collected field samples and data, and prepared samples for laboratory analysis.

This project was funded through a 2013 Vermont NRCS Conservation Innovation Grant Award # 69-1644-13-5 with matching funds provided by UVM Extension for personnel support plus third-party contributions by the participating farmers of time for planning and discussions, farmer-to-farmer outreach, and extra labor for implementation, machinery, land and crop production inputs.

## Background

The primary cover crop planted in Vermont is winter cereal rye planted after corn silage harvest to conserve excess nutrients and protect soil over the winter months. The Vermont NRCS conservation practice standard for cover crops recommends several cereal grain, grass and legume species to use for conservation purposes, but does not include specific guidelines for seeding complex mixtures to use in Vermont. The Vermont State Supplement, Soil Quality Enhancement Activity – SQLOR – Use of Cover Crop Mixes, describes more fully accepted seeds in the non-legume, brassica and legume categories that are recommended for mixes, but no specific mix seeding rates are described, only a note to use a minimum of two different plants with two different maturity dates. It is well documented that cover crops can be used to effectively conserve plant nutrients reduce soil erosion and improve soil health. Mixing multiple species in one cover crop planting can result in diversified benefits over monocultures. Biomass production, nutrient scavenging, compaction alleviation, nitrogen fixation, organic matter accumulation and weed suppression can be achieved with one well thought out mixed planting. These cover crop mixes have been gaining popularity in other parts of the US and Canada due to these advantages. Cover crops are being used increasingly not just to protect the soil from erosion, but also to increase yields of subsequent planted annual crops, provide an opportunity for increased spring forage harvest for livestock feed and to aid in the transition to no-till cropping systems.

Many farms we work with inquired about alternative cover crop species and mixtures. Some of the barriers to adoption have been the need to plant these species earlier than winter rye. Because of our short growing season, farms had already been pinched for time to get a winter rye crop planted after their corn harvest. In order to address that, we built into the project interseeded plantings of all the mixtures and drilled plantings after harvest to compare results from earlier seeded plantings and more typical plantings. Another barrier has been longer residual herbicide usage. Many conventional producers had not adjusted their previous herbicide programs from before adopting cover cropping. This did not seem to impact fall-planted winter rye cover crops. However, more sensitive species like legumes and brassicas as well as earlier planted cover crops interseeded into corn can easily be impacted by these chemicals. We worked closely with producers to select fields with appropriate herbicide programs for this project. UVM Extension agronomy outreach professionals had worked with producers in a pilot aerial cover crop seeding project assisting in the coordination and logistics of arranging a helicopter company to apply cover crop seed into standing crops of corn and soybeans. Custom operators had also started having equipment to enable interseeded cover crops. This all led to a more realistic attempt at planting cover crop species and mixtures that went beyond winter rye alone.

Prior to this project, our team had started investigating cover crop mixtures in corn silage systems in the Champlain Valley. A Northeast SARE funded project, “Cover Crop Diversity in No-Till Systems (PG13-025), investigated just two mixes planted at varying rates in corn silage and wheat systems and also looked at drilling daikon radish into existing pasture. As a result of that project, we identified the potential of these three-way mixes being interseeded prior to corn harvest and drilled after harvest. This original project was limited to one winter-hardy three-way cover crop mix (triticale, winter rape, winter pea) and one winter killed three-way mix (oats, peas, radish). We found that these mixes could outperform winter rye alone in fall biomass, fall percent cover and fall nutrient uptake. We also determined that lower seeding rates of mixtures performed comparably well to the higher seeding rates, negating the need spend additional dollars on extraneous seed. A final report for that project can be found here: (https://mysare.sare.org/sare_project/one13-177/?page=final). As a result of this small project, we realized the need to investigate these mixtures further and see how they could be adapted in corn silage and soybean systems.

There were several beneficiaries identified in developing this project. The primary conservation goal of effective cover cropping is to prevent soil erosion and protect water quality. Therefore, individuals, communities and agencies with a vested interested in soil health and water quality could benefit from increased knowledge about and adoption of cover cropping in the Lake Champlain Basin. The primary sector this project aimed to benefit was the agricultural sector including farmers, technical service providers, and agricultural service and supply businesses. The goal of identifying the agronomic practices that are most effective, without being overly burdensome from an economic or logistical standpoint was aimed to provide knowledge to this sector and increase and encourage adoption and improved implementation of cover cropping as a best management practice.

There are limited potential negative impacts from a project like this. If a farmer adopted a new cover crop practice on their farm that resulted in crop yield loss, that would be a direct impact on that farmer. However, this project was designed to increase the effectiveness and efficiency of the practice and demonstrate the recommended methods of implementing it and reduce risk of failure. The intent of the project is to minimize the negative impacts of cover cropping. Because the nature of this project is to increase the use of a best management practice, the environmental impacts were intended to be only positive.

**Review of Methods**

This project addressed the innovative concept of mixing cover crop species, as opposed to just a single cover crop species, most commonly winter rye. While there is growing interest in cover crop mixes, adoption of this practice in the Champlain Valley has been slow as farmers may be unsure of cost/benefits and what species will work on their soil, with their specific rotations. This project also explored broadcasting cover crops into standing cash crops. This method is relatively new in Vermont, and has been used primarily in corn silage fields with equipment like helicopters and high clearance seeders (with and without fertilizer). We extended this approach to explore whether it could be used in soybean fields. The most common way of seeding winter rye has typically been broadcasting and then rolling or tilling the seed in. Demonstrating the use of our no-till drill continues to provide farmers with an opportunity to see the value of this technology and determine whether it would fit into their system. Broadcasting into a standing crop could potentially saves labor or fuel cost, but could add the cost of equipment of custom planting. Other farmers have explored spreading cover crops at side-dress time to utilize the same pass/labor. If broadcasting is effective, then there may be reduced runoff after harvest, since there is no lag time between harvest and planting/growing of the cover crop. However, results suggest broadcasting has variable success. No-till drilling after harvest provides consistent cover crop stands and saves a tractor pass in comparison to broadcast and then incorporation, meaning less fuel, labor and potential compaction. No-till drilling fits into a no-till system where there is an optimization of residue that slowly builds and decomposes, at least theoretically building soil health over time. It also allows for seed to soil contact at proper seeding rate and depth, but requires calibration and depth monitoring to be most successful. Drilling does create distinct rows as opposed to an even spread of seed over a field however. Regardless of planting method, producers who participated in this project and producers who wish to adopt cover crop mixtures will, in many cases, spend more money on their cover crop seed and may need to 'hire out' the job of planting or acquiring new/different equipment depending on their current equipment. Another accommodation farmers made (or would need to make) is to harvest their corn during the first half of September. This often means planting shorter-season varieties, which may have less reliable yields than longer season hybrids. This may be a minor adjustment for some farms, especially those on clay that tend to already plant hybrids that are 96 Days Relative Maturity (DRM) already.

**Schedule of Events**

The general timeline of the project was as follows:

- *Fall 2013*: Grant awarded; planning and coordination started
- Winter/Spring 2013-2014: planning, coordination, training; selected partnering farms to host research/demonstration locations; coordinated with farmers to plan field operations
- *Summer 2014*: Finalized field selections, laid out plots, planted all interseeded plots
- *Fall 2014*: drilled final plots on all fields, started collecting data on plots; field days held for farmers
- *Winter 2014/2015*: presentations at winter meetings and conferences
- *Spring 2015*: collected spring data on all plots; coordinated with farmers to select fields for 2015 plantings, reviewed preliminary data and changed some cover crop mixes;
- *Summer 2015*: finalized field selections, laid out plots, planted interseeded plots
- *Fall 2015*: drilled final plots, collected fall data at all sites, field days
- *Winter 2015/2016*: presentations at winter meetings and conferences
- *Spring 2016*: collected data at all sites, field days
- *Summer/Fall 2016*: data analysis, fact sheet preparation, final reporting

**Field Demonstration Locations**

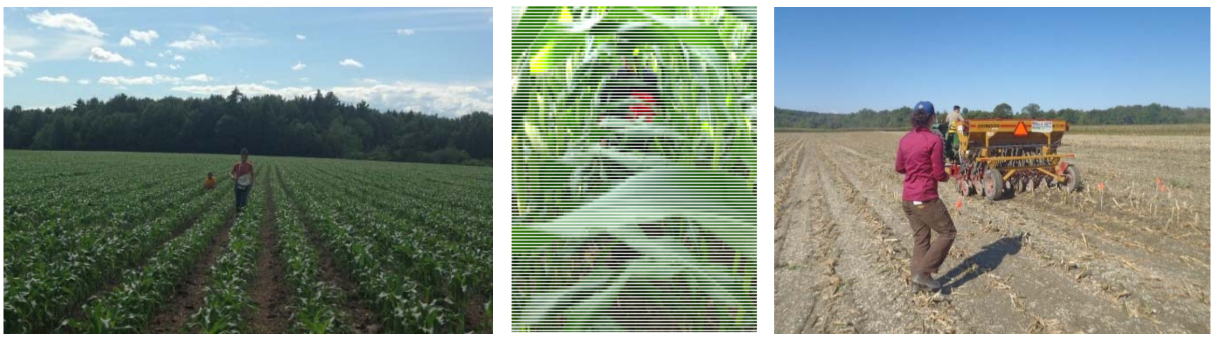
The project occurred in farm fields in the following towns (from north to south), all located within the Lake Champlain watershed:

Richmond, Vermont
Charlotte, Vermont
Starksboro, Vermont
Ferrisburgh, Vermont
New Haven, Vermont
Addison, Vermont
Orwell, Vermont

For a diagram illustrating cover crop mixes by year, see Figure 1 below. For a diagram showing an example of cover crop plot layout, see Figure 2 below. For a table describing which fields were planted in which year, see Tables 1 and 2 below.

## Planting Methods

Demonstration plot years were Summer/Fall 2014 through Spring 2015 and Summer/Fall 2015 through Spring 2016. Cover crops were planted by either broadcasting into standing corn or soybeans simulating a high clearance/helicopter application by using a handheld broadcast spreader (i.e. Earthway EV-N-SPRED), or by planting the seed with a Haybuster No-Till Drill (model 107C) after harvest of the corn crop. Cover crop plots were measured and flagged out before planting and all cover crop planting was performed by the Champlain Valley Crop, Soil and Pasture Extension team. Farmers provided project staff with information about the field. Farmers and manure spreaders coordinated with project staff to spread manure on plots at the rates they would normally plan to do. Cover crop and soil data was collected in both fall and spring of both years by the Extension team. In order to accommodate the project, farmers allowed us use of a field during and after crop harvest and into the following spring before they planted their next crop.



*Planting methods for corn from left to right: interseeding at V4/5, interseeding at R1 and drilling after harvest*

## Cover Crop Mixes by Year

Ten cover crop mixes and seeding rates were identified and then compared to winter rye at a 'control' rate of 100 lb/acre. Seeding rates were adjusted to pure live seeding rates (PLS) to account for other material and germination rates. A diagram describing the cover crop mixes can be seen on the following page (see Figure 1). The first year (2014) the grass/grains used were winter rye, forage oats, winter triticale, winter wheat and annual ryegrass. After the final results in 2015, it was concluded that winter wheat, and to a lesser degree winter triticale, were not performing as well for cover crop purposes as compared to winter rye (more discussion in *Findings*). While winter wheat may be used for the purposed of grain production, for the sake of biomass production and nutrient uptake winter rye was a better fit and was taken out of the mixes. Winter triticale was kept in two mixes but was replaced with winter rye in a third (mix 4). The first year the legumes used were field peas, winter peas, berseem and crimson clover, and hairy vetch. All of these legumes were included in the second year, however in one case (mix 6) crimson clover was replace with forage oats. We concluded that we also wanted to demonstrate stacking multiple grass/grains with either a legume or a brassica, and we also replaced mustard with winter rye for that reason (mix 7). Finally, we also eliminated mustard from the other original mix (mix 8) in the second year as it did not perform as well as the other brassicas and cost substantially more. Mustard may be a useful cover crop for biofumigation, but for the sake of biomass and nutrient uptake it did not compete well with tillage radish, rapeseed and forage turnip.

The following diagrams (Figures 1 and 2) show the plot plan of all cover crop mixes used in this demonstration project for both years. All rates were adjusted to account for pure live seed; a positive ‘control’ of winter rye was used as a comparison of a more common single species cover crop. Some changes were made for the second year of the project based upon results so that Mix 6 & 7 contain two grass/grains.

### Planting Dates by Year

In 2014 cover crops were planted on five corn silage cash crop farms/fields, and one soybean farm/field. Dates and types of planting are described in Tables 1 and 2 in the *Results and Discussion* section. Unfortunately the first year, only Farm Three had successful establishment of cover crops when broadcast into standing corn. In 2015 cover crops were planted on five corn silage cash crop farm fields, and two soybean farm fields.

Note that timing of “early” and “late” broadcasting is different in corn silage and soybeans. “Early” corn silage broadcasting done around V4-5 and “late” done around R1. Soybean “early” broadcasting done around R3-5 and “late” done around R6-8.

### Manure Treatments

In the first year we capitalized on another research project involving manure and decided to split the Farm Three field plots in half so that each cover crop mix and date also had manure spread over half of it, and was not spread over the second half. Liquid dairy manure was spread on the east half of all plots just after corn harvest (and final cover crop planting) with Houle tank spreader at a rate of 6,000 gallons per acre (calibrated in field at time of spreading). On other farms, manure was handled according to farmer protocol, but were similar in nature to the Farm Three plots – surface broadcast in the fall at rates around 5,000 gallons per acre. We found that manure applications positively impacted biomass on all plots regardless of planting date/method. This is an important observation, as many farmers in Vermont that are cover cropping are dairy farms with manure. Fall manure applications are often part of their cropping system, and impacts how/when they establish cover crops. It is important to note and share with farmers that cover crops benefit from manure applications, and improve fall manure nutrient utilization.

**Figure 1. A diagram of all cover crop mixes used in this demonstration project - 2014-2016.**

| First Yr: 2014-2015 | | | | | | Second Yr: 2015-2016 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Grass/Grain* | *Legume* | *Brassica* | *Lbs/Acre* | Stayed The Same Or Changed | | *Grass/Grain* | *Legume** | *Brassica** | *Lbs/Acre* |
| Control: | Winter Rye 100 | | | 100 | Same | Control: | Winter Rye 100 | | | 100 |
| Mix 1: | Forage Oats 30 | Field Pea 25 | Tillage Radish 5 | 60 | Same | Mix 1: | Forage Oats 30 | Field Pea 25 | Tillage Radish 5 | 60 |
| Mix 2: | Winter Triticale 50 | Aust. Winter Pea 25 | Rapeseed 5 | 80 | Same | Mix 2: | Winter Triticale 50 | Aust. Winter Pea 25 | Rapeseed 5 | 80 |
| Mix 3: | Ann. Ryegrass 15 | Aust. Winter Pea 25 | Tillage Radish 5 | 45 | Same | Mix 3: | Ann. Ryegrass 15 | Aust. Winter Pea 25 | Tillage Radish 5 | 45 |
| Mix 4: | Winter Wheat 50 | Aust.Winter Pea 25 | Tillage Radish 5 | 80 | Winter Wheat --> Winter Rye | Mix 4: | Winter Rye 50 | Aust.Winter Pea 25 | Tillage Radish 5 | 80 |
| Mix 5: | Ann. Ryegrass 15 | Clover - Berseem 5 | Tillage Radish 5 | 25 | Same | Mix 5: | Ann. Ryegrass 15 | Clover - Berseem 5 | Tillage Radish 5 | 25 |
| Mix 6: | Winter Triticale 50 | Clover - Crimson 5 | Tillage Radish 5 | 60 | Winter Triticale --> Winter Rye, Crimson Clover --> Oats | Mix 6: | Winter Rye 50 | Forage Oats 30 | Tillage Radish 5 | 85 |
| Mix 7: | Forage Oats 30 | Hairy Vetch 10 | Mustard 5 | 45 | Mustard --> Winter Rye | Mix 7: | Forage Oats 30 | Hairy Vetch 10 | Winter Rye 50 | 90 |
| Mix 8 | Winter Triticale 50 | Hairy Vetch 10 | Mustard 5 | 65 | Mustard --> Forage Turnip | Mix 8 | Winter Triticale 50 | Hairy Vetch 10 | Forage Turnip 5 | 65 |
| Mix 9: | Winter Rye 50 | Aust. Winter Pea 25 | Forage Turnip 5 | 80 | Same | Mix 9: | Winter Rye 50 | Aust. Winter Pea 25 | Forage Turnip 5 | 80 |
| Mix 10: | Winter Rye 50 | Clover-Crimson 5 | Rapeseed 5 | 60 | Same | Mix 10: | Winter Rye 50 | Clover-Crimson 5 | Rapeseed 5 | 60 |

