Under Cover

Integrating Cover Crops into Silage Corn Systems

A Publication of the
University of Vermont Extension
Northwest Crops and Soils Program

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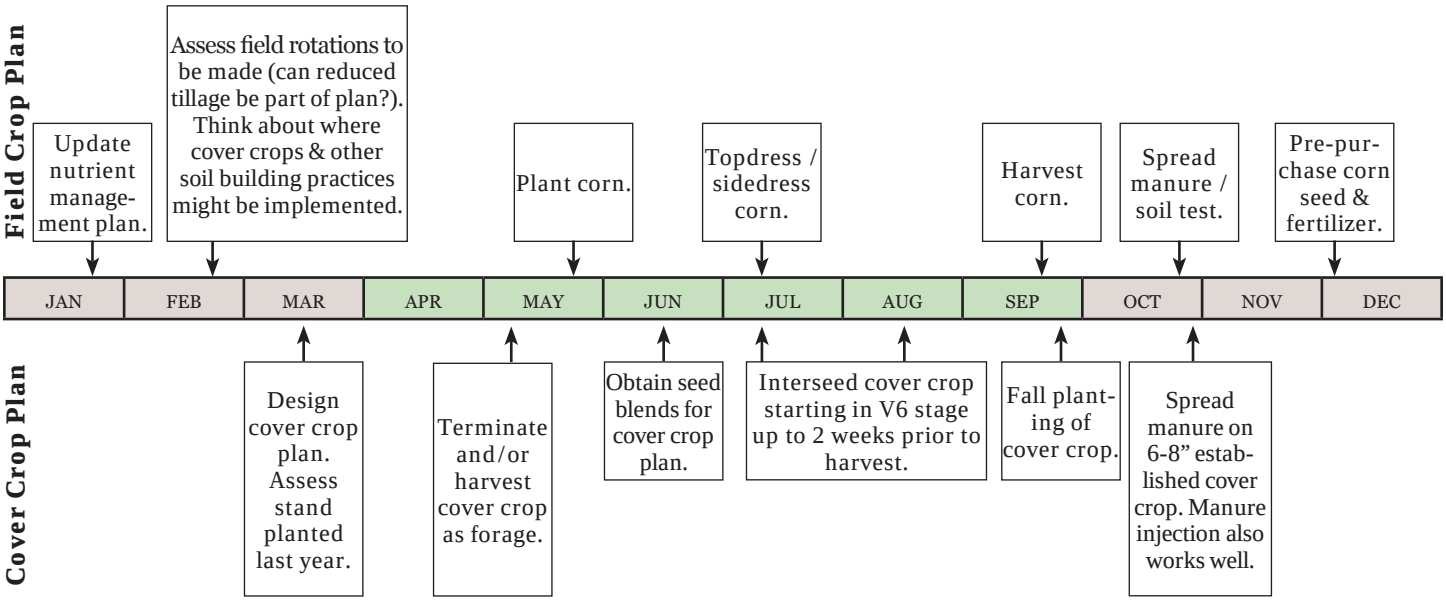
Introduction

Integrating cover crops into field crop production has gained interest in recent years as we discover the multitude of benefits that cover crops can provide to cash crops like corn. For example, cover crops can reduce nutrient and soil loss, increase soil organic matter, suppress weeds, and even serve as extra sources of livestock forage. All of these benefits help translate into increased cash crop productivity. In general, the benefits from cover cropping far outweigh the costs of implementation, but to use them with success, you need to identify your goals for using covers as well as potential farm and field constraints. Various cover crop species can provide different benefits but each comes with their own unique advantages and disadvantages.

Successfully incorporating cover crops into your silage corn production will take advanced planning to realize the benefits these crops can offer. Figure 1 is an example of an annual cropping system that integrates cover crops. Note that timely planting and termination are both critical to the success of *any* cover crop.

This guide covers a variety of agronomic strategies that will help you build a silage corn system that integrates cover crops. These include variety selection, planting dates, seeding rates, and termination strategies. Much of the information in the guide is based on research conducted by the University of Vermont (UVM) Extension Northwest Crops and Soils Program (NWCS). Since 2003, our NWCS team has been conducting on-farm trials throughout Vermont, including several to evaluate cover cropping practices in corn silage systems. You can find a link to our research reports as well as additional cover crop resources at the end of the guide.

FIGURE 1. **Example of 12-month cover cropping schedule.**



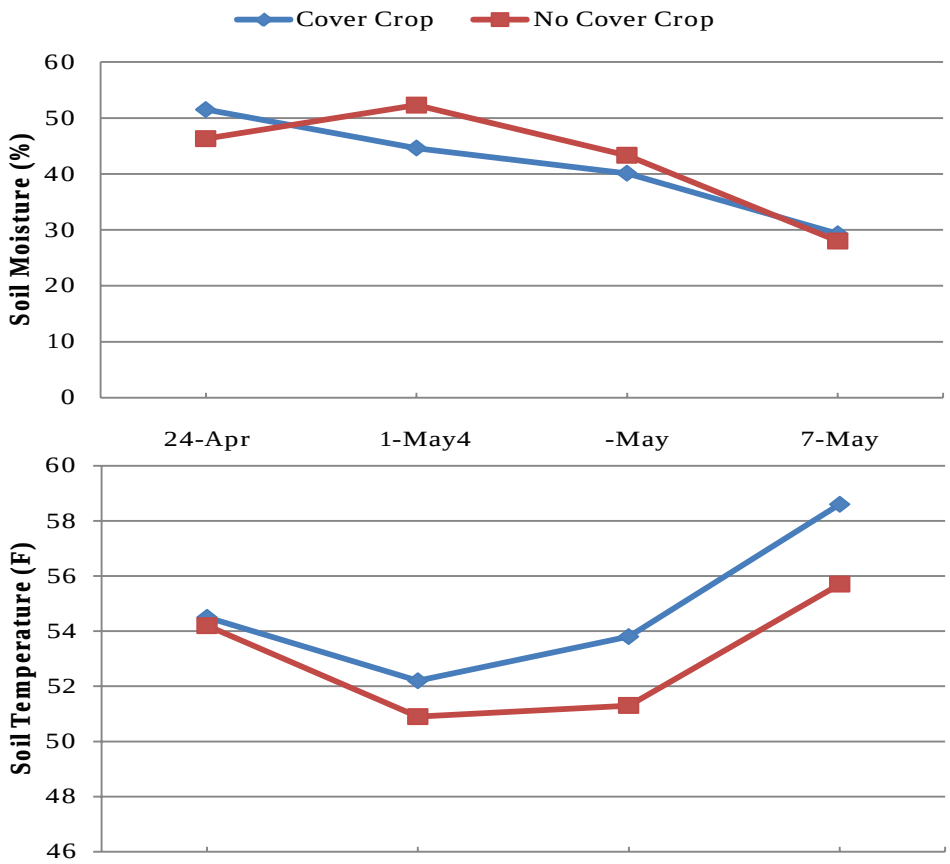
Cover Cropping Benefits

- *Nutrient recycling*
- *Decreased soil erosion*
- *Decreased nitrogen leaching*
- *Improved soil tilth*
- *Increased soil organic matter*
- *Improved soil biology*
- *Manure management*
- *Extra stored or grazed forage*
- *Reduction in fertilizer costs*
- *Moderated soil temperature*
- *Suppression of weeds*
- *Mitigation of disease*
- *Increased crop yields*

Soil Health

Improving soil health is a major benefit to adding a cover crop to your corn rotation. Cover crops can positively contribute to both the physical and biological properties of field soils. For example, when soil is left exposed through the winter, land is physically at risk to erosion and leaching of nutrients and herbicides into water sources. Soil compaction can accumulate from season to season, reducing the corn's ability to scavenge for nutrients and obtain oxygen needed for adequate growth and development. Cover crops reduce these risks by creating root networks that help build soil structure while breaking up compaction and increasing soil aggregation, facilitating air and water flow. Cover crops are also actively growing and require water and nutrients, hence available water and nutrients can be scavenged by cover crops in the late and early season. One of our research projects conducted in St. Albans in Spring 2007 found lower soil moisture levels and higher soil temperatures in cover crop treatments compared to soils without a cover crop (Figure 2). Here, we learned that corn planted following a properly managed cover crop had a head start in a warmer and drier seedbed.