* Except Mix 6    * Except Mix 7

**Figure 2. Example plot diagram showing plot layouts in a field. (Site: Farm Three 2014-2015)**

11-Jul-14 — **Early Broadcast**

| | Grass/Grain | Legume | Brassica/Forbe | $/Acre |
|---|---|---|---|---|
| **Control** | Winter Rye 100 | | | 100 |
| **Mix 1:** | Forage Oats 30 | Field Pea 25 | Tillage Radish 5 | 60 |
| **Mix 2:** | Winter Triticale 50 | Aust. Winter Pea 25 | Rapeseed 5 | 80 |
| **Mix 3:** | Ann. Ryegrass 15 | Aust. Winter Pea 25 | Tillage Radish 5 | 45 |
| **Mix 4:** | Winter Wheat 50 | Aust. Winter Pea 25 | Tillage Radish 5 | 80 |
| **Mix 5:** | Ann. Ryegrass 15 | Clover - Berseem 5 | Tillage Radish 5 | 25 |
| **Mix 6:** | Winter Triticale 50 | Clover - Crimson 5 | Tillage Radish 5 | 60 |
| **Mix 7:** | Forage Oats 30 | Hairy Vetch 10 | Mustard 5 | 45 |
| **Mix 8** | Winter Triticale 50 | Hairy Vetch 10 | Mustard 5 | 65 |
| **Mix 9:** | Winter Rye 50 | Aust. Winter Pea 25 | Forage Turnip 5 | 80 |
| **Mix 10:** | Winter Rye 50 | Clover-Crimson 5 | Rapeseed 5 | 60 |

14-Aug-14 — **Late Broadcast**

| | Grass/Grain | Legume | Brassica/Forbe | $/Acre |
|---|---|---|---|---|
| **Control** | Winter Rye 100 | | | 100 |
| **Mix 1:** | Forage Oats 30 | Field Pea 25 | Tillage Radish 5 | 60 |
| **Mix 2:** | Winter Triticale 50 | Aust. Winter Pea 25 | Rapeseed 5 | 80 |
| **Mix 3:** | Ann. Ryegrass 15 | Aust. Winter Pea 25 | Tillage Radish 5 | 45 |
| **Mix 4:** | Winter Wheat 50 | Aust. Winter Pea 25 | Tillage Radish 5 | 80 |
| **Mix 5:** | Ann. Ryegrass 15 | Clover - Berseem 5 | Tillage Radish 5 | 25 |
| **Mix 6:** | Winter Triticale 50 | Clover - Crimson 5 | Tillage Radish 5 | 60 |
| **Mix 7:** | Forage Oats 30 | Hairy Vetch 10 | Mustard 5 | 45 |
| **Mix 8** | Winter Triticale 50 | Hairy Vetch 10 | Mustard 5 | 65 |
| **Mix 9:** | Winter Rye 50 | Aust. Winter Pea 25 | Forage Turnip 5 | 80 |
| **Mix 10:** | Winter Rye 50 | Clover-Crimson 5 | Rapeseed 5 | 60 |

19-Sep-14 — **Drill**

| | Grass/Grain | Legume | Brassica/Forbe | $/Acre |
|---|---|---|---|---|
| **Control** | Winter Rye 100 | | | 100 |
| **Mix 1:** | Forage Oats 30 | Field Peas 25 | Tillage Radish 5 | 60 |
| **Mix 2:** | Winter Triticale 50 | Aust. Winter Peas 25 | Rapeseed 5 | 80 |
| **Mix 3:** | Ann. Ryegrass 15 | Aust. Winter Pea 25 | Tillage Radish 5 | 45 |
| **Mix 4:** | Winter Wheat 50 | Aust. Winter Pea 25 | Tillage Radish 5 | 80 |
| **Mix 5:** | Ann. Ryegrass 15 | Clover - Berseem 5 | Tillage Radish 5 | 25 |
| **Mix 6:** | Winter Triticale 50 | Clover - Crimson 5 | Tillage Radish 5 | 60 |
| **Mix 7:** | Forage Oats 30 | Hairy Vetch 10 | Mustard 5 | 45 |
| **Mix 8** | Winter Triticale 50 | Hairy Vetch 10 | Mustard 5 | 65 |
| **Mix 9:** | Winter Rye 50 | Aust. Winter Pea 25 | Forage Turnip 5 | 80 |
| **Mix 10:** | Winter Rye 50 | Clover-Crimson 5 | Rapeseed 5 | 60 |

20 feet (plot width); 0 feet (between blocks); 100 feet (block length); N

## Farmer Outreach and Information Transfer

A large component of this project was farmer outreach and information transfer. This was accomplished by hosting on-farm field days at many of the project sites. This was a very valuable method of transferring information to farmers and service providers. We were able to have field days in both the fall and spring, so attendees were able to quantify the information by seeing the results for themselves. In addition, the data and photographs collected on the plots have been used in multiple presentations and workshops, and even highlighted in local television shows. A full description of farmer outreach and information transfer (including descriptions of individual events, etc.) is included in the *Transfer of Information – Farmer Outreach and Education* section of this report.

## Results and Discussion

### Field Demonstration/Research Plots

Over the course of the two years of the project, we planted 14 different three-way mixes (plus a winter rye control) on 10 different farms on 13 fields, with 29 separate 'planting events,' for a total of 319 plots. Nine of the planting events were considered Early Broadcast (BE), interseeding the mixes into the standing crop in the vegetative stage of production for corn and early reproductive stage for soybeans. Eleven of the planting events were considered a Late Broadcast (BL) event and were interseeded into the standing crop at early/late reproductive stages. Nine of the events were drilled (DR) after harvest of the cash crop. The plots were planted with the mixes side-by-side, so that you could compare performance of the same mix planted at different times and with different methods in the same field (see Figure 2).

**Table 1. 2014-2015 Demonstration Farm Details**

| ***Table 1. 2014-2015 "Better Cover Crops in Vermont"*** | | | | Cover Crop Plantings** | | |
|---|---|---|---|---|---|---|
| Farm | Location | Soil Type* | Crop | BE | BL | DR |
| Farm One | New Haven | Hh | Corn Silage | | | x |
| Farm Two | Ferrisburgh | ElB/Cw | Corn Silage | x | x | x |
| Farm Three | Starksboro | Cn | Corn Silage | x | x | x |
| Farm Four | Richmond | Wo | Corn Silage | x | x | |
| Farm Five | Middlebury | VgB | Corn Silage | x | x | x |
| Farm Six | Charlotte | VeB | Soybeans | | x | |

**Cn=Canandaigua silt loam; Cw=Covington silty clay; ElB=Elmwood fine sandy loam; Hh=Hadley very fine sandy loam (frequently flooded); VeB/VgB=Vergennes clay; Wo=Winooski very fine sandy loam*
***BE=Broadcast Early, BL = Broadcast Late, DR = Drilled after crop harvest*

**Table 2. . 2015-2016 Demonstration Farm Details**

| *Table 2. 2015-2016 "Better Cover Crops in Vermont"* | | | | Cover Crop Plantings** | | |
|---|---|---|---|---|---|---|
| Farm | Location | Soil Type | Crop | BE | BL | DR |
| Farm Three | Starksboro | RaC | Corn Silage | | x | x |
| Farm Four | Richmond | MyB | Corn Silage | x | | x |
| Farm Five | Middlebury | VgB | Corn Silage | x | x | x |
| Farm Seven | New Haven | NeB | Corn Silage | | x | x |
| Farm Eight | Charlotte | VeD | Soybeans | x | x | |
| Farm Nine | West Addison | Cw | Soybeans | x | x | |
| Farm Ten | Orwell | VgB | Corn Silage | x | x | x |

**Cw=Covington silty clay;MyB=Munson/Raynham sil loams; Ne=Nellis stony loam; RaC=Raynhum silt loam; VeD/VgB=Vergennes clay*
***BE=Broadcast Early, BL = Broadcast Late, DR = Drilled after crop harvest*

The mixes changed slightly from year one to year two, but they maintained the grass/legume/brassica formula, with the exception of two. Six of the mixes were planted in both years, and the remaining eight were planted in only one of the two years. The winter rye control was planted both years. See Figure 1 for a full description of mixes and seeding rates by year.

## Data Collection

Data was collected on the plots in the fall and spring of each year to gauge overall performance of the cover crops and to compare performance between mixes. More detailed descriptions are included on the Review of Methods and Quality Assurance sections of this report. However, the types of data collected by season are in Table 3 below.

**Table 3. Data Type Collected by Season (both years)**

| **Fall Data** | **Spring Data** |
|---|---|
| Percent Cover | Percent Cover |
| Height | Height |
| Biomass | Biomass |
| Nutrient content (N,P,K) of plant tissue | Nutrient content (N,P,K) of plant tissue |
| | Soil Temperature |
| | Soil Moisture |
| | Soil Compaction |

**Measurements Taken by Season**

In the fall 2014 the Farm Three site had the most growth and we focused more of our measurements there, particularly on the drilled plots. Percent cover, cover crop height, and cover crop forage samples (for biomass and nutrient uptake) were taken October (10/21/14, 10/22/14) on all Farm Three plots and both manured (M) and no-manured (NM) sections separately. In November (11/12/14) percent cover, cover crop height, and cover crop forage samples were taken again at the Farm Three site, but early broadcast M and NM and late broadcast NM were excluded. Percent cover and cover crop height were also measured at Farm One, Two and Five site locations (11/10/14, 11/11/14).

In the spring 2015 percent cover and soil moisture was measured at Farm Three, Two and One locations (4/24/14 & 4/29/14) as well as compaction (depth at 300 PSI) and soil temperature (at 4 inch depth) at Farm Two and Three sites. Limited spring biomass samples were taken at the Farm Three site on two occasions (5/4/14 & 5/14/14) and at Farm Two once (5/4/14).

In the fall of 2015 plots were not separated by manure and no manure. Percent cover was taken once at each location (range of dates 10/19/15 through 11/30/15, corn and soy having different maturity) and cover crop forage samples were taken at the Farm Three, Four, Five and Seven sites.

In the spring of 2016 percent cover, cover crop height, cover crop forage samples (where enough biomass), soil moisture, soil temperature (at both 2.5 and 4 inch depth), soil compaction (PSI at 3 and 6 inch depth), were taken at Farm Three, Four, Five, Seven, and Ten locations (once at each location 4/19/16 to 5/3/16). Forage samples were taken a second time at Farm Three location (5/4/16). Forage samples and soil moisture were also taken at Farm Nine location later (5/26/16).

## Transfer of Information - Farmer Outreach and Education

A large component of this project was to share information with farmers and to demonstrate to local producers how these cover crops perform planted in different way at different times on different soil types under different conditions. Beyond the general presence of these plots (along with signage and flagging) in real farm fields throughout the Lake Champlain region, we had a concerted effort to have people see them in the fall and the spring in both years. This outreach extended beyond just local farmers, but included local agricultural businesses, NRCS staff, Vermont Agency of Agriculture staff and other technical service providers. As a result, through 12 different field days and at least six different workshop/conference presentations we directly reached the following numbers of people as a result of this project:

**Table 4. Direct Contacts from Outreach Efforts**

| ***Direct Contacts Through Workshops, Presentations & Field Days*** | Farmers | Agricultural Businesses personnel | Education, Governmental and other TSPs | Total |
|---|---|---|---|---|
| Field Days | 201 | 61 | 112 | 374 |
| Workshops, Conferences, Presentations | 153 | 81 | 221 | 455 |
| *TOTAL (by category)* | *364* | *142* | *333* | |
| **TOTAL** | | | | **829** |

### Newsletter Articles

In addition to direct contacts through these educational events, we highlighted the project through our newsletter. Our newsletter mailing list currently includes 796 email contacts and is direct mailed to 425 people through the postal service for each edition. At the commencement of this project, we initiated a recurring 'Cover Crop Corner' section to highlight work related to this and other cover crop projects. Some editions used this section to advertise and/or highlight upcoming field days, workshops or conferences. However, many times an informational article about cover crop management was included. Those specific articles were as follows:

April 2014: *Is Your Herbicide Program Compatible with Your Cover Crops?*
May 2014: *Spring Management for Cover Crops…Termination and Harvest*
June 2014: *Manure and Cover Crops…A Winning Combination*
July 2014: *What Vermont Farmers Want to Know About Cover Cropping*
July 2015: *Sponge or Stone: Cover Crops and Wet Weather*
October 2015: *Learning as We Go*
September 2016: *Legumes: Getting More Out of Your Cover Crop (https://blog.uvm.edu/cvcrops/legumes/)*

**Field Day Events**

Multiple Field Day events were held throughout the project. Many of them were held at the locations were cover crop demonstration plots were planted. However, some were at other farms where similar practices had been implemented (cover crop mixtures). A synopsis of each event is included and handouts from field days are included in Appendix A.

*CVFC/SeedWAy® Cover Crop Lunch (3/26/2014)*

This event wasn't a 'field day', but more a conversation about cover cropping on Vermont dairy farms. With the Champlain Valley Farmer Coalition and SeedWay®, we co-hosted a lunch, heard from a small seed specialist, and had a spirited conversation about the challenges of cover cropping in corn systems in the Champlain Valley. Roughly 20 farmers and 3 ag business professionals attended this event.

*Additional Farm Site (10/31/2014)*

This event was co-hosted with UVM Extension's Northwest Crops & Soils Program and the farmer in Westford, Vermont. Roughly five farmers and 10 ag business professionals attended. In addition to a good discussion and looking at no-till corn planter at the farm shop, the whole group went down to look at a corn silage field that had been interseeded with annual ryegrass, white clover, and radish with their sidedress nitrogen application in July. We were able to see how the cover crop was doing after the corn harvest and troubleshoot application problems like banding of ryegrass seed, poor clover germination, and the 'right' seeding rates for radish.

*Additional Farm Site (11/6/14)*

In addition to our formal CIG Cover Crop plots, project staff were able to work with another farm at the beginning of this grant to investigate planting cover crop mixes after a winter wheat/rye harvest, no-till drilled in August. The cover crops had a great catch, so we partnered with a local manure spreader, a custom service operator, to have an informative field day in Panton, Vermont. Nine farmers and nine ag business professionals attended the event and many of them stayed beyond the scheduled time to look at other fields and continue the conversation. *A handout from the field day is included in the Appendix.*

*Farm Three (11/7/14)*

This field day was held at one of the CIG Cover Crop demonstration fields. The farm had the best cover crop establishment with all three seeding dates, so we were able to illustrate differences between planting dates and differences between mixes. In addition to these plots, a second project funded by USDA-NIFA and Northeast SARE entitled, "Evaluating the Use of Forage Radish to Enhance Winter Rye Cover Crops." was also highlighted as it was located in the same field. This field also received a manure application on the south half of all of the plots, which made for a good comparison of cover crops with and without manure. Nine farmers and 16 service providers attended this field day in Starksboro, Vermont. *A handout from the field day is included in the Appendix.*

*Farm Ten – with CVFC (8/14/2015)*

This event was part of a *Crop Patrol* in partnership with Champlain Valley Farmer Coaltion. Earlier in the day, the group visited a no-till cornfield in Shoreham, Vermont. Afterwards, they visited one of our CIG Cover Crop demonstration fields. We had just planted our second interseeded planting of the mixes, but attendees were able to see germination from the first planting in addition to winter rye that had been interseeded by the farmer at the same time as our first planting. Twenty-three farmers and 5 service providers attended this event in Orwell, Vermont.

*UVM Plant & Soil Science Forages Class (10/12/15)*

Sid Bosworth, Agronomy Specialist, brought his PSS 143: Forage and Pasture Management class out to Farm Three for a field lab. During their time there, Kirsten Workman held a 'field day' for students showing them the CIG Cover Crop plots and describing the projects and results. Roughly 15 UVM students were in attendance.

*Additional Crop Patrol (10/23/15)*

On October 23rd UVM Extension and the Champlain Valley Farmer Coalition held Cover Crop Mixes *Crop Patrol* in Orwell. There were 14 total attendees (6 farmers, 2 Agribusiness, 3 Service Providers, 3 Extension).

The goal of the workshop was to show farmers cover crops individually and in mixes with the end of goal of having them better understand the roles, benefits, and possible issues when selecting cover crop seeds. The field was planted the same weekend that corn silage was harvested, September 12th. With timely rain and about 40 days of growth, the cover crops were well established and were looking very vigorous for our field day. There were fields/strips with the following cover crops: winter rye planted at 112 lb./acre, winter rye and radishes; radishes alone; oats, rye, and radish; and barley, field peas, rye, and radishes. While describing what he did, you could tell that the farmer enjoyed planting his trials. As we went up the hill looking at the various strips, we would stop and dig up samples to look at. The group was especially interested in seeing the differences in root mass between barley and rye, and also seeing root nodulation on field peas. We also showed the group earthworm castings, and talked about basic nutrient cycling in cropland with cover crops. One topic that received a lot of discussion was how to both reduce tillage and get a cover crop planted early. Farmers expressed their concern about planting shorter day corn, but most of them felt like it was the right thing to do. There was also a lively discussion about no-till corn, and the farmer indicated that with some assistance, he is thinking of planted some acreage to no-till corn in 2016. Several other farmers indicated that they are going to try or expand their no-till corn and cover crop acres next year.

*Fall Soil Health Workshop & Field Day (10/28/2015)*

As part of a larger Soil Health Workshop & Field Day that was part of the CIG Soil Health Demonstration Farm project (Award # 69-1644-13-74), some of this project's work was presented during the workshop portion, as well as during the cover crop portion of the field day. There were 82 participants at the event held in Middlebury, Vermont and at Farm Five (40 farmers, 11 ag business professionals, 17 agency staff, and 14 Extension/University).