Figure 2. **Soil moisture and temperatures of heavy clay planted to cover crop as compared to no cover crop.**



As mentioned, cover crops can act as nutrient storage. For example, in our region, it is a common practice to apply manure to corn acreage in the fall, especially where fall tillage is practiced. But plant available nitrogen (N) can be lost from fall manure applications through erosion, leaching, and denitrification. If a cover crop is planted, these plants can absorb nutrients and store them in their biomass through the winter. Our research has shown that 50% of manure nitrogen was available for corn to scavenge from a fall-planted cover crop, as compared to 15% of manure N available to corn without a cover crop. Cover crop biomass can hold high quantities of nutrients, especially if the cover crop is able to obtain sufficient growth prior to termination. Table 1 shows nutrient levels in soil where cover crops were grown. Levels of nutrients were higher in soil with no cover crop indicating that the cover crops were able to scavenge considerable levels of nutrients. Nutrients such as phosphorus (P) held by cover crop biomass are less prone to environmental losses. Integrating cover crops can also reduce the leaching of potassium (K), ultimately reducing the amount of purchased fertilizers for successive crops.

TABLE 1. **Effects of cover cropping on soil health.**

Cover Crop Treatment	Soil pH	Available P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	CEC (meq 100 g^{-1})	Zn (ppm)	Soil Organic Matter (%)
Annual ryegrass	7.23	44.3	284	193	3231	18.5	1.33	3.93
Radish	7.10	39.8	253	191	3009	17.3	1.13	4.07
Control (No cover)	7.20	57.4	322*	219	3175	18.5	1.40	4.30
LSD (0.10)[1]	NS	NS	34	NS	NS	NS	NS	NS
Trial Mean	7.18	47.2	286	201	3138	18.1	1.29	4.10

[1]Least significant difference. NS=Difference between treatments was not statistically significant.

Tillage radish.

Cover crop residues increase the microbial or biological activity in the soil as well. Research has shown that the soil's biological activity is very low when bare soil is left following silage corn harvest. By growing cover crops, you are helping to feed microorganisms in the soil, including fungi, bacteria, arthropods, and protozoa. These microorganisms release nutrients bound up in the soil, making them more available to your crop. In addition, they interact with plant growth regulation and enhance pest (insect, disease, and weed) defense mechanisms within cash crops.

Individual cover crop species perform very specific roles—clover, for example, fixes nitrogen—but *all* cover crops help improve soil health in some way.

Costs and Benefits

When getting started with cover crops, it is a good idea to determine what this practice is going to cost. The following spreadsheets provide estimated costs and benefits for establishing cover crops, based on calculations made in 2014 using the USDA Natural Resources Conservation Service (NRCS) Cover Crop Economics Tool at: www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/econ.

The spreadsheets use five examples of typical cover crop scenarios in silage corn as follows:

1. Cereal rye that has been drilled after corn harvest and terminated in the spring by plow down;
2. Annual ryegrass that has been broadcast seeded and terminated by disking;
3. Triticale that has been drilled following corn harvest and harvested for forage in the spring;
4. A cereal rye and radish mix that has been aerially seeded and terminated by herbicide; and
5. A mix of annual ryegrass, clover and radish that has been broadcast seeded at the time of topdress and terminated by herbicide. In this scenario, corn is planted using a no-till system.

The calculations we've provided rely on several built-in formulas and look-up tables included in the NRCS Cover Crop Economic Tool. Clearly, these are estimates; for example, per pound seed costs are based on NRCS recommended seeding rates and estimated seed costs per pound in 2014 (see below).

While the actual costs and benefits will vary from farm to farm and from year to year, these estimates should give a general financial picture of what you might expect when implementing cover crops on your farm.

Estimated Seed Costs

NRCS Seeding Rates (Pounds of Seed)	Cereal Rye	Annual Ryegrass	Triticale	Cereal Rye & Radish Mix	Annual Rye-grass, Clover & Radish Mix
Planted	75	20	75	60, 3	12, 5, 2
Broadcast	112	30	112	85, 4	18, 6, 4
Cost per pound (2014 prices)	$0.25	$0.60	$0.50	$0.41	$1.86

Expenses (Costs per Acre)

	Scenario 1 Cereal Rye: Drilled & Plowed Down	Scenario 2 Annual Rye: Broadcast & Disked	Scenario 3 Triticale: Drilled & Harvested	Scenario 4 Cereal Rye & Radish: Aerially Applied	Scenario 5 Annual Rye, Radish & Clover: Broadcast
Seed	$18.75	$18.00	$50.00	$36.49	$52.08
Application Method					
Broadcast	-	$4.84	-	-	$4.84
Broadcast & Disked	-	-	-	-	-
Aerial Applied	-	-	-	$40.00	-
Drilled	$13.26	-	$13.26	-	-
Termination Costs					
Plow Down	$18.63	-	-	-	-
Disk	-	$17.35	-	-	-
Herbicide	-	-	-	$30.00	$30.00
Crimping	-	-	-	-	-
Increased Management (time & effort)	$1.50	$1.50	$1.50	$1.50	$1.50
Decreased Yield (price per ton at bunk)			3 * $55.00 = $165.00		

Benefits / Income (Income per Acre)

	Scenario 1 Cereal Rye: Drilled, Plowed Down	Scenario 2 Annual Rye: Broadcast & Disked	Scenario 3 Triticale: Drilled & Harvested	Scenario 4 Cereal Rye & Radish: Aerially Applied	Scenario 5 Annual Rye, Radish & Clover: Broadcast
Nutrient Credits					
Nitrogen	30 * $0.40 = $12.00	-	-	30 * $0.40 = $12.00	35 * $0.40 = $14.00
Phosphorus	-	-	-	-	-
Potash	-	-	-	-	-
Other Credits					
Herbicide Reduction	-	-	-	-	$30.00
Insecticide Reduction	-	-	-	-	-

(continued next page)

Benefits / Income (continued)

	Scenario 1 Cereal Rye: Drilled, Plowed Down	Scenario 2 Annual Rye: Broadcast & Disked	Scenario 3 Triticale: Drilled & Harvested	Scenario 4 Cereal Rye & Radish: Aerially Applied	Scenario 5 Annual Rye, Radish & Clover: Broadcast
Corn Yield Increase Credit (price per ton at bunk)	2 * $55.00 = $110.00	-	-	1 * $55.00 = $55.00	-
Erosion Reduction Credits					
Tons of Topsoil (typically 2 to 3 tons per acre in VT)	2 * $20.00 = $40.00	2 * $20.00 = $40.00	3 * $20.00 = $60.00	2 * $20.00 = $40.00	1 * $20.00 = $20.00
Field Maintenance Reduction (work done to fix erosion per acre)	$2.50	$2.50	$2.50	$2.50	$1.00
Effects of Erosion to Public Waters (per ton of lost soil)	2 * $4.93 = $9.86	2 * $4.93 = $9.86	3 * $4.93 = $14.79	2 * $4.93 = $9.86	1 * $4.93 = $4.93
Forage Credit (per ton of forage harvested)			5 * $50.00 = $250.00		
Silage harvested per acre			$30.00		
USDA NRCS EQIP Payment	$62.00	$62.00	$62.00	$73.00	$73.00

Totals

	Scenario 1 Cereal Rye: Drilled, Plowed Down	Scenario 2 Annual Rye: Broadcast & Disked	Scenario 3 Triticale: Drilled & Harvested	Scenario 4 Cereal Rye & Radish: Aerially Applied	Scenario 5 Annual Rye, Radish & Clover: Broadcast
Total Expenses	($52.14)	($41.69)	($229.76)	($107.99)	($88.42)
Total Benefits / Income	$236.36	$114.36	$419.29	$192.36	$142.93
Total Return per Acre	**$184.22**	**$72.67**	**$189.53**	**$84.37**	**$54.51**

What to Grow

There are a number of cover crop species you can choose to grow with your corn silage crops. The species and/or mixtures you choose will depend upon your goals for using them. For example, you may be looking to specifically address soil erosion or compaction, fix or scavenge nitrogen, manage weeds, and/or provide an additional forage source. Your choice of cover crops will also depend upon your planting and termination windows--these dates are naturally dependent on weather conditions but may also be directed by your farm's participation in state and federal cost-share programs. Table 2 lists some common cover crop species that have been used in Vermont's corn silage systems and the benefits they can provide.

Winter rye seed.

TABLE 2. **Beneficial roles of some cover crops used in silage corn.**

SPECIES	NITROGEN SCAVENGER	SOIL BUILDER	EROSION CONTROL	WEED MGT	FORAGE CROP
Winter rye	excellent	excellent	excellent	excellent	fair
Triticale	very good	excellent	excellent	excellent	excellent
Oats	very good	good	very good	excellent	good
Red clover	good	very good	good	good	excellent
Annual ryegrass	very good	very good	very good	very good	good
White or alsike clover	fair	good	very good	good	excellent
Hairy vetch	fair	very good	good	good	fair
Forage radish	excellent	very good	very good	excellent	good
Adapted from "Managing Cover Crops Profitably"					

GRASSES

The most common cover crops are those in the grass family. Popular covers for silage corn include: a) cereal grains like winter rye, oats, triticale, wheat, and barley; and b) bunch grasses like annual ryegrass. In general, these grasses are easier to fit into a corn silage production system than other cover crops. They tend to germinate quickly and can produce significant biomass under a diverse set of growing conditions. Therefore, these covers can be great for erosion control, adding organic matter to the soil, suppressing weeds, and to scavenge nitrogen and store it for the next crop. In addition, some of these crops are often thought of as dual purpose, as they can be used as a cover as well as a forage crop.

Of all the cover crops used in silage corn plantings, winter or cereal rye *(Secale cereale)* has been the most popular in our region. Winter rye is a hearty cereal grain that does well in cool climates. This annual is considered a "workhorse" and, although it is not the highest quality forage crop, it is often chosen for its proven reliability and versatility.

Winter rye thrives on well-drained, loamy soils but it also performs adequately in heavy clays as well as droughty, sandy soils. It can grow in low-fertility soils; it prefers a soil pH of 5.0 to 7.0, but can tolerate soil pH ranges from 4.5 to 8.0.

Winter rye establishes and grows at cooler temperatures so it can be planted later than most other cover crops and still performs well. It is the most winter-hardy of all cereal grains, tolerating temperatures as low as -30°F once it is well established. It can germinate and grow (with limited vigor) at temperatures as low as 33°F.

Compared to other cereal grains, winter rye grows faster in the fall, providing quick cover to otherwise bare soils. It persists well, even during severe winters. Once spring arrives, it breaks dormancy before other cereal grains and quickly begins to produce biomass. Its quick growth in the spring can catch farmers off guard! If not managed properly, excessive amounts of this cover crop's spring residue may actually delay cash crop planting or impede its growth and development. The decomposing winter rye may "tie up" nitrogen and delay its availability to the silage corn crop. Therefore, termination strategies should be carefully considered and planned (see page 23).

Winter rye in silage corn field.

Legumes

Legumes like perennial clovers (red and white), annual clovers (crimson and berseem), field peas, and hairy vetch are typically used as cover crops for their "nitrogen fixing" value. Special soil bacteria—*Rhizobium* spp.—establish within the roots of legumes; through this symbiotic relationship, rhizobia are able to draw nitrogen from the air and store it in nodules within the plant's root system. As the legume plant decomposes, nitrogen is released, making it available to other plants as a fertility source. As cover crops, legumes are generally slower than other species to establish and so they are often included as a mixture with other types of covers. Since most are perennials, they do tend to survive the winter; therefore, proper termination strategies in the spring should be well planned.

Nitrogen-fixing nodules on Austrian winter pea.

Brassicas

Another species of cover crop used in silage corn is the brassica. Brassicas include radish, turnip, canola (rapeseed), and mustard. The most popular brassica cover crop is the tillage radish. This cover crop is typically used to improve soil structure with their hearty taproots which can alleviate soil compaction and improve soil aeration. In addition, because they produce a canopy quickly and provide substantial cover, brassicas can help reduce erosion. Our research conducted in Fall 2014 indicates that brassica can be successfully established in our region in mid-August through mid-September and still have adequate growth into the late fall.

Some brassicas, like mustard, contain glucosinolates, naturally occurring compounds that provide soil biofumigant properties to combat soil-borne diseases and other pests. However, care needs to be taken to avoid contamination in feedstocks as plants like mustard can be toxic to livestock at high concentrations.

On the other hand, brassicas including kale, turnip, and rape are common as grazed forages. These crops are interseeded in late summer for late fall grazing. Because the forage quality of the brassica is so high in terms of digestibility and crude protein, care needs to be taken to avoid overfeeding (the feed value is often compared to a concentrate).

Tillage radish planted at four planting dates at the Borderview Research Farm in Alburgh, harvested November 12, 2014.

Examples of Cover Crops Used in Vermont Silage Corn Acreages

Winter (Cereal) Rye

Oats*

Triticale

Annual Ryegrass

Crimson Clover*

Berseem Clover*

Austrian Winter Pea*

Hairy Vetch

Forage Turnip*

Tillage Radish*

Winter Canola

Mustard*

* Winter kills.

Cover Crop Cocktails: Putting Them All Together

Of recent interest is the blending of multiple cover crop species into a single planting. These "cover crop cocktails" can enhance the overall benefits of cover cropping by adding the contributions that each species provides. For example, planting a cereal with a legume can take advantage of the cereal's quick growth habit to provide ground cover while the legume establishes, and the legume's nitrogen-fixing properties to add nutrients to the soil. There are several Vermont on-farm research trials underway to assess the performance of various cover crop mixtures in silage corn plantings around Vermont. Guidance as to the best cover crop mixtures has been provided by Vermont Natural Resources Conservation Service (NRCS). This guidance is especially useful if you need to comply with NRCS program standards for cover cropping (Table 3). While there are advantages to planting a diversity of cover crops, challenges do exist, including different planting depths and seeding rates of the various seeds in the mixture, as well as expense (some species are more expensive than others). In the end, however, the soil and your crops will benefit from the biodiversity these multiple species plantings can provide.

An example of a cover crop mix (Austrian winter pea and tillage radish).

Table 3. **Cover crop mixes, specified by Vermont NRCS.**

Mix		Min Seeding Rate (lb/ac)		Seeding Depth (inches)	Primary Purpose		
		broadcast	drilled		erosion control	nitrogen fixation	nutrient scavenging
1	Ryegrass (annual or perennial)	20	15	1/4 - 1/2	x		x
	Brassica (radish, canola, turnip, rapeseed)	4	3				
2	Winter small grain	85	60	1/2	x		x
	Brassica (radish, canola, turnip, rapeseed)	4	3				
3	Spring small grain	85	60	1/2	x		x
	Brassica (radish, canola, turnip, rapeseed)	4	3				
4	Spring small grain	85	60	3/4	x		x
	Mustard	4	3				
5	Winter small grain	60	40	1/2	x	x	x
	Red clover	6	5				
	Brassica (radish, canola, turnip, rapeseed)	4	2				
6	Ryegrass (annual or perennial)	15	12	1/4 - 1/2	x	x	
	Red clover	8	6				
7	Winter small grain	70	56	1 - 1-1/2	x	x	
	Hairy vetch	20	15				
8	Winter small grain	85	60	1/2	x	x	
	Clover (red, ladino, berseem, crimson, etc.)	8	6				
9	Winter small grain	70	56	1	x	x	
	Austrian winter pea	60	40				

Adapted from "Vermont NRCS Cover Crop Specifications Guide Sheet (340)"

Establishment

When it comes to cover crop success, timing is everything! Planting dates will dictate how well a cover crop establishes and/or overwinters to produce its intended results. Cover crops are commonly planted at one of three times during the corn growing season: 1) just prior to canopy closure, 2) just prior to harvest—the technique of establishing a cover crop into the already growing crop is called "interseeding"—and 3) post-harvest.

Planting Cover Crops Just Prior to Canopy Closure

The first potential window to establish a cover crop is just prior to canopy closure of the corn. This commonly occurs near the time of topdress or at the sixth leaf stage of corn development. At this time, cover crop seed can be broadcast using a tractor-mounted seeder or mixed with fertilizer and applied at the time of topdress. New equipment like the PennState interseeder has been developed to interseed cover crops at the same time of N topdress and herbicide application.

Planting the cover crop at this time in the growing season allows it to become established just prior to canopy closure. The cover will remain relatively small since little sunlight will penetrate through the corn leaf canopy and, therefore, will not reduce corn yields. Once the corn matures and begins to dry down and the corn leaf canopy is reduced, the cover crop will grow rapidly.