*Additional Farm Sites (11/4/15)*

This was another field day that was not at a CIG Cover Crop demonstration farm, but highlighted the work being done by showing two farms who had started adopting interseeding of cover crop mixtures. Two nearby farmershave been interseeding cover crops into corn fields for the last three years. Initially they hired a helicopter to fly on winter rye with into standing corn after tassel. This last year one farmer seeded a mixture of annual ryegrass and clover into his grain corn at different times, beginning at sidedress time (V6/V7). Since this farmer grows corn for grain, he is especially interested in establishing his cover crops alongside his cash crop, since harvest often takes him well into October and later. The other farmer used the UVM Hagie Highboy seeder this year to broadcast winter rye prior to corn silage harvest. He will share his comparison of this technology with the helicopter he has used in year's past. Both farmers have started trying reduced tillage in an effort to increase soil health in conjunction with their cover crops. We will chat with them both to see what strategies are working the best on their fields along the mouth of the Winooski River as it enters Lake Champlain. During the field day we discussed: the results of varying methods/species of interseeded cover crops in corn grain and silage systems; burcucumber effects and management strategies for this annual weed; and GPS technology for cover cropping and other field operations. Eight farmers and 8 service providers attended this field day held in conjunction with UVM Extension's Northwest Crops and Soils Team in Colchester, Vermont. *A handout from the field day is included in the Appendix.*

*Impromptu Field Day at Farm Four (3/23/16)*

A manure training was being held at one of our CIG Cover Crop demonstration farms, in Richmond, Vermont. The farmer suggested inviting attendees to go out and see the CIG Cover Crop demonstration plots after the training ended. Weather cooperated and we were able to spend about an hour out at the plots with 12 farmers and 3 service providers talking about the project, looking at the plots and discussing cover cropping strategies. *A handout from the field day is included in the Appendix.*

*Additional Farm (4/21/16)*

**Event:** 2016 Cover Crop Field Day - April 21st, 2016 - 10:00 am – 12:00 pm
**Location:** Panton, Vermont
**Particpants:** 18 total attendees (7 farmers, 5 agribusiness service providers, 6 Extension/University)

**Summary:**

The UVM Extension Champlain Valley Crop, Soil & Pasture Team hosted a cover crop field day in Panton, Vermont. The farm was host to a NE SARE and USDA NIFA funded research project in cooperation with UVM Extension called, "Evaluating the use of forage radish to enhance winter rye cover crops".

Kirsten Workman, CV Crops team member, described the project that is also the basis for Master's thesis in Plant & Soil Science. We discussed and looked at the different winter rye and radish treatments in the field. All plots had good growth, as a warm fall and mild winter really favored cover crops this year. A handout from the field day is attached with some preliminary data from the project and a plot map.

Josef Gorres, UVM Soil Science Professor, also discussed how to identify Vergennes clay soil, described a project looking at the K Factor and erosion rates of this common Champlain Valley soil, and what some of the management implications are.

In addition to the research plots, we talked with one of three brothers who operate the farm about their reduced tillage system, and the Winter Rye/Oat/Radish cover crop mixture that they implemented on over 800 acres this last fall.

A good discussion was had about ways farmers approach phosphorus reductions, practices they are implementing, and how economics play a role in managing environmental stewardship.

**SPONSORS**: This field day was based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2014-68006-21864 and a Northeast SARE Graduate Student Grant GNE-14-091, but also touched on work related to the NRCS Conservation Innovation Grant 69-1644-13-5

*Technical Service Provider Training - May 3, 2016 at Farm Five and Three*

**Event:** **2016 Cover Crop Field Day for TSPs** - May 3, 2016
**Location:** Farm Five (Middlebury, VT), and Farm Three (Starksboro, VT)
**Participants:** 23 total; 1 farmer, 2 agribusiness service providers, 16 Agency staff, 4 Extension/University
**Event Summary:**

The UVM Extension Champlain Valley Crop, Soil & Pasture Team hosted a cover crop field day targeted to individuals who provide technical assistance or other services to farmers who are interested in growing cover crops. The field day was advertised to service providers through email announcements from UVM Extension as well as internally through VACD and NRCS. The goal was to share some of the results from our Vermont NRCS Conservation Grants, "Better Cover Crop Mixes for Vermont" and "Soil Health Demonstration Farm" and a USDA-NIFA and SARE funded research project, "Evaluating Forage Radish to Enhance Winter Rye Cover Crops" in hopes that it will assist them when giving recommendations to producers relating to successfully implementing cover cropping practices.

We visited four different demonstration/research sites during the field day:

1. *Farm Five – CIG Soil Health Demonstration & CIG Compaction projects*
   We re-visited the soil health field day site from October 2015 to see how the cover crop plots over wintered and discussed preliminary results from cover crop, soil health and compaction projects funded through CIG grants
2. *Farm Five – CIG "Better Cover Crop Mixes for Vermont"*
   We visited a no-till corn field that was one of 7 locations for our demonstration project evaluating 10 different three-way cover crop mixes planted at three different times (interseeded @ V7, interseeded @ R2 and drilled after corn harvest)
3. Farm Three - CIG "Better Cover Crop Mixes for Vermont"
   Another corn field that was a demonstration site for the CIG grant evaluating cover crop mixes on a different soil type.
4. Farm Three – USDA-NIFA Winter Rye and Radish cover crops
   In another field on the same farm, we visited a NIFA funded research project evaluating forage radish and winter cover crops, both broadcast and drilled at different seeding rates after a timely corn harvest.

The field day was successful, and we received positive feedback from multiple individuals expressing appreciation for the opportunity to see and discuss these different cover cropping systems. Having a targeted field day seemed a good way to discuss the particular issues relevant to technical service providers who are assisting producers.

**Sponsors**: This field day was based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2014-68006-21864 and a Northeast SARE Graduate Student Grant GNE-14-091 and a Vermont NRCS Conservation Innovation Grant.

*A handout from the field day is included in the Appendix.*

**Conference/Workshop Presentations**

Multiple presentations were given sharing the methods, results, and initial findings of this project throughout the project timeline. Below is a list of those presentations. Slide handouts for a selection of these presentations can be found in Appendix B.

- UVM Forages Class: Project staff presented to UVM Plant and Soil class, PSS 143: Forage and Pasture Management on the use of cover crops as forage crops and highlighted this new project. (October 2013)
- NH Cover Crop Soil Health Conference. University of New Hampshire Extension Meeting: *Improving Soil Health, Case Studies & Research Results* (December 2014)
- Vermont No-Till and Cover Crop Symposium. University of Vermont Extension Conference: *Cover Crops in Vermont, Building the Toolbox* (February 2015)
- New England CCA InService. University of Maine Extension training: *Multi-Species Cover Crop Mixtures* (February 2016)
- Vermont No-Till and Cover Crop Symposium. University of Vermont Extension Conference: *Multi-Species Cover Crop Mixtures* (February 2016)
- Coffee Break for Cover Crops. Northeast SARE Webinar Series: *Cover Crop Variety Selection for Interceding* (May 11, 2016)

**Across the Fence Episodes**

This work from this project was highlighted in five different *Across the Fence* episodes. *Across the Fence*, a 15-minute program produced by University of Vermont Extension, is the longest running daily farm and home television program in the country. The program airs weekdays at 12:10 pm on WCAX TV, Channel 3. ATF producers did a series of episodes highlighting UVM Extension work addressing agriculture and water quality. The episodes that highlighted this project were:

| | |
|---|---|
| 1/28/16: | Water Quality and Research by UVM Extension (https://youtu.be/smymSsFlsqM) |
| 2/8/16: | Making an Impact: UFM Extension's Work in Water Quality Improvement (https://youtu.be/WkdvAzh7CYE) |
| 2/18/16: | Making an Impact: UVM Extension's Work in Water Quality (https://youtu.be/bYPLAc-b2MI) |
| 7/5/16: | Making in Impact: Improving Water Qaulity with Innovative Approaches to Planting Corn (https://youtu.be/-COxFsv8GdY) |
| 9/6/16: | On the Farm: UVM Extension's Research to Improve Water Quality (Part 2) (https://youtu.be/S7RELaa_e1s) |

**Vermont Public Radio**

A general story about cover cropping, featuring Kirsten Workman, was featured on Vermont Public Radio on January 29, 2016. The article and recording are here: http://digital.vpr.net/post/farmers-embrace-cover-crops-improve-soil-reduce-runoff#stream/0

## Cover Crop Outreach Materials

See Appendix C for the following Factsheets developed and/or revised as a result of this project.

- UVM Extension Factsheet – Multi-Species Cover Crop Decision Tool for Corn Silage Systems.
- UVM Extension Factsheet – Manure and Cover Crops

## NRCS Cover Crop (340) Specification Guide Sheet

This project has provided us with an ample amount of data related to cover crop performance in the Lake Champlain Basin. We were able to use this information to build on previous knowledge and build a solid foundation on which to focus future research, demonstration, outreach and investigations surrounding cover cropping, soil health and related cropping system practices. Because this was the first large scale look at cover crop mixtures, we are now able to combine this (along with information gathered from farmers implementing these mixes) to help adjust and refine the NRCS Specification for Cover Crops (340). In Appendix D, is a proposed addendum to NRCS Vermont's *Cover Crop (340) Specification Guide Sheet* (https://efotg.sc.egov.usda.gov/references/public/VT/VT340_Specs.pdf). This addendum adds Tables 1d and 1e with guidance about seeding rates, depths and planting dates to accomplish the intent of the *Cover Crop 340 Practice Standard* to: reduce erosion, increase soil organic matter, capture/recycle/redistribute soil nutrients, promote biological nitrogen fixation, increase biodiversity, suppress weeds, manage soil moisture and minimize/reduce soil compaction. This proposed addendum has been submitted to Sandra Primard, Vermont NRCS Conservation Agronomist, for her review.

| Table 1d - VT 340 | Min.Seeding Rate (lbs/acre) | | Seeding Depth | Latest Seeding Dates* (USDA Hardiness Zones 3b - 5a) | | | | Primary Purpose** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Cover Crop Mixes ‡** *(3-Species Mixes)* | Broadcast (includes aerial) | Drilled | Inches | Fall Cover | Winter Cover | Spring Cover | Summer Cover | Erosion | Nitrogen Fixation | Nutrient Scavenge |
| **2-1: *Winter Killed Mix* ‡** | | | | | | | | | | |
| Forage Oat | 40 | 30 | 1-1½ | Aug. 15 | Sept. 1 | April 15 | May 15 | x | x | x |
| Field Pea | 30 | 25 | | | | | | | | |
| Radish | 5 | 3 | | | | | | | | |
| **2-2: *Marginally Winter Hardy* ‡** | | | | | | | | | | |
| Annual Ryegrass | 15 | 12 | ½-1 | Aug. 15 | Sept. 1 | April 15 | May 15 | x | x | x |
| Winter Pea | 30 | 25 | | | | | | | | |
| Radish | 5 | 3 | | | | | | | | |
| **2-3a: *Winter Kill & Winter Hardy* (Brassica) ‡** | | | | | | | | | | |
| Forage Oat | 50 | 40 | 1-1½ | Aug. 15 | Sept. 15 | NA | NA | x | | x |
| Winter Rye | 50 | 40 | | | | | | | | |
| Radish | 5 | 3 | | | | | | | | |
| **2-3b: *Winter Kill & Winter Hardy* (Legume) ‡** | | | | | | | | | | |
| Forage Oat | 50 | 40 | 1-1½ | Aug. 15 | Sept. 15 | NA | NA | x | x | x |
| Winter Rye | 50 | 40 | | | | | | | | |
| Hairy Vetch | 15 | 10 | | | | | | | | |
| **2-5: *Winter Hardy , Low Spring Biomass* ‡** | | | | | | | | | | |
| Winter Rye | 50 | 40 | 1-1½ | Aug. 15 | Sept. 15 | NA | NA | x | x | x |
| Winter Pea | 30 | 25 | | | | | | | | |
| Turnip | 5 | 3 | | | | | | | | |
| **2-6: *Winter Hardy, Moderate Biomass* ‡** | | | | | | | | | | |
| Winter Rye | 50 | 40 | ½-1½ | Aug. 15 | Sept. 1 | NA | NA | x | x | x |
| Crimson Clover | 12 | 10 | | | | | | | | |
| Winter Rapeseed | 5 | 3 | | | | | | | | |
| **2-7: *Winter Hardy , High Spring Biomass* ‡** | | | | | | | | | | |
| Winter Rye | 100 | 75 | ½-1½ | Aug. 15 | Sept. 15 | NA | NA | x | x | x |
| Hairy Vetch | 15 | 10 | | | | | | | | |
| Winter Rapeseed | 5 | 3 | | | | | | | | |

**Table 1e - VT 340**

| ‡ Seeding Rates (in a three-way mix) Pounds/Acre | | |
|---|---|---|
| **Cover Crop Species** | **Broadcast** | **Drilled** |
| **Grasses & Grains** | | |
| Winter Rye | 50 | 40 |
| Winter Wheat | 50 | 40 |
| Winter Triticale | 50 | 40 |
| Spring Grain | 50 | 40 |
| Forage Oat | 50 | 40 |
| Annual Ryegrass | 15 | 12 |
| **Legumes** | | |
| Red/White Clover | 8 | 6 |
| Crimson Clover | 12 | 10 |
| Berseem/Sweet Clover | 10 | 8 |
| Field Pea | 30 | 25 |
| Winter Pea | 30 | 25 |
| Hairy Vetch | 15 | 10 |
| **Brassicas** | | |
| Radish | 5 | 3 |
| Turnip | 5 | 3 |
| Rapeseed | 5 | 3 |

*These rates are in pure live seed (PLS):*
*% PLS = % germination x % pure seed/100*

*To determine actual seeding rate, divide desired PLS seeding rate by your seeds' % PLS*

*Example: To achieve a 50 lb/acre PLS seeding rate with seed that has 85% PLS*
*50 ÷ 0.85 PLS = 59 lbs/acre actual seed*

** Locations in USDA Hardiness Zone 5b may plant up to 5 days later for the Fall and Winter Cover dates.*
*** Other purposes may also be accomplished, but this is meant to help you select cover crops to address the primary resource concern in the conservation p*
*‡ to substitute species in a mix listed above, or create your own mix, use seeding rates in Table 1e (only to be used in mixes that contain three different specie*

**Discussion of Quality Assurance**

**Project Site Descriptions**

Project site locations were chosen based on criteria that included:

- Physical location in the watershed: The goal was to have well-distributed site locations that would represent the project area from north to south.
- Soil Type: a broad range of soil types was selected in order to evaluate how cover crop mixes would perform compared across multiple soil types.
- Cropping System: crop type, tillage regimen, manure, and other factors were considered
- Producer Willingness: partnering farms were chosen who were active partners in the project, communicated well with the project team, and were willing to provide in-kind match in the form of use of their land, equipment, manure applications, participation in field days/workshops, etc. This was a vital component of the project's success.

Lists of these farms, fields, and attributes located in Tables 1 and 2.

**Calibration & Planting**

Cover crop seeds were premixed at SeedWay®. Seeding rates were adjusted to pure live seed (PLS) based upon the seed tag, to account for coating and other inert material, as well as germination rates. For example, while the original target rate of the 'control' winter rye was 100 lb/acre, when accounting for PLS, the actual target seeding rate was 109 lb/acre (the second year of the project). For broadcasting, seed was pre-weighed per plot and placed in labeled paper bags. Each plot was 20 x 100 feet which is 2000 square feet or 0.046 acres. In the above example, broadcasting winter rye at 109 pounds per acre, was five pounds per plot. We also calibrated our walking speed and broadcast seed opening to cover the plot with the given amount of seed. When planting drilled cover crop plots, again PLS was taken into account in calibration. We have developed a system of calibrating our drill by turning the drill wheel 50 times and calculating what the equivalent seeding rate/acre is, and then adjusting the drill openings accordingly.

*Below is a step-by-step description of that process:*

1. Pour seed in just one side of the box (we generally use the left side)
2. Remove one tube on that side to catch the seed with a small jar or container
3. Pre-weigh the container, or tare your scale based on it
4. Turn the front wheel 50 times catching the seed (you will need 2 people or set up the seed catchment)
5. Weigh the seed in oz. and multiply this number by 16.38 to get lb/acre estimated seeding rate
6. Adjust the opening and re-measure if the rate is not close enough

**Measurement Techniques**

- **Percent Cover:** Using the protocol from VT NRCS Agronomy Technical Note 1 (The Line Transect Method for Estimating Crop Residue Cover), we measured percent cover of all residue in the plots. This included growing cover crop, crop residue from previously harvested cash crop, and weeds. Because this is a metric for prevention of soil erosion, all residue was counted. Four subsamples per plot were combined to calculate average percent cover (in the instance of our first fall, where we had separated manure and non manured sections, we took two subsamples each for a total of four).

- **Height:** Plant height was measured in inches. Three to five subsamples per plot were combined to calculate average plant height.
- **Biomass:** Plant material was harvested in each plot by clipping 1.5 square foot quadrats (6 x 36 inches). At first we took four subsamples per plot, but later realized six was needed to ensure enough biomass in some cases. Plant material was placed in cloth bags and dried at 110 degrees Fahrenheit for multiple days until all moisture was gone. These samples were then weighed and calculated for total dry matter in pounds per acre. The spotty nature of broadcast plots made it difficult to determine the best sampling method. The first year we struggled to get an accurate representation of the plots and were concerned that our measurements may have overestimated growth. The second year, we ensured we were randomly subsampling, and even if a random location had no or little growth we counted that as one of the subsamples. However, because biomass is less consistent in broadcast plots, more replication would make the results more accurate.
- **Tissue Analysis for nutrient content:** Dried plant samples (see Biomass above) were ground using a Wiley Cutting Mill to 2 mm. Samples were then sent to Dairy One Forage Lab (Ithaca, NY) for wet chemistry mineral analysis for Nitrogen (via Crude Protein), Phosphorus and Potassium. These were reported as percent of dry matter and then paired with biomass measurements to calculate pounds of nutrient per acre in the cover crop.
- **Soil Moisture:** Volumetric water content (reported as a percent soil moisture content) was collected in each plot using a Spectrum Technologies Field Scout TDR 300 Soil Moisture Meter. Fields with Vergennes clay (or heavier) soils used the 'Hi Clay' setting. Five subsamples per plot were combined to calculate average soil moisture. The meter was calibrated with distilled water (according to the User's Manual) at the beginning of each sampling event/location.
- **Compaction:** Penetration resistance expressed in pounds per square inch was measured using a DICKEY-John Soil Compaction Tester. The first season measurements were taken by measuring the depth when the penetrometer reached 300 PSI. We adjusted the protocol the second year to reflect the root zone where compaction changes would be occurring. Measurements were then taken at 3 inches and 6 inches to estimate effects of cover crop on shallow soil compaction. Five subsamples were collected to calculate average PSI resistance at both depths.
- **Soil Temperature:** Soil temperature in degrees Fahrenheit was measured using Hanna Instruments 145-01 digital soil thermometers. Measurements were taken at 2

inches and 4.5 inches. Four to five subsamples per plot were combined to calculate average soil temperatures at each depth.

- **Photo Documentation:** Photos of all plots were taken to give visual representation both at the whole plot scale and looking straight down.

**Data Analysis**

Data collected was entered and graphed in Microsoft Excel and double checked to maintain accuracy. Not all data could be analyzed statistically in a valid manner due to the nature of this project as a demonstration primarily. However, there was some data that was replicated enough to perform statistical procedures. All data was first checked to meet the assumptions of normality, at least to a reasonable extent (via histograms and box plots for skewedness and outliers). All analysis was conducted with JMP (v. 12, SAS Corp.). Data that was not normal was tested to see if a transformation would make the dataset more normal (for example log transformation). Across years, 2-way ANOVAs were calculated using a general linear model (GLM), with site year (2014/15 v. 2015/16) and treatment seeding mix - treatment as the factors, as well as a calculation of the interaction of the two factors. GLM was used because there were an unequal number of replications between the two years and an uneven number of some plot replications when establishment was poor. Since there was more successful replication the second year of the project, separate 2-way ANOVAs were calculated using GLM, with seeding mix treatment and seeding replication (time / method) as factors, as well as a calculation of the interaction of the two factors. In some cases, missing values for particular treatment-seeding replications meant that instead 1-way ANOVAs analyzing treatments by (some) seeding replications and all seeding mix treatments combined to compare seeding replications (time / method) were run. Tukey-Kramer HSD was calculated to identify significant differences between treatments. Threshold alpha levels were examined at both 0.05 and 0.1 for significant difference. In one case where normal distribution could not be met (Spring Temp 2016, 2 inch), a similar non-paramentric test - Kruskal Wallace with Wilcoxon comparisons, was used in place of an ANOVA. Simple correlations were calculated in Excel to compare soil properties, with a best fit linear regression of a data graph and a corresponding $R^2$ value.

**Findings**

Data points for all plots (averages where multiple subsamples were collected) is located in Appendix E. The most striking results are explained in this section. Addition data and graphs can also be found in the Appendices.

**Soybean Fields**

In the first year, the soybean trial was unsuccessful. There was very little germination in the fall, and the plots were plowed under before any assessment could happen in the spring. In the second year there was some success with interseeding. We found that earlier seeding dates (mid-august) are an option, and the cover crop does not become competitive or interfere with harvest. Moisture at the time of planting (and following planting) seems the most critical. Beans planted on thirty inch centers seem more conducive to interseeding as they allow easier access of planting equipment and let more light penetrate the canopy. We did have some success with beans planted on fifteen inch centers. In another study, drilled beans (on 7-8-inch centers) did have reasonable success with an interseeded winter rye cover crop. One complication with interseeded soybeans is that as a grain crop, there is a fair amount of residue after harvest. While we did manage to see the cover crop establish, it is unclear if the cover crop provided substantial *additional* soil coverage that was significant over the residue itself. Table 5 below shows the high percent cover readings we recorded. Again, much of this was from the crop residue, not the growing cover crop. The photo at right shows a typical scenario in the soybean fields.

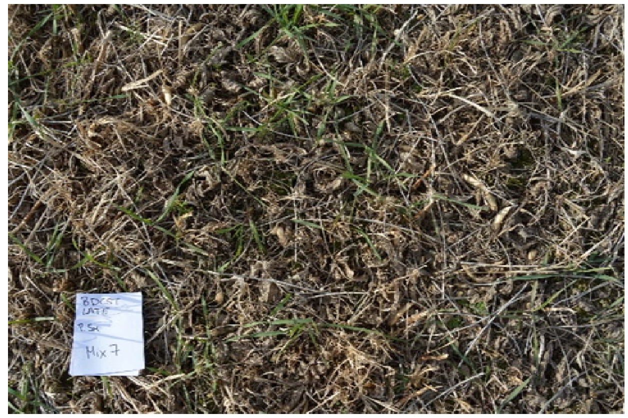
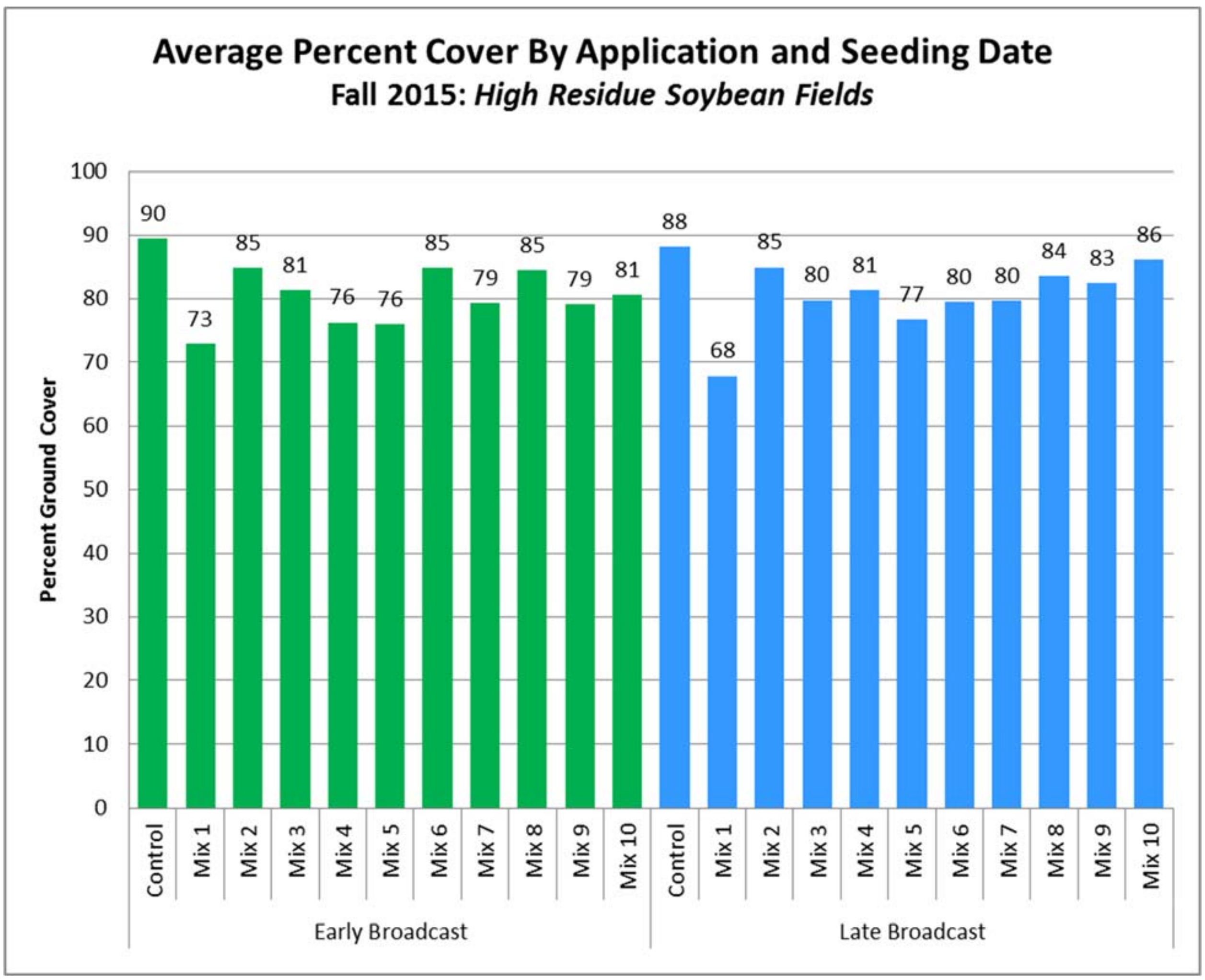


**Table 5. Percent cover measurements from soybean field plots in Fall 2015. Most of this was from the residue left from harvesting the soybean crop.**



**Corn Silage Fields**

In both years the corn fields yielded field data for summary reports. The data below was all collected from cover crop plots planted into corn silage fields.

**Percent Cover**

Percent cover is an indirect way to measure soil conservation, through resistance to erosion. Percent cover in this context measures both the cover crop and also residue left from the cash crop (i.e. corn stalks). In the case that the field is no-tilled the percent of residue generally increases. Also, there were some cases where weed pressure may have skewed the results of soil coverage. Nevertheless, a general trend emerged that drilling the cover crop was much more consistent and successful than broadcasting.

**Year 1 - Fall 2014**

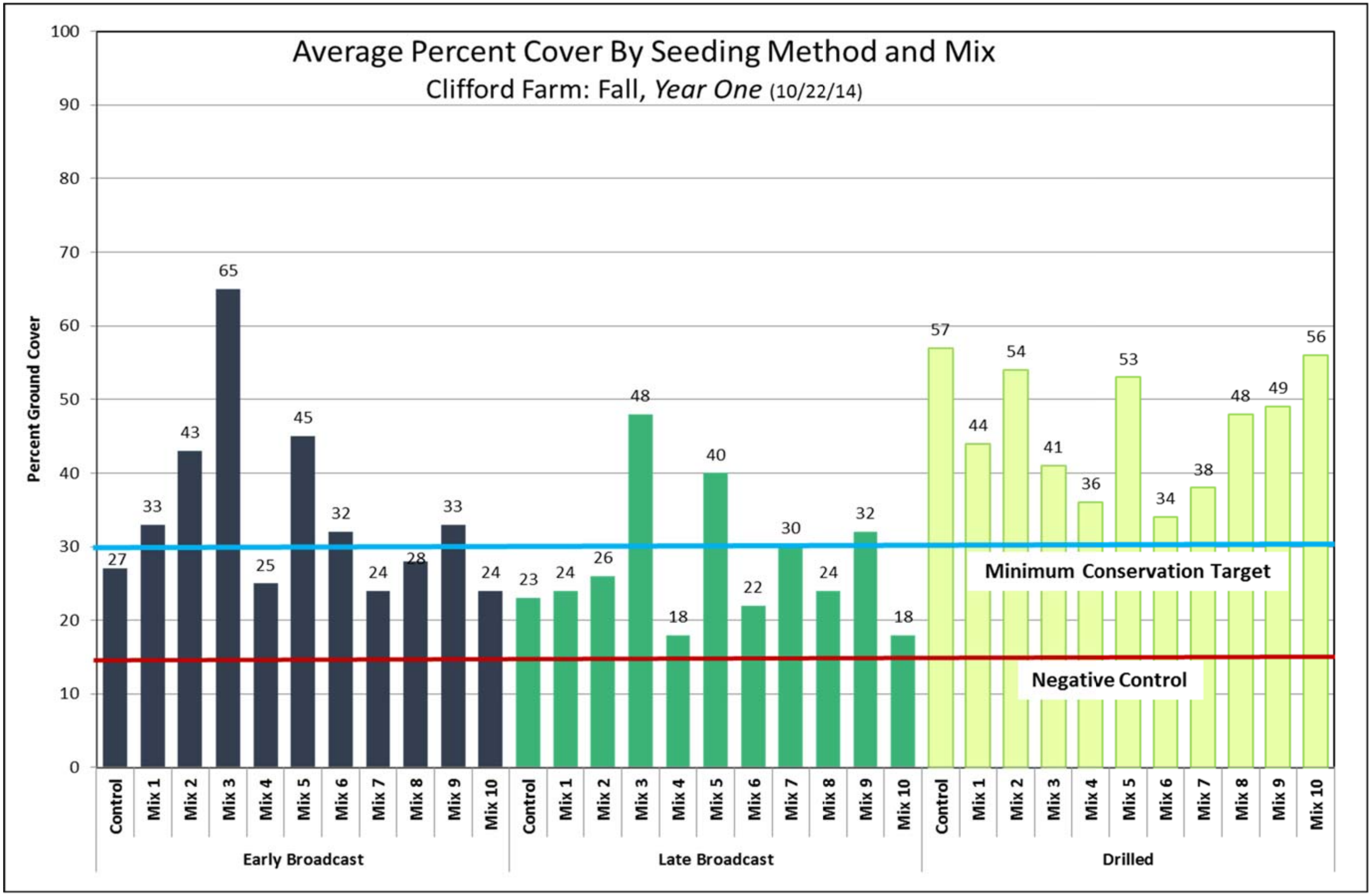
In the first fall broadcasting cover crops was only successful at one farm location, the Farm Three site. At that location, measurements in October showed that drilled cover crops had greater percent cover than either early or late broadcast in all cases except for Mix 3. For Mix 3, early broadcasting actually resulted in greater coverage, followed by late broadcast. Mix 5 also produced good soil coverage in early and late broadcast plots. Both of these mixes contained annual ryegrass. All drilled plots had more percent cover than the conservation target of 30%, which was not the case in either early or late broadcast plots. Mix 2, 5 and 10 had near equivalent cover to the 'control' in the drilled plots at the Farm Three site. See Figure 3, below.

Additional measurements were taken in November on drilled plots at four sites (Farm One, Two, Three and Five). The effects of manure were also compared the first year when drilled. For all mixes manured plots had greater percent cover (between 3 and 19 %), see Figure 4 below. Another realization that occurred during this first date of sampling was that percent cover changed disproportionately from October to November. Specifically, drilled Mix 9 and 10 had slightly lower percent cover than the drilled 'control' in October, but had greater percent cover than the control in November, see Figure 5 below.

**Year 1 - Spring 2015**

These fall results translated to the spring but not for every mix equivalently. In late April, measurements of percent cover at the Farm Three site revealed only Mix 3 had greater than 30% residue in the early broadcast plot (dead residue), while only Mix 5 and 9 had greater than 30% residue in the late broadcast plot. The drilled 'control' outperformed all other mixes drilled or broadcast (70% cover), followed closely by Mix 10 (66% cover), while Mix 9, 4 and 6 also had greater than 30% residue. From these results Mix 9 and 10 proved the most promising, see Figure 6.

Figure 3 . Average percent ground cover for each cover crop plot, by plant (both manured and non-manured treatments combined) at Farm Three location only, October 22, 2014. The negative control is residue from just the corn silage residue (15%); the minimum conservation target is for soil conservation purposes (30%).



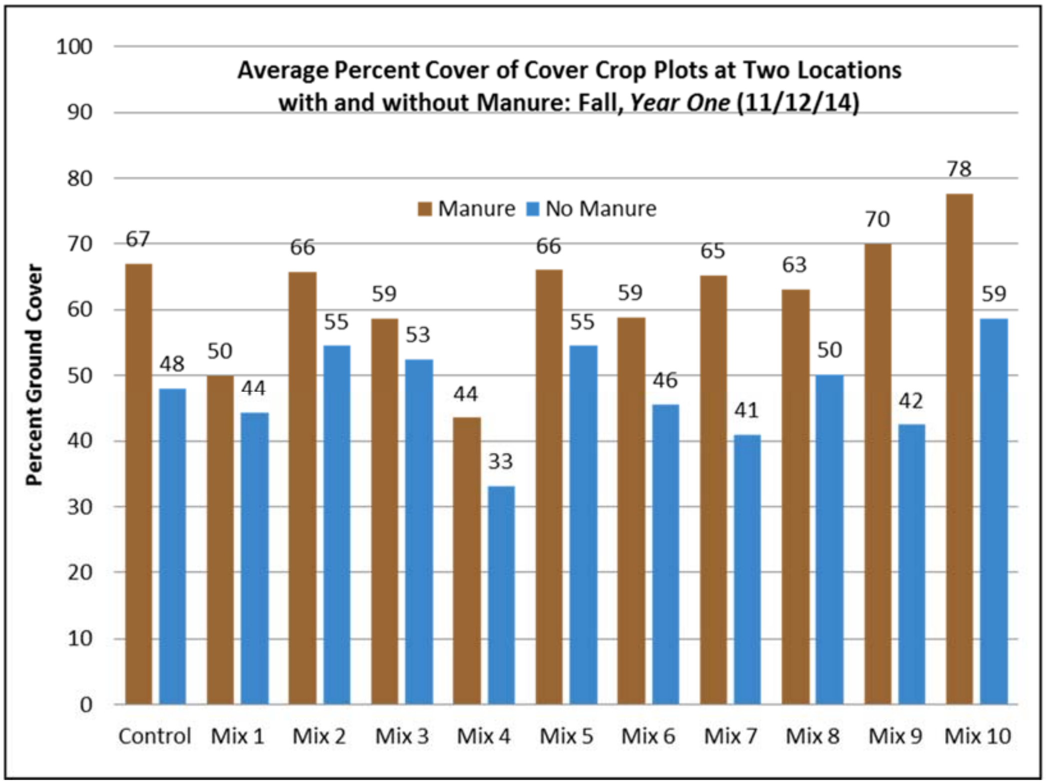



**Figure 4.** Average percent ground cover for *drilled cover crop plots,* showing differences in cover between manured (Farm Two and Three locations) and non-manured plots (Farm One and Three locations), all measured on November 12, 2014.