Tractor-mounted broadcast spreader.

Interseeding earlier in the growing season presents an opportunity to select from a broader range of cover crop options as there is more time for covers to become adequately established before going into the winter. For example, a trial conducted in 2013 evaluated the interseeding of clover, tillage radish, and annual ryegrass into corn at the sixth leaf stage of development. Results suggested that planting cover crops at this time can provide adequate establishment of these species.

Penn State cover crop interseeder and applicator.

There are several considerations to keep in mind while seeding at the sixth leaf stage. Often seeding at this time occurs shortly after herbicide has been applied to the cash crop. So, if you are planning to apply cover crop seed in June or early July, adjustments will likely need to be made to your herbicide program to avoid any residual effects they may have on the establishing cover crop (see page 21).

If you plan to apply the seed with a broadcast spreader while fertilizing, pay close attention to your spread pattern; lighter seed will not spread in the same pattern as fertilizer and heavier seed. If these weight differences are not taken

An example of a cover crop planted prior to canopy closure -- interseeded tillage radish in silage corn.

into account, you may see a banding effect in your fields where the lighter-weight seed did not uniformly cover the field. Adjust by reducing your spread pattern (i.e., travel 35 feet between passes instead of 50 feet) and/or adjust fertilizer rates accordingly to prevent over-fertilization.

If you plan to use a cultivator to improve soil-to-seed contact, take care to avoid burying the seed more than the recommended depth. If the seed is over-incorporated and/or there is too little moisture, it may not germinate. Some farmers choose to apply larger seeded cover crops prior to cultivation while smaller seeded species are applied just following cultivation.

Interseeded red clover as a cover crop.

Seeding Covers Prior to Corn Harvest

The second time to seed cover crops occurs in the late summer, approximately one month prior to corn harvest. Planting a cover crop at this point gets the seed on the ground, allowing ample time for germination prior to corn harvest. Seeding at this point during the growing season will allow for earlier establishment of the cover crop, reducing the workload following corn harvest and allowing the cover to potentially gain more biomass from this earlier planting date.

High clearance cover crop inter-seeders like the "highboy" pictured here can effectively seed cover crops just prior to corn harvest. Photo credit: Julia Bourque, The Nature Conservancy.

However, a challenge to establishing cover crops at this point is securing the equipment needed to interseed the cover into/over a crop of mature corn. New equipment innovations to apply seed above the corn plants are being introduced to our region. An example is the "highboy," a high clearance air seeder with drop tubes that deliver the seed to the soil.

Initial research has indicated that very little in-field corn damage has been found from driving a highboy through the corn; one study found that only one-half of one percent of the corn was damaged and that was isolated to the end rows. The effectiveness of the highboy may be limited to 30 inch corn rows. Rows planted closer together may increase crop damage.

Aerial seeding has also re-gained popularity in our region. This practice was implemented widely in the 1980s but fell to the wayside when cost share dollars for implementation became less available. More recently, the seeding of cover crops into standing corn by helicopter has addressed some of the equipment and timing issues of getting covers planted on large acreages during the busy time of the year. In 2012 and 2013, working with the UVM Extension Champlain Valley Crops, Soils and Pasture Program, our team conducted a pilot project to aerially seed winter rye into standing corn before harvest. In 2012, 2,544 acres in Vermont and New York were planted to cover crops; in 2013, that acreage more than doubled to 5,600 acres seeded to winter rye, providing year round vegetative cover. To be effective, aerially applied winter rye should be planted by late August or early September to give the cover crop a chance to become established yet not fully mature to interfere with corn harvest. Best results are obtained when the cover crop seed is flown on shortly before a rain event as establishment of the crop is dependent on good soil-to-seed contact and seed moisture; rain is beneficial in this respect.

Another consideration for aerial seeding is the seeding rate. The amount of seed actually making it to the ground can vary widely depending on flying conditions, pilot procedures (flying close to the corn using rotor wash to "push" seed to the ground versus flying high above the corn), and the specific seeding equipment used. When applying seed in unfavorable conditions, applications rates may need to be adjusted to ensure adequate establishment rates. In general, the use of aircraft to apply cover crops is efficient and it can be a viable method of seeding a large number of acres in a short period of time.

Aerially seeding winter rye by helicopter.

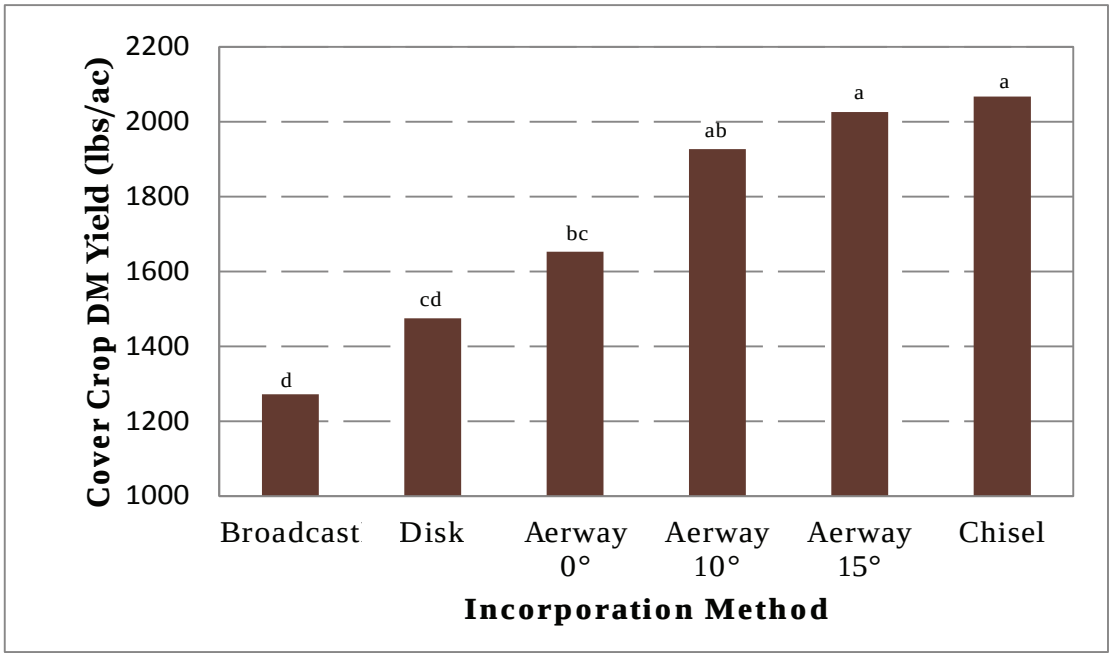
Planting Cover Crops Post-Harvest

Many farms wait until after silage corn has been harvested to establish a cover crop. At this point, seeding generally occurs between mid-September and late October.

There are many methods to plant cover crops following corn harvest. For example, a grain drill is best used to establish cover crops that will be harvested for forage or grain the following season. The advantage to seeding with a grain drill is more accurate seeding rates and uniform establishment. However, not everyone has a grain drill and drill seeding can be time consuming. Our research has shown that winter rye can also be effectively established by broadcasting then lightly incorporating the seed with a variety of tillage implements (Figure 3). Good seed-to-soil contact is critical at this time of year so it is best to avoid broadcasting seed on the surface of the ground alone—this is a risky practice and often ends in poor cover crop establishment.

Also of critical importance is knowing the optimal timing for this “last chance” planting of cover crops. Our Northeast growing season is short and adverse fall weather can delay planting. However, our research results have shown that, not surprisingly, the earlier cover crops are planted in the fall, the more successful their growth and development will be and hence the more benefits a farm will gain from the practice.