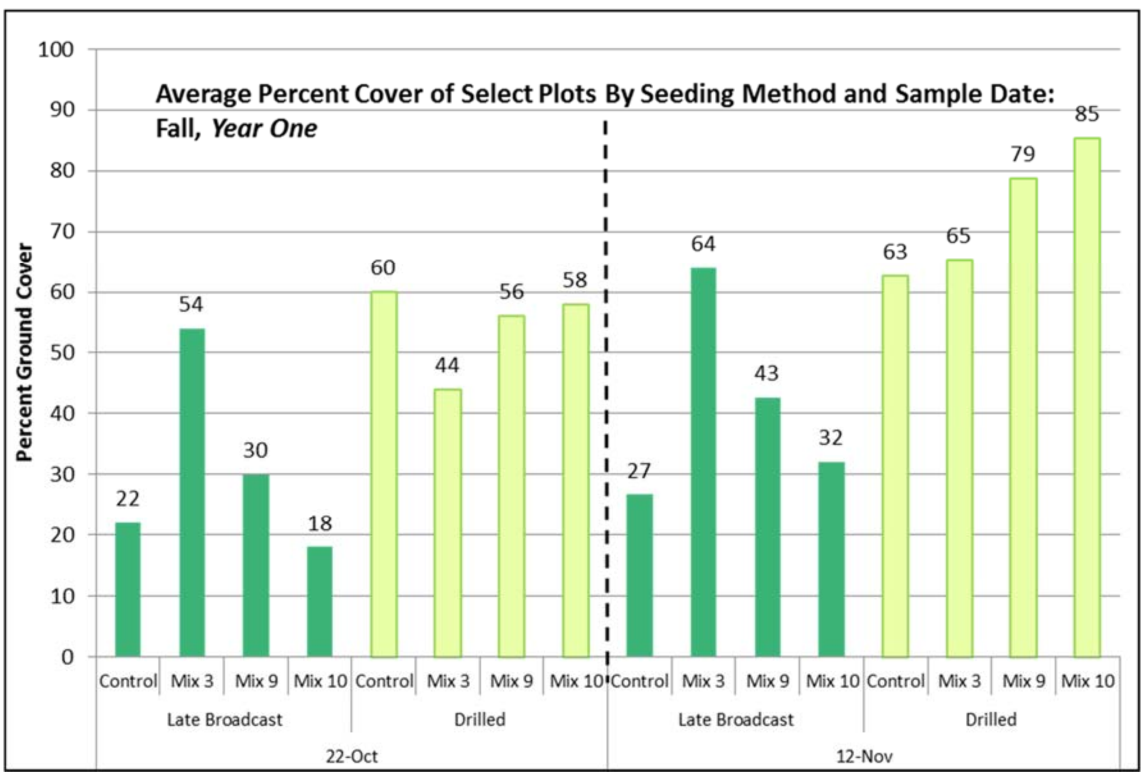
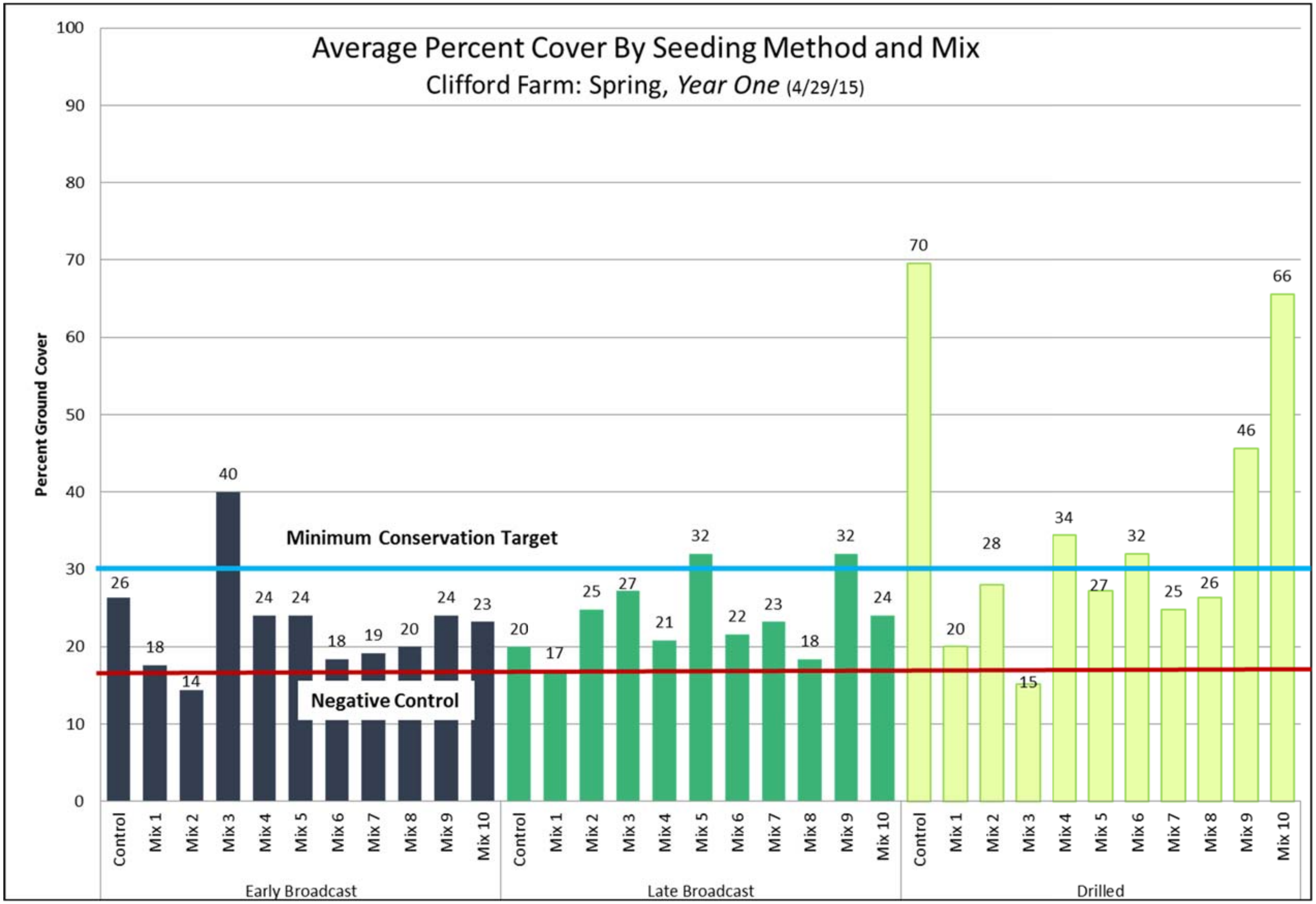



**Figure 5.** Average percent cover of select cover crop mixes comparing October 22, 2014 and November 12, 2014, measured at the Farm Three location, illustrating the effect of sampling date on the results.

**Figure 6.** Average percent ground cover for each cover crop plot, by plant (both manured and non-manured treatments combined) at Farm Three location only, April 29, 2015. The negative control is residue from just the corn silage residue (16%); the minimum conservation target is for soil conservation purposes (30%).



**Year 2 - Fall 2015**

The second year of the demonstration there was more success in establishment of cover crops at multiple locations and seeding dates/methods. This was probably due in part to potential conflicts with herbicide usage which may have suppressed cover crop growth the first year. There were also differences in weather, namely a very mild fall/winter in the second season. The second fall percent cover was only measured once at each location. There was a significant difference in seeding replication (alpha 0.05) but not seed treatment or the interaction term (alpha 0.1; model excluded late broadcast). Interestingly, drilled and early broadcast plots had slightly less percent cover than late broadcast plots, and the means were significantly different, see Figure 7, below. This is clearly different than the results from the first year, but replication was not even across all seeding methods, which complicates the analysis. However, as seen in the first year, drilled plots may catch up with and then surpass broadcast plots. In fact, this was seen visually though not measured in fall of the second year. The second year we had unseasonably warm temperatures even in late December, allowing drilled plots to catch up, which translated to percent cover in the spring.

**Year 2 - Spring 2016**

In the spring of the final year percent cover was significantly different in the drilled plots than in the broadcast plots (alpha 0.05), see Figure 8 below. Additionally, there was a significant difference in mixes, as well as the interaction. This interaction term was because drilled plots had significant differences by mix. Mix 2, 4, 6, 7, 8, 9 and 10 all had percent cover averages equivalent to the 'control'. Mix 1 had the lowest percent cover average, see Figure 9 below.

**Figure 7.** Average percent ground cover across all corn silage farm locations. Measurements were taken in mid-October to early November 2015 at each site once. A one-way ANOVA (GLM, Tukey HSD means comparisons) showed that there was a difference in percent cover by seeding method (alpha 0.05); different letters designate differences in means. Differences in mixes were not statistically significant.

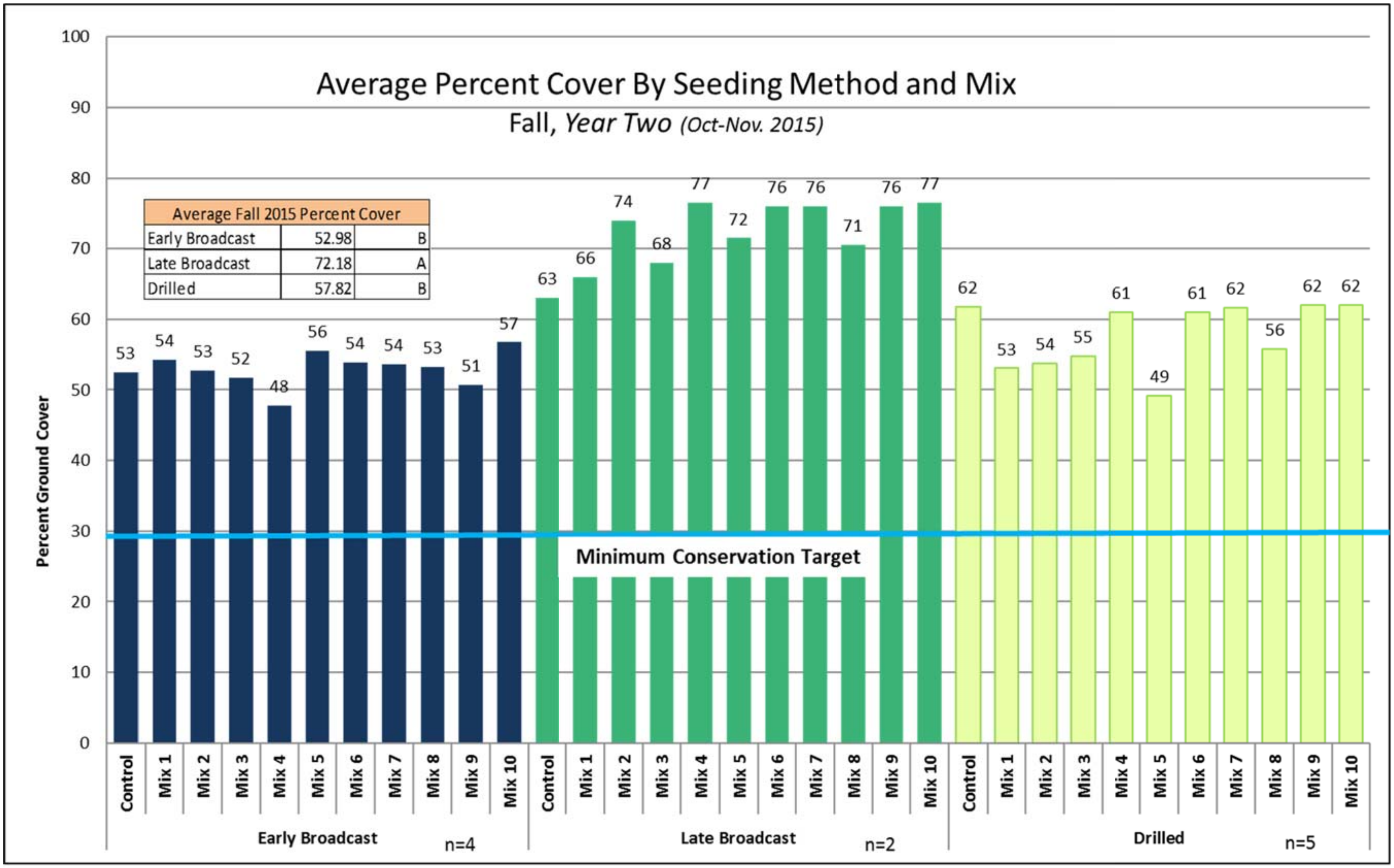
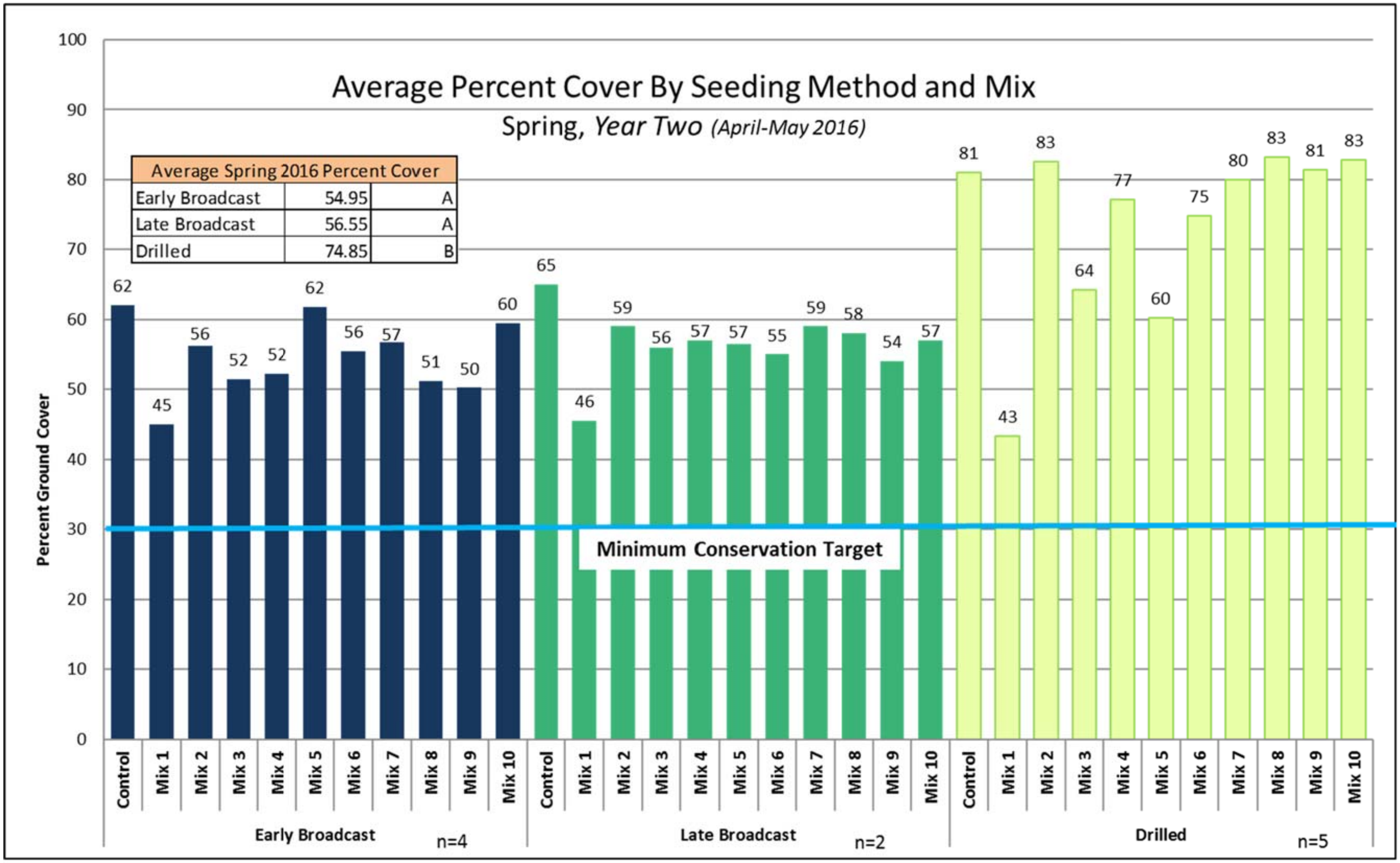


Figure 8. Average percent ground cover across all corn silage farm locations. Measurements were taken in mid-April to early May 2016 at each site once. A one-way ANOVA (GLM, Tukey HSD means comparisons) showed that there was a difference in percent cover by seeding method (alpha 0.05); different letters designate differences in means. Differences in mixes were only statistically significant for drilled cover crops, described in Figure 7.



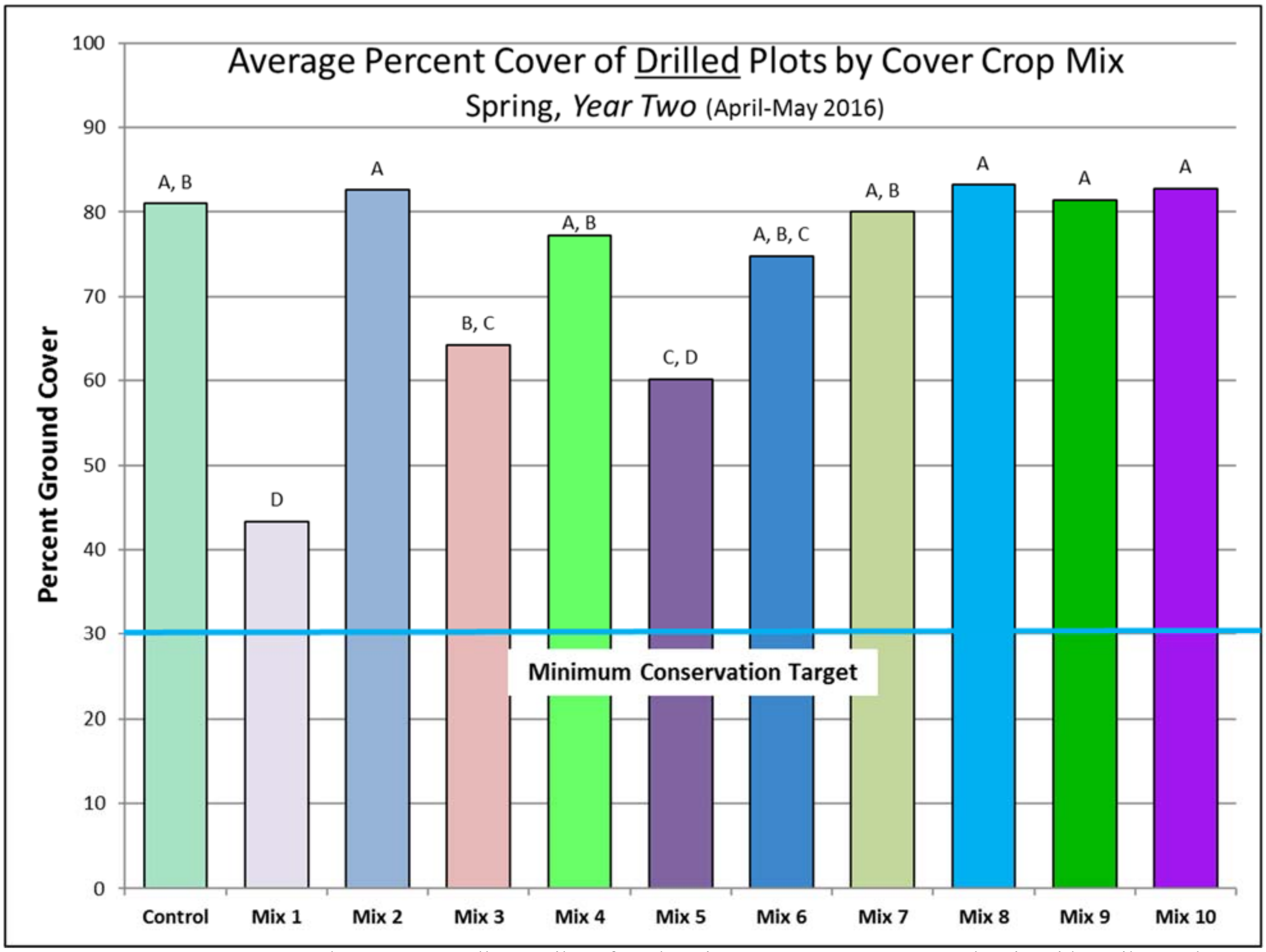



**Figure 9.** Average percent ground cover across all corn silage farm locations. Measurements were taken in mid-April to early May 2016 at each site once. A one-way ANOVA (GLM, Tukey HSD means comparisons) showed that there was a difference in percent cover by cover crop mix (alpha 0.05); different letters designate differences in means. Differences in mixes were only statistically significant for drilled cover crops.

### Two Year Summary - No-Till Drill Plots

The following analysis only includes the mixes that stayed the same between the two years. Statistical analysis of fall drilled percent cover did not yield any significant differences by mix or site year when comparing drilled plots (alpha 0.1, 2014 n=4, 2015 n=5). There were statistically significant differences in spring drilled cover crop by mix, site year and the interaction term (alpha 0.5, 2015 n=3, 2016 n=5). Specifically, spring 2016 had greater percent cover across all mixes in comparison to spring 2015. Mix 1 had the lowest percent cover the second year, which is unsurprising since it is a winter killed cover crop. The other two mixes with lower percent cover, Mix 3 and 5, were winter killed the first year. However, the annual ryegrass in these mixes survived the second winter. Forage turnip and radish also survived the second winter. Comparing the same mix across the two years, there was a significant difference in years for all mixes except Mix 1, see Figure 10 below. It is important to note that the control had a higher average percent cover the second year.

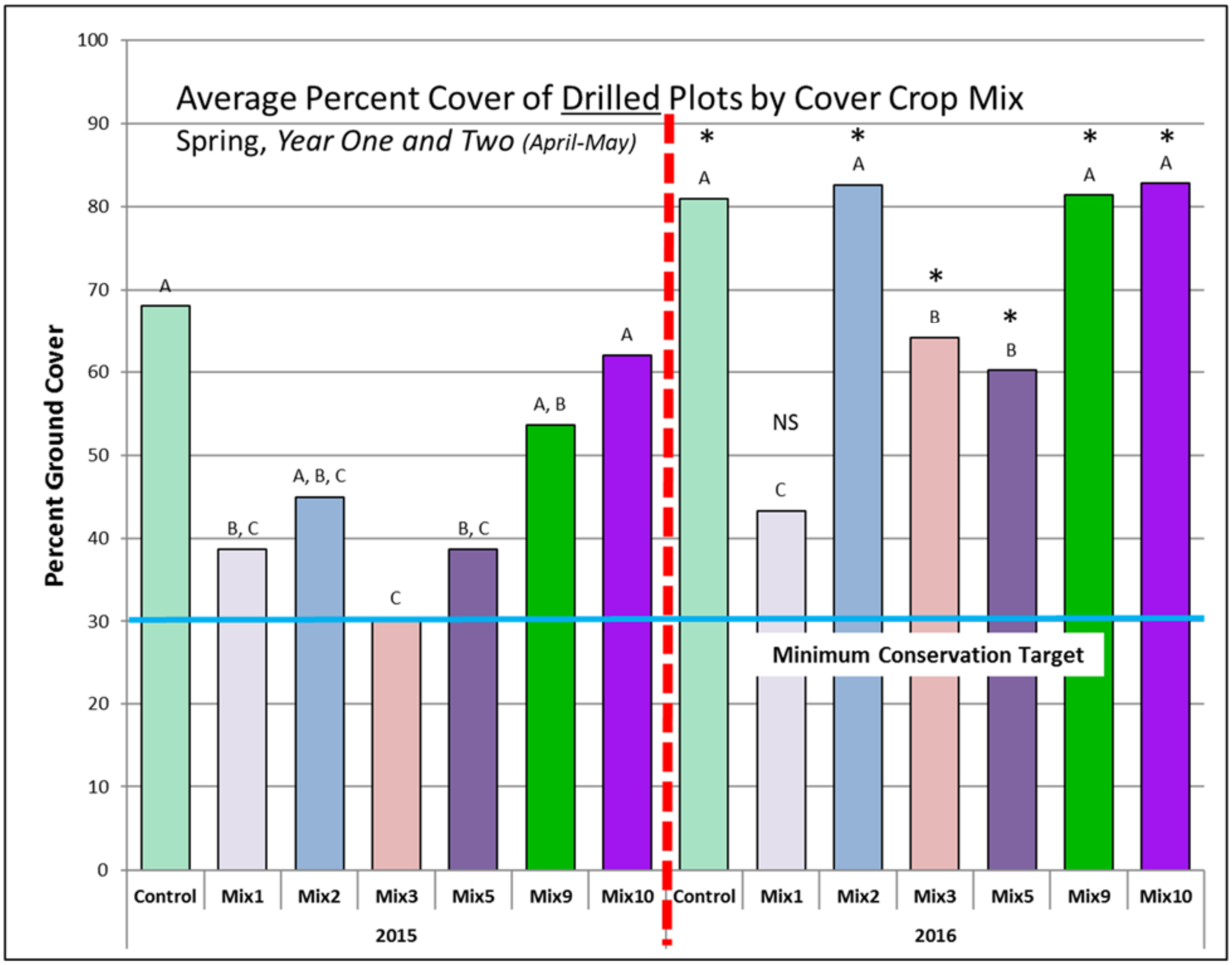



**Figure 10.** Average percent ground cover across all corn silage farm locations comparing spring 2015 to spring 2016. Measurements were taken in mid-April to early May 2016 at each site once. There was a significant difference in percent cover by cover crop mix, within a given year (alpha 0.05); different letters designate differences in means. Significant differences in a mix across both years are denoted with a star (*) (or NS for not significant).

For the mixes that changed (Mix 4, 6, 6, and 8), comparisons were made between site year one (2014/15) and site year two (2015/16). In the fall site year two had greater percent ground cover across mixes, but this number was only statistically significant for Mix 4. In the spring however, site year two had significant differences for all of the mixes that changed. However, there is a confounding factor that while we changed the mixes, there was also a change in the weather. Notably, this is seen by the fact that the 'control' plot has significantly more cover the second spring.

### Biomass Production and Nutrient Uptake

Biomass production and nutrient uptake were related in that the forage analysis was used to determine the pounds of nitrogen, phosphorus and potassium taken up by the cover crop on an acre basis.

**Year 1 - Fall 2014**

Comparing just the drilled crops at the Farm Three location, where biomass measures were most accurate, biomass was generally greater in manured plots than in non-manured plots, and this trend continued when using biomass production to estimate phosphorus uptake, see Figures 11 & 12 below. Mix 10 showed the most promise, and had the same or greater biomass production and phosphorus uptake compared to the 'control'. The percent of nutrient content in cover crop samples were generally greater in manured plots than in non-manured plots at the Farm Three farm. The percent of nitrogen content was in the range of 2-5%, the percent of phosphorus content was in the range of 0.4-.0.7% and the percent of potassium content was in the range of 2-5 %.

**Year 1 - Spring 2015**

Not all mixes have spring samples, since not all the mixes were winter hardy, particularly the first year. In the spring of the first year Mix 9 and 10 produced the most biomass, see Figures 13 & 14. One very interesting result was that sampling date can effect which mix seems to produce the most biomass. Which means that determining termination rate may be somewhat mix dependent. In the case of Mix 10 in particular, 10 days of growth made over threefold difference in biomass production. Mixes 2,4,6,8 contained a grass/grain other than winter rye and did not perform as well in the spring. Figure 15 shows the increase in biomass in sampling dates only eleven (11) days apart in May 2015.

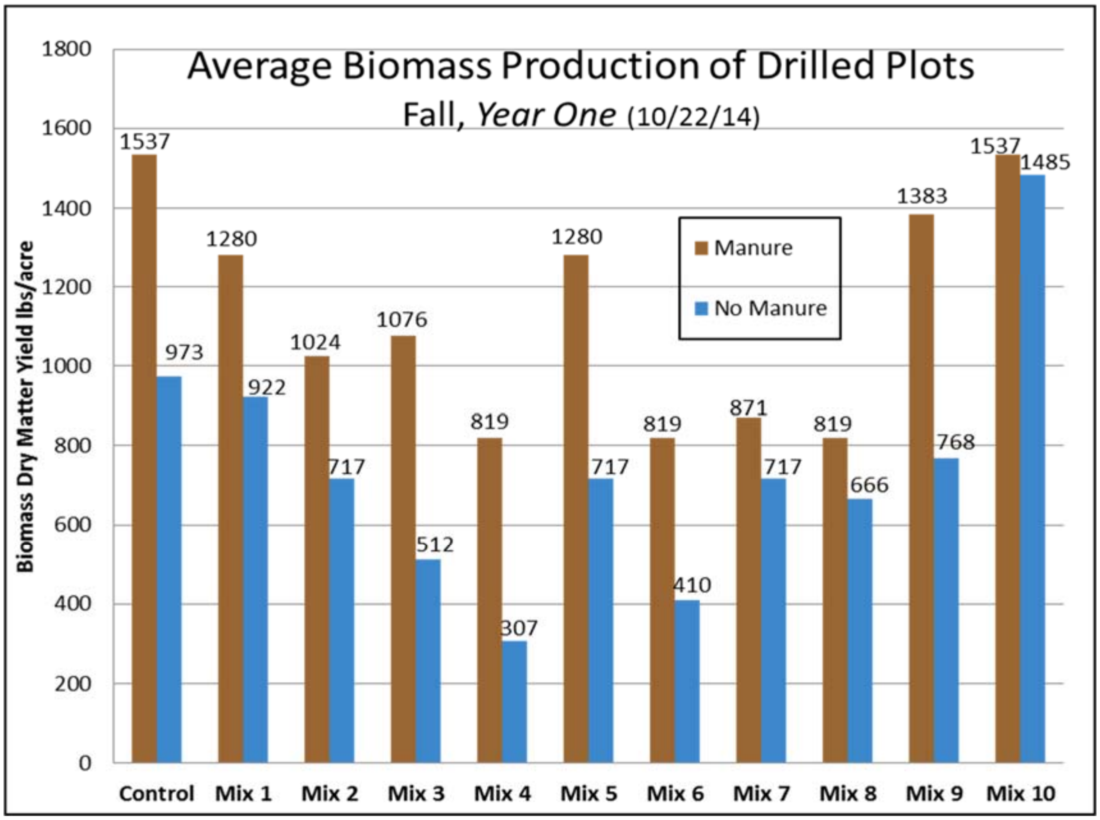



**Figure 11.** The average biomass production of cover crop mixes in drilled plots in dry matter lbs/acre, sampled October 22, 2014.

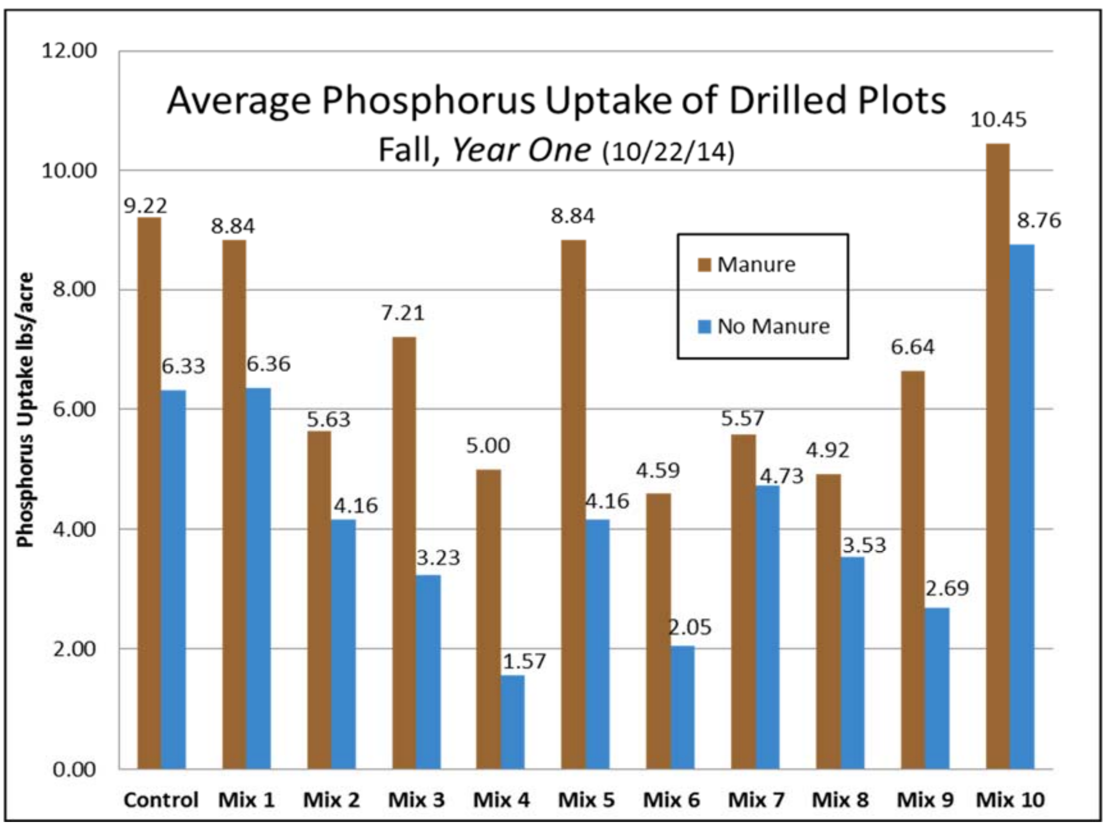



**Figure 12.** The average phosphorus content of cover crop mixes in lbs/acre, calculated with biomass, sampled October 22, 2014.