FIGURE 3. **Efficacy of establishing a winter rye cover crop by broadcasting seed as compared disking, and incorporating seed with an Aerway (set at varying angles) and a chisel plow (2010).**



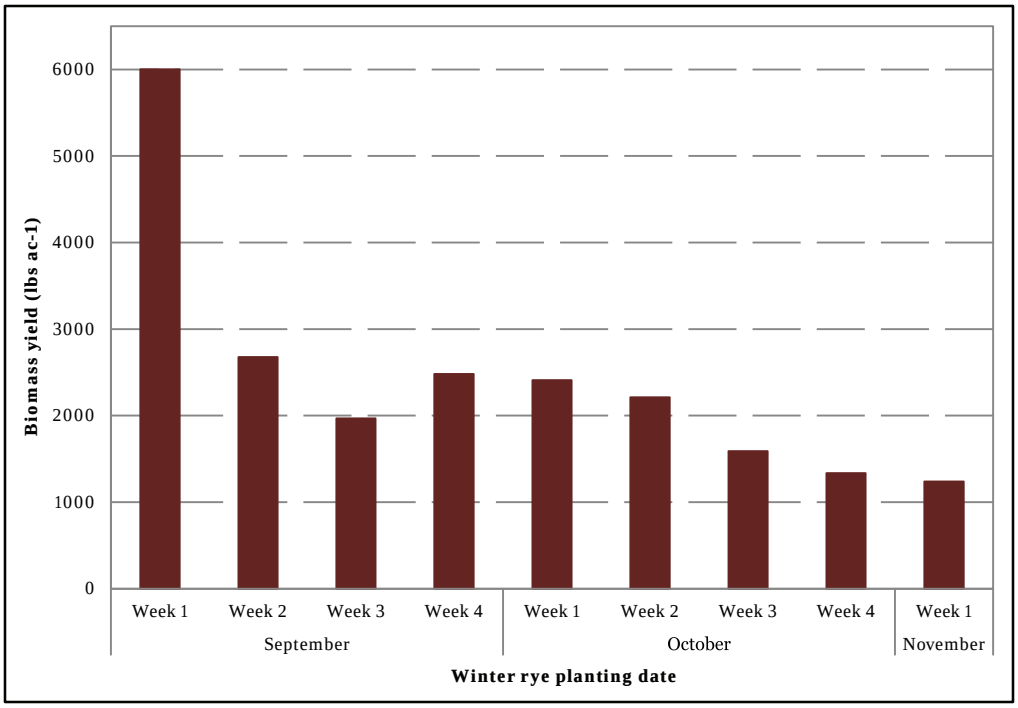
Planting dates of winter rye have been evaluated by our team for more than four years. Dates for rye seeding have ranged from early September through early November (Table 4). Results have revealed that winter rye does best when planted early in the season (Figure 4). In all years of the study, yields were drastically higher for winter rye planted in early September versus later planting dates, averaging 6,000 pounds (3 tons) of dry matter per acre. Plants were taller (averaging 18.7 inches) when planted in the first week of September, with an average of 75% plant coverage of the soil. In contrast, winter rye planted in November yielded only 1,238 pounds (0.62 tons) of dry matter per acre, with an average of 33.5% plant coverage; this is not enough biomass accumulation for adequate soil coverage, animal grazing, or crop production, and would probably not justify the cost of rye seed.

Effect of planting date on tillering of small grains.

TABLE 4. **Winter rye cover crop stand establishment and yield by planting date, Alburgh, VT, 2009-2012.**

	Sept				Oct				Nov
	wk 1	wk 2	wk 3	wk 4	wk 1	wk 2	wk 3	wk 4	wk 1
Plant cover (%)	75.0	68.2	53.3	52.0	48.6	47.6	47.5	53.0	33.5
Plant height (in)	18.7	17.7	13.7	13.7	10.9	10.1	8.5	8.7	8.1
Biomass yield (lbs ac)	6001	2677	1968	2480	2410	2211	1588	1336	1238

FIGURE 4. **Effect of planting date on winter rye biomass accumulation, Alburgh, VT, 2009-2012.**



For winter rye and other cereal grain cover crops, the production of side shoots—tillers—is critically important in their establishment. Tillering can contribute up to 60% of total yields for these plants. Later plantings of cereals, including winter rye, generally do not have enough time to set tillers, resulting in lower yields and insufficient biomass accumulation.

The Importance of Tillers

A tiller is a shoot that grows out from the original stem of a grass plant. We want to encourage as much tillering in our grass species—including winter rye and other cereals—to provide optimal amounts of biomass and soil cover. Planting dates, seeding rates, and fertility will all determine the amount of tillering in these cover crops.

Tillering. The plant on the right, planted later in the fall has little tillering while the plant on the left shows good tillering going into the fall and winter.

A Note About Planting Dates

If planted early enough, winter cover crops have ample time to scavenge nutrients and incorporate them into their biomass. Research has shown that winter rye can scavenge 2% to 4% of nitrogen in their biomass (Figure 5). The more plant biomass produced in the fall and early spring, the more nitrogen a plant consumes. Once the cover crop is terminated, this nitrogen should become available to the following corn crop. While timely planting of cover crops may be difficult to manage with a corn crop, early planting dates are essential for cover crop success. Studies have shown that utilizing a shorter day corn with the addition of a cover crop can lead to higher overall corn yields than longer season corn with bare soil through the winter months (Figure 6). Growing a shorter season corn can also result in corn harvest almost one month earlier than longer season varieties, allowing for more flexibility with post-harvest covers.

FIGURE 5. **Impact of winter rye planting date on nitrogen scavenging.**

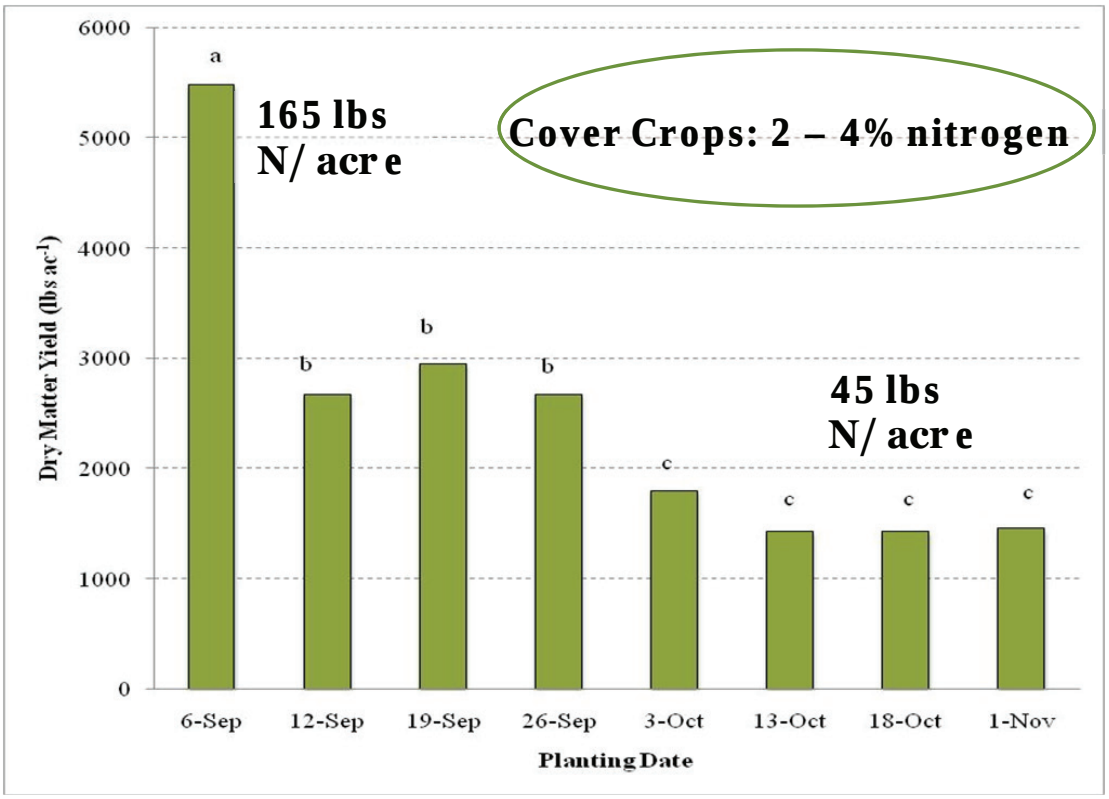
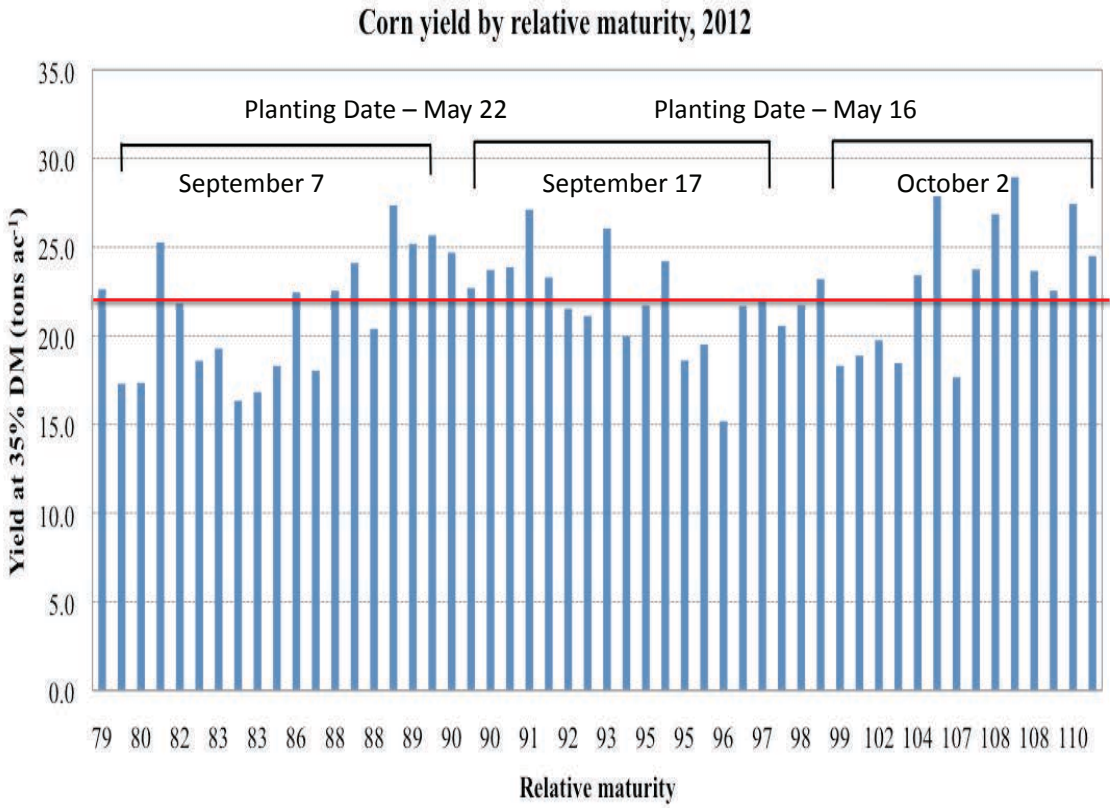


FIGURE 6. **Effect of corn silage relative maturity on harvest date and yield.**



SEEDING RATES

Seeding rates will depend upon the species of cover crop and how it will be sown. For example, smaller seed have higher seeding rates per acre than larger seed; drilled covers tend to have lower seeding rates per acre than those seeding by broadcast. Seeding rates used will also depend upon the desired end use for the cover crop. For example, a higher seeding rate may be preferred for winter rye utilized for forage.

In addition, participation in specific state and federal programs may determine seeding rates. For example, the USDA Natural Resources Conservation Service (NRCS) currently offers cost-share rates for establishing cover crops through its Environmental Quality Incentives Program (EQIP). Table 5 provides minimum seeding rates of some of the more common cover crops used in Vermont, specified by USDA NRCS.

Our on-going research is determining optimal cover crop seeding rates in silage corn for our area. For example, our team has been conducting an on-farm project to evaluate seeding rates of winter rye. Thus far, rates have ranged from 50 to 150 pounds per acre (Figure 7). Across three years of replicated trials to date, the study found that winter rye seeded at 125 pounds per acre had the highest average plant cover (83.3%) and biomass yield (2,602 pounds of dry matter per acre). However, we found that adequate yields were also obtained with seeding rates as low as 75 pounds per acre. Plant height varied, with taller plants at higher seeding rates (with the exception of the heaviest seeding rate of 150 pounds per acre).

Figure 7. **Effects of seeding rate on winter rye plant cover and biomass accumulation (Alburgh, VT, 2009-2012).**

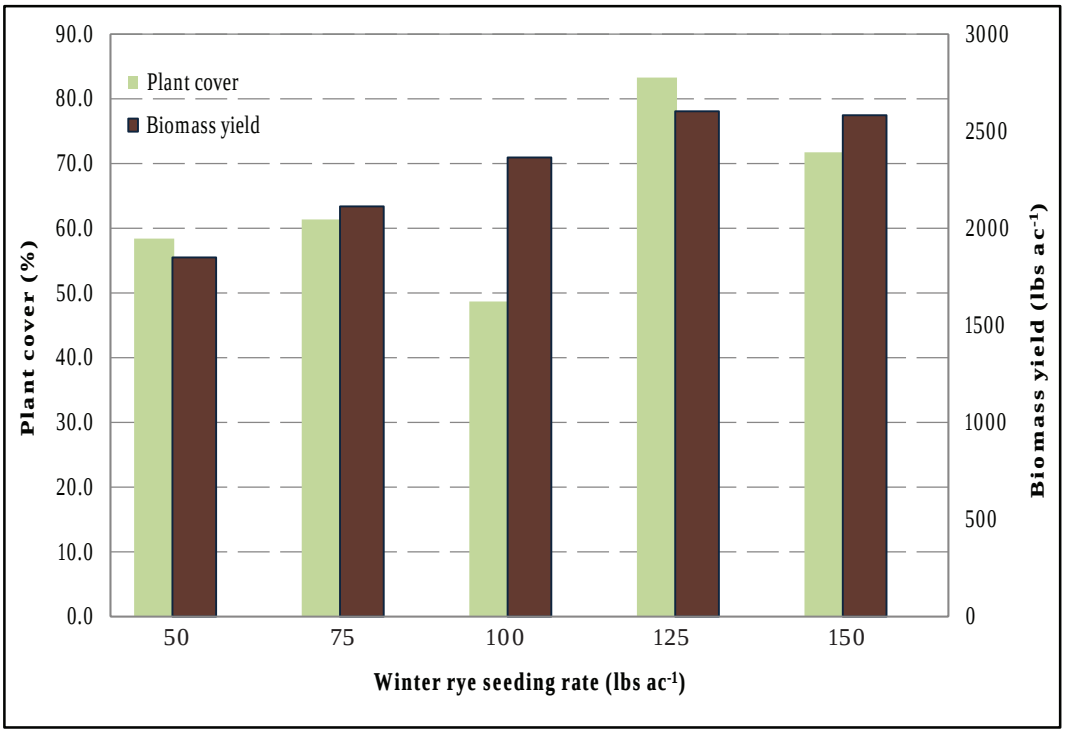


Table 5. **Minimum seeding rate (pounds per acre) of common cover crops, specified by Vermont NRCS, 2014.**

Species	Broadcast (including Aerial seeding)	Drilled or Planted
Winter rye	112	75
Winter triticale, wheat, spelt	112	75
Spring wheat, triticale, barley	100	75
Oats	112	75
Red clover	12	10
White or alsike clover	10	8
Berseem clover	18	10
Crimson clover	25	20
Hairy vetch	35	20
Winter pea	100	65
Forage brassica (radish, turnip, spring canola)	15	10
Mustard	10	6
Winter canola	10	6
Annual ryegrass	30	20
Adapted from "Vermont NRCS Cover Crop Specifications Guide Sheet (340)"		

Potential Herbicide Impacts on Cover Crop Establishment

Herbicides have been critical management tools in growing conventional silage corn and there are a couple of considerations regarding your herbicide program that need to be taken into account when integrating cover crops into these systems.

First, there are questions about cover crop sensitivity to herbicide residues in soils. Little research has been conducted on the susceptibility of cover crop species planted into these soils but we do know, from research conducted at Penn State University, that legumes, tillage radish, and annual ryegrass seem to be particularly sensitive to Atrazine and Simazine residues.

We also know that soil factors and weather conditions affect the length of time an herbicide persists in the soil. For example, herbicides tend to persist in soils high in clay and/or organic matter longer than in other soil types. Here, soil particles are more likely to bind or hold herbicides resulting in decreased plant uptake initially and leaving more herbicide residue to impact subsequent crops. In addition, soil pH can affect the persistence of herbicides. For example, the breakdown of some herbicides—especially the triazines (including Atrazine and Simzaine) and sulfonylureas (like rimsulfuron)—slows down as soil pH increases, particularly above pH of 7.0. That means that liming a field can sometimes "re-awaken" herbicide effects.