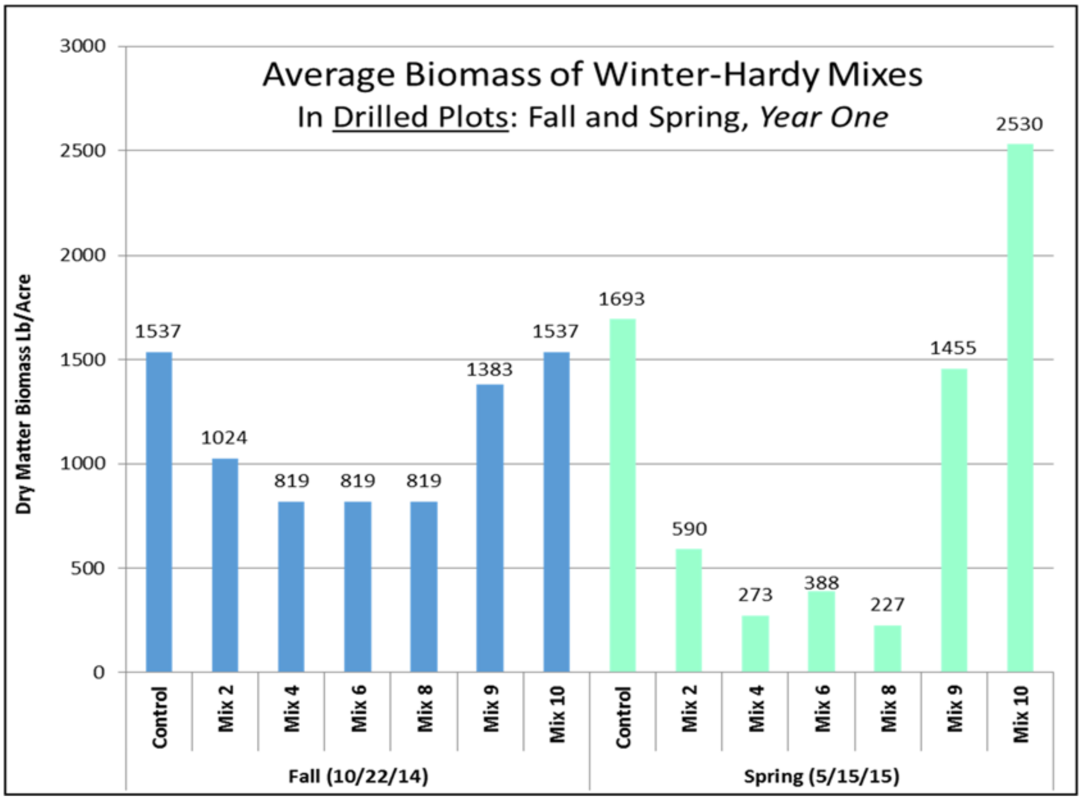



**Figure 13.** Average dry matter biomass in lbs/acre of drilled, manured cover crop plots in fall and spring of year one.

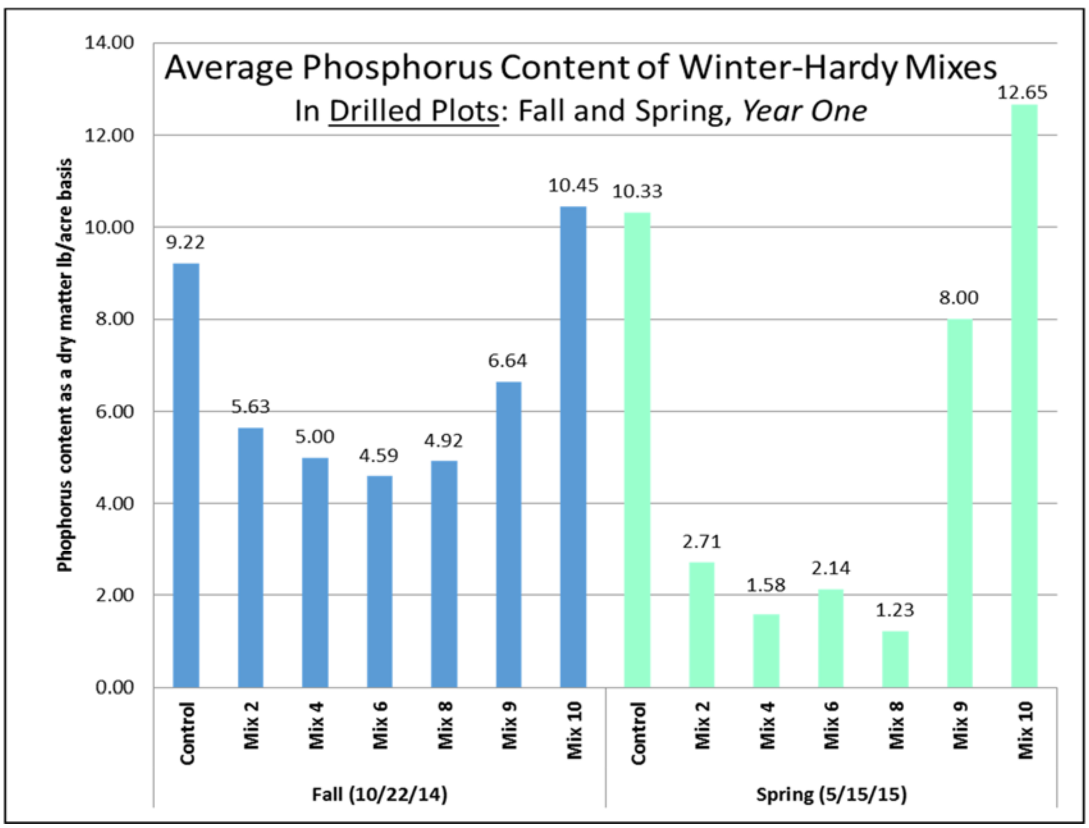



**Figure 14.** Average phosphorus content in lbs/acre of drilled, manured cover crop plots in fall and spring of year one.

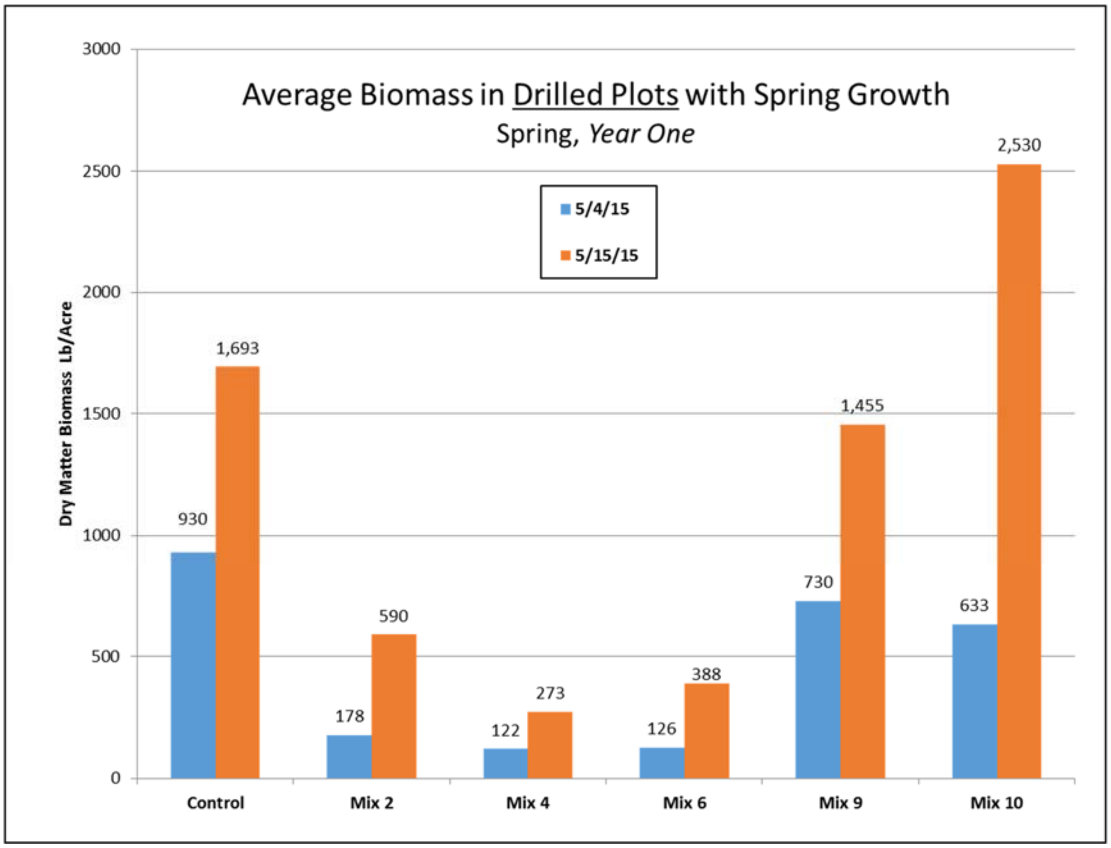



**Figure 15.** Average dry matter biomass in lbs/acre of cover crop mixes in drilled, manured plots at two sampling times: May 4, 2015 and May 15, 2015.

### Year 2 - Fall 2015

Biomass and P uptake were not significantly different by seeding mix or seeding method (alpha 0.1). With greater establishment over multiple locations and differences in weather, the mixes didn't have as much difference between them. However, the 'control' still produced the most biomass, while Mix 4, 7 9 and 10 all performed well. Mix 4 actually had slightly greater P uptake per acre, followed by the 'control', Mix 6 and Mix 7. However, N and K uptake was different by seeding method (at 0.1 alpha only) and specifically early broadcast was greater than drilled. It should be noted however that spotty broadcast samples meant that not every plot on every location was sampled. Overall, the percent of nitrogen content was in the range of 3-6%, the percent of phosphorus content was in the range of 0.4-.0.6% and the percent of potassium content was in the range of 2-4 %.

### Year 2 - Spring 2016

Results were significantly different by seeding method but not seed mix for biomass and nutrient uptake. Specifically, drilled plots had greater biomass, while early and late broadcast were statistically similar though early broadcast produced more. Drilled plots had greater nutrient uptake (N, P and K) than late broadcast, but were statistically similar to early broadcast plots, see Table 6. Unlike the first year of this project, the only mix that did not have any species overwinter was Mix 1(oat/pea/radish). The annual ryegrass, forage turnip and rapeseed all overwintered. Winter peas overwintered but did not produce much biomass. Some crimson clover was observed in small amounts. This was clearly an atypical winter. The species that was most prevalent for each mix varied by seeding method. For example, Mix 10 was dominated by rapeseed in broadcast plots, but also contained winter rye (and clover) in drilled plots. The pictures below illustrate how species composition was impacted by timing of planting. Mix 7 had the greatest biomass for early broadcast, while Mix 10 had the greatest biomass for late broadcast and drilled plots. Mix 8 and 9 also produced equivalent amounts of biomass. Comparison of fall and spring biomass and phosphorus uptake can be seen in Figure 16 & 17. All cover crop plots had some survival the second spring, except for Mix 1 which was completely winter killed. This was very different than the first year. There wasn't enough replication the first year to perform statistical analysis across both years.


**Table 6.** Average cover crop dry matter biomass and nutrient uptake in lbs/acre by seeding method in Spring 2016 across all farms (sampled once each mid-April to early May). Different letters represent significant differences in means.

| Average Cover Crop Biomass and Nutrient Uptake Lb/Acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Dry Matter | | Nitrogen | | Phosphorus | | Potassium | |
| Early Broadcast | 568 | B | 19.11 | A, B | 2.69 | A | 15.13 | A, B |
| Late Broadcast | 436 | B | 13.54 | B | 1.39 | B | 10.37 | B |
| Drilled | 748 | A | 20.61 | A | 3.06 | A | 18.27 | A |

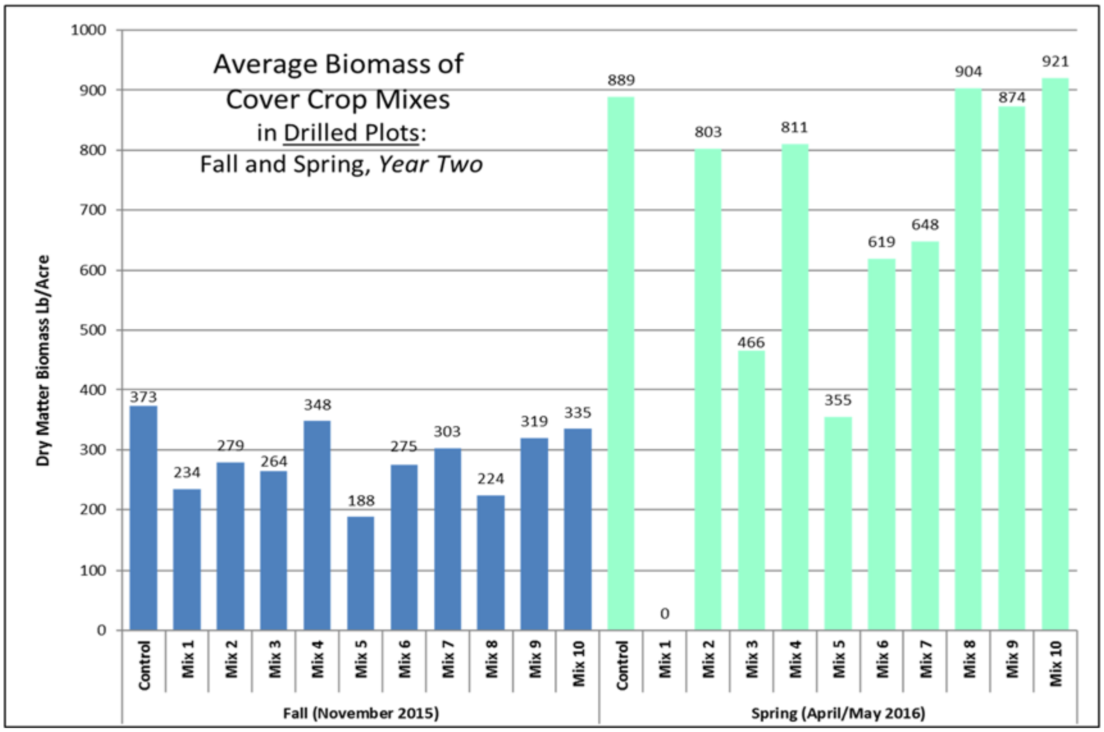



**Figure 16.** Average dry matter biomass in lbs/acre of drilled cover crop plots in fall and spring of year two.

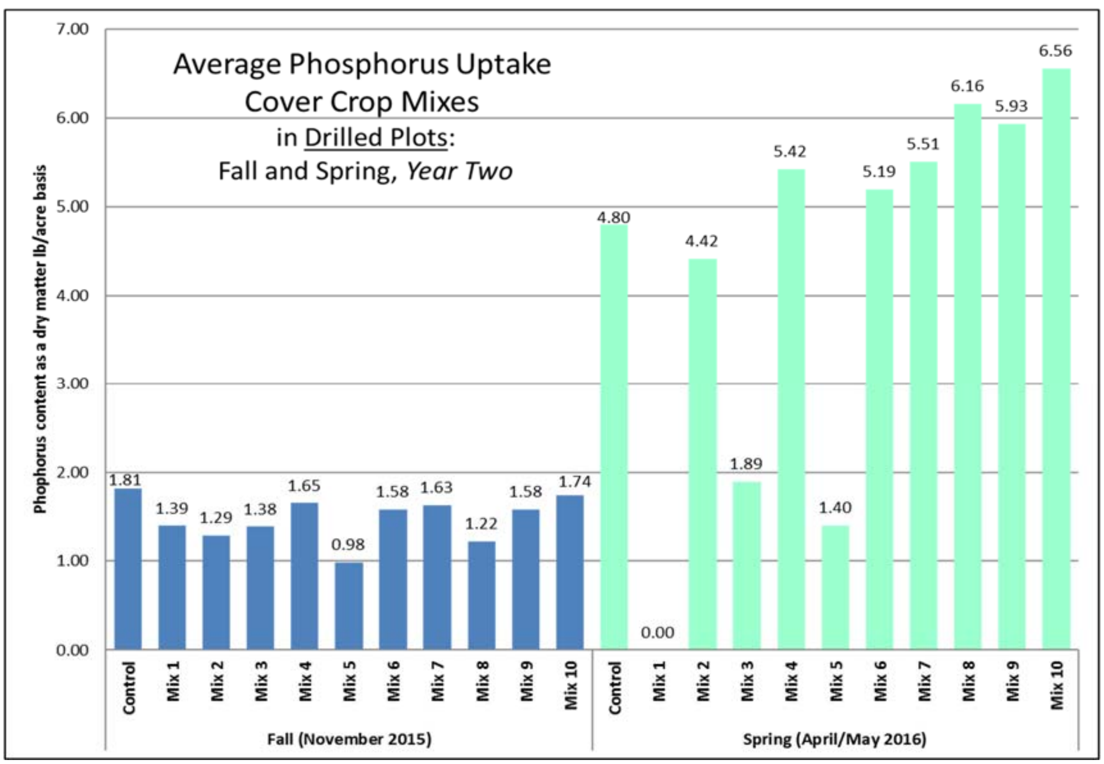



**Figure 17.** Average phosphorus content in lbs/acre of drilled cover crop plots in fall and spring of year two.

### Cover Crop Height

Cover height was measured in conjunction with biomass sampling. At each quadrat a representative height was recorded. We did not do any statistical analysis on height as it seemed to be most related to either species (ryegrass vs. cereal grain) and biomass. It did not represent any direct benefit or detriment in the parameters being analyzed for this project. However, we do see issues at termination with an excessively tall cover crop in a no-till situation when the cover crop doesn't 'lie down' after termination and creates shading and low light situations for the next crop. This, however, was not a part of this project. (See Appendix E for actual).