Moisture, temperature, and sunlight can also affect herbicide breakdown. In general, herbicides degrade faster in soils with high moisture and temperatures because microbial activity is also favored under such conditions. Sunny days also accelerate degradation. On the other hand, cool and dry conditions tend to slow herbicide degradation.

The success of establishing a good cover crop stand will depend on the timing of your cover crop planting (pre-canopy closure, pre-harvest, or post-harvest), cover crop species you choose, and the herbicides you use. Table 6 lists some common herbicides used in silage corn and their potential affects on cover crops; you can use the table as a general reference when considering your herbicide program but be sure to follow the label for all agricultural chemicals.

The second consideration around cover cropping and herbicide use is whether or not you plan to use the cover crop as a forage. Essentially, if you intend to use a cover crop as livestock feed (grazed or harvested), it is considered a "forage crop"; therefore, you must follow any and all herbicide labeled uses and restrictions for this crop as well as any succeeding or plant-back crop restrictions.

In summary, the use of cover crops necessitates a close look at your herbicide program to avoid any potential herbicide residue carry-over that may impact cover crop establishment and/or entering cattle feedstocks. Always follow herbicide's current label restrictions and instructions; herbicide labels are always changing so it is critical that the label is read every season.

TABLE 6. **Examples of common herbicides used in Vermont silage corn, estimated half-lives, cash crop restrictions, & their potential to injure fall cover crops.**

Herbicide	Primary Active Ingredient	Half Life[1] (Days)	Cash Crop Restrictions	Fall Cover Crops		Other
				OK to Plant	Concern for	
Aatrex 4L	atrazine		Do not plant any crops except corn, grain sorghum or forage sorghum the spring following after harvest.	Sorghum species	Do not graze treated areas within six months after application.	Do not rotate to any crop except corn or sorghum until the following year. Pre-plant application not approved for application in Vermont.
Atrazine 90DF	atrazine	60	Can plant corn, sorghum, and soybean the following year.	Sorghum species	Cereals, ryegrass, legumes, and mustards.	More persistent in high pH soils (> 7).
Bicep II Lite Magnum	S-metolachlor/ atrazine		Corn, sorghum, soybeans, cotton, or peanuts may be planted the spring following treatment.	Sorghum species	Do not plant spring-seeded grains, or small-seeded legumes the year following application, or injury may occurs.	If applied after June 10, do not rotate to any crop except corn or sorghum until the following year, or injury may occur.
Cinch ATZ Lite Herbicide	metolachlor	15 to 50	Labeled for use on many crops	Almost anything	Annual ryegrass or other small seeded grasses	Higher rates and later applications more of a potential problem
Lumax Selective Herbicide	S-metolachlor	5 to 32	4.5 mo for winter wheat, barley, or rye; 10 to 18 mo for legumes	all grasses	Small seeded legumes, mustards.	Sequential applications increase potential for injury; do not rotate to food or feed crops other than those listed.
Harness Xtra	acetochlor	10 to 20	Four mo. for wheat and 9 mo. for alfalfa and clovers	Most crops should be fine	Food or feed residues rather than crop injury may be a concern	Nonfood/feed winter cover crops are allowed after corn harvest
Honcho Plus	glyphosate	2 to 174	No restrictions preemergence	All	None	Glyphosate does not have soil activity at normal use rates, but does adhere strongly to soil.
Prowl H20 Herbicide	pendamethalin	44	Wheat and barley after 4 mo. Other rotational crops the following year.	Cereal grains	Small seeded legumes and annual ryegrass	We have not seen this herbicide carryover in PA. Nonfood/feed winter cover crops should be OK
Require Q	sodium salt of dicamba		4-10 mo for winter wheat, spring wheat, oats, barley, and other crops (see label); 18 mo for other crops not listed on label.		Italian ryegrass, clover, sorghum, buckwheat, wheat, to popcorn or to sweet corn	
ResolveQ	rimsulfuron	2 to 4	Winter cereals have a 3 mo. restriction and many crops are restricted for 10 mo	Based on the short half-life, most fall cover crops should be OK in PA	None.	More persistent in drought conditions
Roundup Power Max	Potassium salt of glyphosate	2 to 174	No restrictions.	All	No restrictions.	
Simazine 90DF	simazine	60	Can plant corn, sorghum, and soybean the following year (some products allow others)	Sorghum species	Cereals, Ryegrass, legumes, and mustards	Soil pH > 7

Adapted from "Herbicides Persistence and Rotation to Cover Crops." Be sure to follow all labels for usage and restrictions.

Cover Crop Termination

There are several ways to terminate a cover crop: winter kill, plow down, herbicide, harvest, and "rolling" (using a roller crimper). Each termination strategy has its advantages and disadvantages. The strategy you choose ultimately depends on your overall cropping system goals. For example, many farmers are interested in terminating the cover crop with an herbicide or incorporation in early May to prepare for corn planting. Others wait and let the cover crop grow to obtain sufficient biomass for a forage harvest.

The good news is that all termination strategies will result in overall soil health improvement. Research has shown that even a single season of cover cropping can improve levels of soil aggregation, active organic matter, and potentially mineralizable nitrogen (Table 7). However, it should be noted that removing the plant biomass for forage or even terminating a crop with herbicide does diminish the nitrogen value that the cover crop could provide to the subsequent crop.

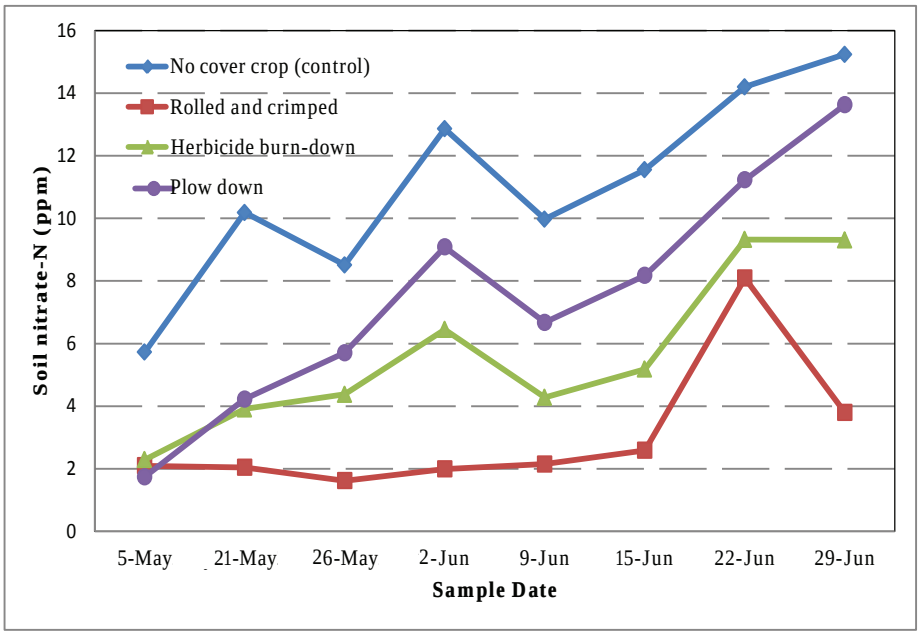
TABLE 7. **Quality of soil with and without cover crop production.**

	Organic matter (%)	Water stable aggregration (%)	Active carbon (mg kg^{-1})	Potentially mineralizable N (ug N g^{-1} d soil)
No cover crop	4.46 [a]	61.4 [b]	676 [b]	11.1 [a]
Cover crop	4.42 [a]	63.2 [a]	701 [a]	12.3 [a]

Winter Kill as a Termination Strategy

Probably the easiest way to terminate cover crops is to choose those species that die naturally over the winter. These include covers like tillage radish, winter peas, and oats. Residues do provide soil cover and brassicas, like radish, provide natural "tillage" by loosening and aerating the soil. However, to gain adequate benefit from winter killed cover crops, timely planting is required. Hence, you want to produce enough plant biomass in the fall prior to freezing to provide adequate residue throughout the winter. This requires that most winter killed cover crops be planted in mid to late summer.

FIGURE 8. **Nitrogen release from cover crops terminated by plow down, herbicide and roller-crimper, compared to no cover crop.**



Plow Down

Incorporating cover crops with tillage equipment or "plowing down" is another way to terminate the cover crop.

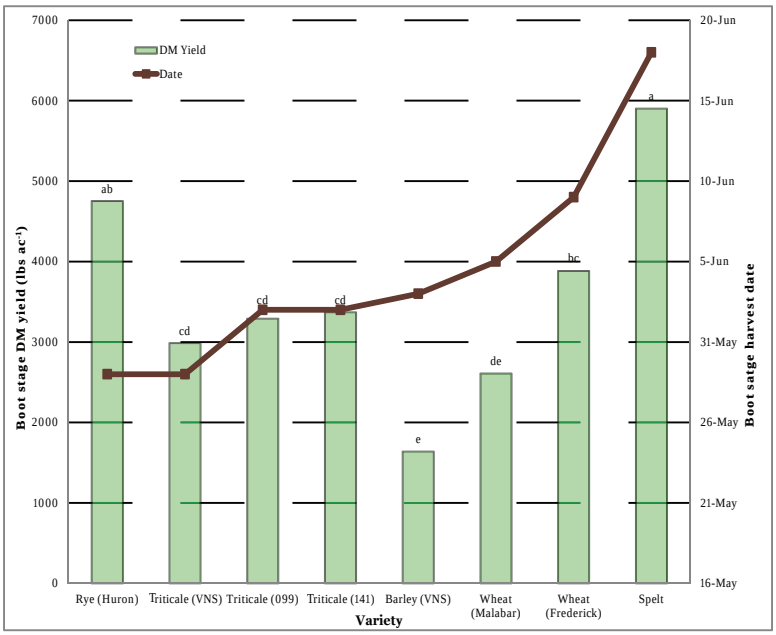
Incorporating a winter rye cover crop in its vegetative stage will result in the quickest nitrogen release to the succeeding corn crop. Figure 8 illustrates the nitrogen release of cover crops terminated by plow down, herbicide, and rolling. Cover crops that were incorporated released the most nitrates to the succeeding corn crop. Timing of incorporation can be critical in terms of nutrient release or immobilization. For example, a winter cover crop incorporated in the boot stage contains far more carbon than nitrogen. This imbalance can slow degradation and tie up valuable crop nitrogen after incorporation.

Terminating Cover Crops with Herbicide

For those cover crops that do not winter kill—like winter rye, for example—other termination strategy is the use of herbicides. Many conventional farmers chose to apply herbicides early in the season with an herbicide that works at cooler temperatures. Be sure to apply the labeled rate. To draw optimal nitrogen value from the covers, it is a good idea to wait until they green up and start to grow (about 6 inches tall). It is important to time termination carefully; if you wait until the cover crop is too tall, they can be slow to break down and tie up nitrogen needed for your cash crop.

To ensure the success of your herbicide program, keep the weather in mind. The crop should be terminated prior to a weather event that might keep the sprayers out of the field for more than 7 days, especially if it is the middle of May. If rain is in the forecast and you are contemplating whether or not to spray, it is likely prudent to go ahead and spray. If you wait, you may miss the window of an effective kill; by the time the sprayer might be able to get on the field again, the cover crop might quickly produce significant biomass and there will be additional expense in dealing with the cover crop to get the cash crop planted. In a no-till silage corn system, many farmers spray right before planting or right after planting. The goal here is to plant the corn into a "green" crop. This will drastically reduce problems related to the cover crop residue mucking up the planting equipment; depending on soil conditions, the planter may pull the dead cover crop out and its residue has a tendency to get wrapped on moving parts of the planter.

Figure 9. **Boot stage dry matter yield of winter grain forage by date of harvest.**



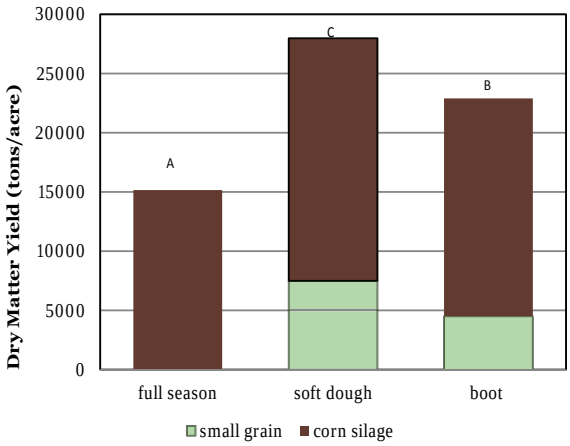
Harvest

Harvesting a cover crop as a forage can help you gain more production per acre from your fields. Cover crops as forages grow during months not commonly utilized for cash crop production so there is little competition with the main corn crop.

The harvest of these cover crops may be made by grazing or through mechanical harvest. Grazing a cover crop can allow for spring forage almost one

to two weeks earlier than perennial cool season pasture. If the winter forage is mechanically harvested, it will likely be cut in the boot stage to allow for a timely corn planting date. Winter forage harvested in the boot stage generally occurs between the third week of May and the first week of June (Figure 9). Fall planting dates can influence spring heading dates of small grains. Hence, an earlier planting date will result in cover crops ready to harvest for forage earlier in the spring. As a reminder, yields of the forage will be highly dependent on the number of tillers initiated in the fall. Our research has shown one to three tons of dry matter per acre from a harvested cover crop forage (Figure 10).

FIGURE 10. **Small grain cover crops harvested for winter forage and double-cropped with corn silage.**



To "double crop" effectively, silage corn must be harvested in a timely manner in the fall to allow the cover crop enough time to tiller in the fall and get a substantial yield in the spring. Depending on your location, a shorter day corn may need to be planted to allow sufficient time in the fall to get your cover crop growing well before the growing season ends. One strategy used by farmers in our area is to plant the corn for your "burn-down" pile on the fields on which you wish to double crop. You will harvest this feed early to allow it to ferment before feeding it to the cows. You can then plant the cover crop with ample time to get it established before the growing season ends.

Rolling

Rolling cover crops is a termination strategy that is gaining in popularity as more farmers adopt no-till and/or certified organic production. Here, cover crops (typically, cereal covers like winter rye) are allowed to mature until they flower. Once the cover is in the flowering stage, it is rolled. The machine (a roller-crimper) crimps the stems, killing the plant. Timing is critical; if covers are rolled too early, their stems will bend instead of break and won't die. If you wait too late, covers may produce viable seed that competes with your cash crop. The rolled cover crop acts as a mulch mat, suppressing weeds and the cash crop is then planted into the mat using a no-till, zone-till, or strip-till technique.

Example of one roller crimper design.

One of the challenges with rolling cover crops in corn silage systems in our region is to determine the optimal timing of termination of various cover crop species.

As the use of cover crops becomes more widespread, equipment innovations are starting to emerge. For example, some farmers are now testing roller crimping systems that mount directly to crop planters to allow for roll-crimp and planting in just one pass.

Final Thoughts

As with any innovative technology used on the farm, it is important to evaluate how to best implement cover cropping on your particular operation. The potential to increase farm profitability, improve environmental conditions, and more effectively use limited resources are within every farmer's grasp by adding cover crops to the management toolbox. However, just the opposite can occur if cover cropping field practices are undertaken without proper planning and implementation.

Cover crop variety selection, seeding techniques, proper planting rates, termination methods, and timing all play critical roles in the overall effectiveness of cover cropping. The implementation of cover crop technology can affect many different areas of the farm business as it deals with the soil and the crops produced, which are key to any farming operation. The degree of success with cover cropping is directly related to the level of management the operator devotes to it. Learning from other farmers with experience growing cover crops and/or from Extension and other agricultural service providers with whom they've worked can help ensure that you harvest the benefits of a cover cropping program on your operation.

Resources

Our Research Reports

The UVM Extension NWCS Program has been conducting on-farm trials on cover crops since 2007. You find the research reports of these trials, including the projects listed below, on our website at: **www.uvm.edu/extension/cropsoil**.

- Cover Crop Planting Date x Seeding Rate Trials (2010 - 2013)
- Cover Crop Termination and Reduced Tillage Studies (2010 - 2012)
- Cover Crop Planting Date Trial (2011)

Other Resources

- Cover Crop Solutions: www.covercropsolutions.com
- Managing Cover Crops Profitably: www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition
- Penn State Cover Crop Website: extension.psu.edu/plants/crops/soil-management/cover-crops

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