### Soil Conditions

Moisture measurements were taken both springs for drilled plots and was significantly different by site year. Moisture was not significantly different by seeding mix or by the interaction of seeding mix and site year. Therefore, overall weather conditions affected soil moisture to a much greater extent than did cover crop mix in drilled plots over the two years. The first year had a higher average moisture content, while the second year had more variability in moisture content. Moisture content in spring 2016 was statistically different in drilled plots than in early or late broadcast plots (one sampling date). Soil temperature at both 2 and 4.5 inches was significantly different by seeding method as well, with early broadcast plots being warmer than either late broadcast or drilled plots.

**Table 7.** Average soil moisture at 12 cm (or 4.72 inches) depth and temperature (Fahrenheit) at 2 and 4.5 inch depths in cover crop plots in the spring of the second year (April-May 2016) sampled once at each location. Means with different letters are statically different (alpha 0.05). Differences between mixes were not statistically significant.

| Average Moisture @ 12 cm | | |
|---|---|---|
| Early Broadcast | 22.9 | B |
| Late Broadcast | 20.4 | B |
| Drilled | 27.1 | A |

| Average Temp (F) @ 2 Inches | | |
|---|---|---|
| Early Broadcast | 57.1 | A |
| Late Broadcast | 54.9 | B |
| Drilled | 52.0 | B |

| Average Temp (F) @ 4.5 Inches | | |
|---|---|---|
| Early Broadcast | 51.6 | A |
| Late Broadcast | 49.7 | B |
| Drilled | 47.7 | B |

It would make sense that plots with more water might be slower to warm up. However, there was only little to weak correlation between soil moisture and soil temperature (at 2 inch depth $R^2$= 0.36, at 4.5 inch depth $R^2 = 0.4$). Cover crop biomass and soil moisture were not correlated, neither was percent cover or cover crop biomass and soil temperature. Due to the demonstration nature of these plots, as opposed to replicated blocks, there may be some field properties that are confounding results of mixes in this case. More graphs and data are located in Appendix F.
Soil compaction was significantly different by seeding method at 0-3 inches. Specifically, late broadcast plots had greater soil compaction, which probably related to less root growth (observed visually not quantified). Soil compaction was not significantly different by seeding replication or treatment at the lower measurement of 3-6 inches.

**Table 8.** Average maximum PSI as a measure of soil compaction at 0 to 3 inch depth in cover crop plots in the spring of the second year (April-May 2016) sampled once at each location. Means with different letters are statically different (alpha 0.05). Differences between mixes were not statistically significant.

| Average Max PSI 0-3 Inches | | |
|---|---|---|
| Early Broadcast | 138 | B |
| Late Broadcast | 185 | A |
| Drilled | 142 | B |

**Conclusions and Recommendations**

Overall the project was a success. All of our deliverables were accomplished and this project was a big catalyst in the cover crop conversation and adoption with Chittenden and Addison County field crop producers. The sheer act of planting multiple demonstration projects focused on cover crops throughout the Lake Champlain basin was probably the most impactful. Both years of the project we were able to identify willing producers to partner with us on the project and donate their land, time and equipment. We were able to plant our 10 mixes at all the farms each year and collected valuable data. Another success was the opportunity this project allowed us for field days, workshops, and even videotaping of television segments. It was well-received by farmers, ag service providers, and agency staff who provide technical assistance.

While the original project included planting mixes in conjunction with wheat or other cereal grain production, we felt that would be less informative overall. We know that these mixes will all perform well planted in August in conventional production, and frost seeding clover into organic fields also is successful. Another CIG project, "Soil Health Demonstration Farm on Clay Soil" also looked at these scenarios during the same project timeframe.

A major challenge was reliable and consistent successful establishment of our interseeded cover crop plots. Some of the factors that make this challenging are: timing, weather, canopy of cash crop, herbicide program, and harvest conditions. While not all interseeded plots established successfully, that was one of the goals of this project to evaluate and demonstrate 'real life' conditions and make recommendations accordingly. Confronting these challenges in our demonstration plots has allowed us to identify these factors and advise farmers who are interested in this method of cover crop establishment.

The project demonstrated that utilization of 3-way mixes can be an effective way to add more biodiversity to cover crops and capture multi-species benefits. Farmers and agronomy service providers were able to observe these mixes hands-on, and decide for themselves how the mixes could be adapted to their operation. We generated excitement about cover cropping in general as well as exploring how cover crop systems can be fine-tuned to meet the needs of no-till farming. This project helped demonstrate how cover cropping can be successful on different soil types.

**Broadcast Seeding vs. No-Till Drill Planting**

There is increasing discussion of using multi-species cover crop tools as a way to optimize the soil health and conservation benefits of cover cropping. This demonstration project supports that this practice can be beneficial, however getting good establishment of the cover crop is crucial to see the 'fruit' of these practices. There are two factors that are particularly influential in cover crop success: seed-soil contact and soil moisture. The spring success of the cover crop is also dependent on winter conditions in addition to fall establishment. Farmers cannot predict or control weather, but they need to aware of the drawbacks and advantages of their cover crop application method and species selection on success.

Farmers growing corn silage may find that their biggest challenge is finding adequate timing after corn silage harvest. For this reason, farmers in the area have been exploring broadcast seeding into a standing corn crop. However, the most striking result for our project was not the difference between mixes but the difference between broadcast inter-seeding and drilling. The first year we had four farms with corn silage in our trials, and of those broadcasting was only moderately successful on one farm and failed on the other three. In the second year we had five corn silage farms in our trial; on one farm it was a failure, on another it was minimally successful and on the three others it was moderately successful. There was also variation in specific mix performance broadcasting by year. Adjustments to increase success of establishment of broadcasting include being more diligent in making sure *herbicide applications* were compatible with inter-seeding. However, lack of seed-soil contact, year to year season variation in summer weather, along with shading, uneven broadcasting and traffic damage may all contribute to uneven stands when broadcasting. Time of most successful broadcast (early v. late) differed between the two years. Broadcasting may be our beloved 'problem child'; teasing out under what circumstances it is actually appropriate needs consideration.

Drilling clearly provided more consistency but has the drawback that it requires another field pass and there is a lag before the cover crop reaches its potential in the fall. Still, drilled plots will probably catch up with and then surpass broadcast plots under most conditions. It is important to note that in both fall and spring, the day of measurement may affect the conclusions reached for this reason. In the spring, drilled cover crops may 'take off' and must be monitored in the spring so that they do not become unmanageable.

Other methods of planting should also be explored in relation to the 'best mixes'. Using an inter-seeder may address a number of the concerns with broadcasting, though it will not solve the shading or traffic issue. Developing a whole system approach where the cash crop timing and cover crop timing are in sync is also of importance in this decision. If farmers are not no-tilling, broadcasting and then incorporating is an option. However, in order to maximize conservation benefits and minimize soil disturbance, that option was not included in this demonstration.
It should also be noted that we used the same seeding rate broadcasting as well as drilling to control that factor. However, under NRCS EQIP contract, a farmer is required to apply broadcast seed at a higher rate in attempt to offset challenges that were evident in this demonstration. However, density may not make up for these challenges if there are more extreme soil conditions, for example if it is a particularly dry year.

**'Best' Mixes Described**

The 'best' mix may be relative to the benefits and goals a farmer is trying to achieve. Determining the right soil health improving mixes for a farm will also depend on the desired termination timing/method. Winter killed mixes, not surprisingly, did not provide as much spring cover as winter hardy mixes. However, the first year at least, Mix 3 did establish well enough to leave decomposing residue in the spring that did cover the soil. The ideal mix for broadcasting may be different than for drilling.

Rainfall and temperature may make the search for an 'ideal' mix confusing. Annual ryegrass actually seemed to establish better than winter rye broadcasting the first year, but this did not hold true the second year. During this demonstration we had a uniquely mild winter that resulted in survival of rapeseed and forage turnip, and also annual ryegrass. For that reason, broadcast plots had increased percent cover the second year with mixes that otherwise would have been winter killed. Winter peas are not reliably winter hardy in this area, but may overwinter and grow back from the crown some years. Clovers are generally slower growing perennials, and winter survival appeared better the second year, after the mild winter that allowed for better root establishment. The date of planting is a clear consideration when choosing whether or not to use a mix with a legume in general, as the cost has to be balanced with the benefits. Timely planting can make legume cover crops pay.

Over both years, Mix 9 and 10 proved most promising in comparison to the 'control' winter rye. These mixes contained either forage turnip or rapeseed. It seemed there was some stimulation benefit to the winter rye in the spring that was above and beyond just the winter rye by itself. In the first year the crimson clover was not observed to be a substantial factor in the success of the Mix 10, although we cannot say definitively since we did not compare this mix just with and without the clover. The second year the legumes seemed to establish better and may have been more of a factor. The second year other mixes were also comparable; for example, Mix 2, 4, 6, 7, 8, 9, and 10 all had equivalent percent ground cover in spring drilled plots. Looking at the percent cover between the years, in addition to alteration in mixes and methods, weather clearly impacted success. The second year all mixes satisfied minimum conservation target for soil coverage, but this was not the case the first year. Based on these results, climate change will over time likely affect the long term use of cover crops in this area, and may result in a longer growing window and more over-wintering. Farmers and agronomist will have to continue to adapt their conservation practices to both their farm and changes over time.

Since it seemed that at least in some cases not all brassicas are alike, it would be interesting to simply compare radish to less 'popular' rapeseed and forage turnip, which could provide more soil coverage, at least in some circumstances. Radishes popularity comes from its use as a 'biodrilling' agent, but radishes should be planted in August without competition from a cash crop in order for those benefits to be seen. Radishes can still provide soil coverage when applied in late September, but other brassicas should be considered as alternatives when planting later for leaf as opposed to root growth.

After planting these mixes the first year, we realized that incorporating a winter killed and a winter hardy cereal might maximize the benefits of both – balancing the need for quicker fall soil coverage, provided by the oats, while also providing spring growth in a winter hardy cereal, provided by the winter rye. Mix 6 and 7 show great promise for this reason. Finding the right seeding rate, so that farmers do not have too much spring biomass to contend with, needs further exploration. Fine-tuning this system to determine which brassica or legume works best with an oat-winter rye combination is also up for consideration. Overall, winter rye is still the 'old standby' when it comes to cover crops and in comparison to other cereal grains, is a higher performing cover crop in this region. However, if a farmer is making a decision based on forage quality or actually wants less biomass, s/he may consider winter triticale instead.

**Other Observations**

The first year of this demonstration project we split plots at one site into manured and no-manured plots. From this, we saw not surprisingly that manured plots did grow better. We were not able to quantify what percentage of the manure phosphorus was taken up by the growing cover crop, but this is clearly a better utilization of fall manure than spreading on bare ground. It presents an alternative which can create a better cover crop that provides enhanced environmental and soil health benefits. Further exploration is need to quantify benefits and tradeoffs of this approach. Further, we observed at another site that manure application might suppress cover crops under different circumstances, namely in a very sandy manure that may have smothered the crop too much. Looking at type and rate of manure application could elucidate best practices. Also, tire tracks from the manure applicator were observed to create compaction, but the cover crop seemed to have recovered by spring.

In the second year, drilled cover crop plots were wetter and cooler in spring than early broadcast plots. Spring drilled plots have more ground cover and biomass than either early or late broadcast plots. Spring drilled plots also had more nutrient uptake and less compaction than late broadcast plots. This suggest there is clearly tradeoffs with the benefits of cover crops, but regressions did not elucidate direct or clear relationships. The debate still continues, as other research has actually suggested a growing cover crop can take up moisture and make spring plots drier. There probably is some relationship to the extent of cover crop growth/cover, type of crop, and weather conditions that affect whether the cover crop makes a field warmer or colder, moister or drier in the spring. As we did not have a negative control plot, we cannot say for sure how this would compare to bare ground. We suggest however, the cover crops may be 'moderators' and dampen both extreme wet or dry conditions. However, if a dead mat of cover crop sits over the soil, then it may take longer to warm or dry.

It should be noted that the effects of no-till had on ground cover, irrespective of cover crop treatment. The second year we added more fields that we no-tilled and this seemed to have an effect in increasing overall ground cover, which is expected. There were also weeds that actually increase ground cover. Future demonstration and research should explore percent ground cover measurements which tease out weeds, crop residue and cover crop soil coverage.

**Recommendations for Cover Crop (340)**

As a result of this project, it is clear that there is a role for cover crop mixes in Vermont. The following list of recommendations is meant to serve as sound agronomic advice for producers adopting this practice. In addition to this list, proposed update/addendum to Vermont NRCS Specification Guide Sheet- Cover Crop (340) located in Appendix D should also be considered as recommendations.

- When choosing mixes and/or selecting species for those mixes, evaluate what benefit you hope to gain from the cover crop. If there is only one objective (ie. erosion protection or biomass), a monoculture cover crop may be a better alternative. If you have multiple management objectives, then chose species to accomplish those objectives.
- Most mixtures will require an earlier planting date. Adjustments may need to be made to accommodate this. These include, but are not limited to changing herbicide programs to exclude long residual materials, having access to equipment to facilitate interseeding into a cash crop, harvesting the cash crop earlier to plant the cover crop.
- Until better methods/equipment are developed and/or adapted to our systems here in Vermont, broadcast interseeding is a less reliable approach than planting the cover crop after harvest. It can be done effectively, but it may take some trial and error on an individual farm to get it to work within that farm's system.
- Manure works well in conjunction with cover cropping. A good strategy to increase cover crop growth, but prevent runoff from excess manure nutrients would be to apply 5,000 gallons per acre as soon as possible in the fall and/or 5,000 gallons per acre in the spring once winter hardy cover crops have 'greened up' and resume growth. This should be in following with an operation's nutrient management plan (and rates should be adjusted accordingly), but the general concept is to apply manure to a growing, living cover crop. This provides the dual benefit of reducing nutrient loss and increasing effectiveness of the cover crop.
- Termination of cover crop mixes can be more complicated than monocultures. Be sure to read herbicide labels and pay attention to species and growth stage in order to have effective termination and not impact growth of the following crop. Growth stage is important regardless of termination method (chemical, tillage, rolling/mowing, grazing, etc). Producers will need to weigh maximizing the benefit of the cover crop by letting it grow longer in the spring, with the ability to terminate the cover crop and avoid negative impacts. Mixtures may be able to buffer some of these negative impacts. For example, by decreasing the carbon to nitrogen ration over a monoculture of winter rye cover crop which has reached advanced growth stage.

**Future Investigation Needs Identified**

One major area that requires further investigation is the use of a drill interseeder that enables proper planting and seed-to-soil contact while achieving an earlier planting date. Our colleagues in the UVM Extension Northwest Crops & Soils team are currently doing this work with a InterSeeder™ drill and we hope to utilize that technology in the southern have of the Lake Champlain basin to evaluate its success here.

We have found through our work with this project, and generally with farmers in this area, that in challenging soil conditions too much spring biomass can be a problem. While these producers want good fall biomass and erosion protection, they would prefer a less vigorous cover crop to terminate in the spring. From our preliminary work in the second year of the project, Mix 6 (rye/oat/radish) and Mix 7 (rye/oat/vetch) had comparable biomass in the fall to a winter rye monoculture or other mixes with winter cereal grains, but reduced spring biomass. Particularly interesting was that while spring biomass was moderated, phosphorus uptake in pounds per acre was higher than the monoculture. We hope to continue to investigate these winter rye/forage oat mixtures and better understand the appropriate seeding rates and what/if other species compliment them the best. In addition to understand how corn and soybean crops perform following these mixtures.

A better understanding of how cover crops impact the manure nutrient cycling in crop fields on dairy farms also warrants better understanding. We know manure applications increase cover crop biomass, but a closer look at how the cover crop impacts the nutrient cycling after termination is warranted.

**Appendices [Not included here but can be requested]**

**A - Field Day Handouts**

**B - Slide Handouts from Select Presentations**

**C - UVM Extension Factsheets**

**D - Proposed Update/Addendum to Vermont NRCS Specification Guide Sheet- Cover Crop (340): an additional page with two tables and corresponding explanations to augment existing document.**

**E – All data points by year**

**F – Additional charts and graphs**