Strategies within cover crop-based, rotational no-till systems to build soil quality and reduce tillage frequency and intensity.

Organic grain producers typically rely heavily on tillage to incorporate amendments, bury residues, prepare seedbeds, and control weeds. Despite its utility, frequent tillage is fuel and labor intensive, can damage soil structure, leaves soil prone to erosion, and can reduce soil organic matter. Complete elimination of tillage in organic row crop production is not currently feasible but reducing tillage during certain phases of the crop rotation is possible. In an organic reduced-tillage cropping system, cover crops perform some of the functions associated with soil disturbance, such as weed or nutrient management, and creates the opportunity for limiting tillage frequency and intensity in the crop rotation. This practice is sometimes called cover crop-based rotational no-till. Similarly, relay cropping, where cover crops are seeded into standing cash crops, can provide opportunities to overcome management constraints to incorporating cover crops and can contribute to increasing soil quality.

In this article, we will present three main strategies within cover crop-based rotational no-till systems to build soil quality and reduce tillage frequency and intensity:

1. No-till cash crop planting into rolled cover crop mulch
2. Relay cropping
   - 2.1. Frost seeding cover crops into small grains
   - 2.2. Interseeding cover crops into corn
3. Incorporating a perennial crop into the rotation

1. No-till cash crop planting into cover crop mulch

In this approach, winter cover crops are grown to achieve large amounts of biomass and are terminated using a roller-crimper (Figure 2). In the spring, cash crops are no-till planted into the cover crop mulch. The mulch helps suppress weeds during the cash crop growing season as well as preserve soil moisture and provide habitat for beneficial predatory insects.

Reliable cover crop performance is a critical factor determining whether rotational no-till techniques can be successfully integrated into organic annual grain production. To fit into rotational no-till systems in the Mid-Atlantic region, cover crops must be winter hardy and capable of establishing after cash crop harvest in the summer or fall. Cover crops need to be susceptible to effective control with a roller-crimper to prevent them from becoming weeds and competing with or contaminating the cash crop. Additionally, in the Mid-Atlantic US, cover crops must produce about 5,000 to 7,000 lb/ac or more of biomass (dry matter) to form a mulch capable of suppressing weeds. Biomass production at the lower end of this range can be sufficient to suppress weeds in northern areas of the Mid-Atlantic, but the upper portion of the range is typically needed farther south where warmer temperatures accelerate mulch decomposition and weeds germinate over a longer period of time. To achieve these biomass levels, cover crops are seeded September-early October, usually after a winter grain or corn silage harvest. Even if high biomass levels are needed to create a weed suppressive mulch, optimizing cover crop management rather than biomass production should be the primary management objective. Management decisions such as delaying cover crop termination to obtain more biomass may improve weed
control, but this can reduce cash crop yields due to a shortened growing season. Integration of other weed management tactics, for example, high-residue inter-row cultivation, can improve weed control consistency and may reduce reliance on maximizing cover crop biomass for weed suppression.

For more information about the use of the roller crimper in Northeastern grain production visit the Penn State extension site.

Figure 2. Roller crimper mounted ahead of the tractor rolls cereal rye and planter seeds soybean after it.

1.1. Choosing the right cover crop: when to plant and when to terminate

Two cover crop species consistently identified as having the potential to meet the demands of organic rotational no-till production in the Mid-Atlantic are cereal rye (Secale cereale L.) and hairy vetch (Vicia villosa Roth). Both species are winter hardy and can produce sufficient biomass to form the mulch needed to suppress weeds. Usually cereal rye is seeded before soybeans and hairy vetch, usually combined with a grass, is used before corn.

Cereal rye before soybean. Cereal rye is the most winter hardy small grain, making it a good candidate for planting after corn or other later summer/fall harvested crops. Cereal rye is also well suited to follow corn in a corn-soybean rotation because soybean can be planted into rolled cereal rye and does not need the nitrogen that may be immobilized by decomposition of the cereal rye residues. However, for cereal rye to accumulate enough biomass to be rolled and effectively suppress weeds in the soybean phase, cereal rye needs to be seeded by early October in central PA. The target date may need to be earlier as you move north into New York and can be delayed a few weeks moving south into Maryland. In central PA and North, corn may have to be harvested as silage to meet optimum cereal rye seeding date.

Sow cereal rye at a minimum of 120 lb/acre. Drilling improves establishment and provides a more uniform plant population in comparison to broadcast methods. Prepare a seedbed that is smooth and free of weeds to ensure the cereal rye emerges quickly and becomes well established. Also, if levels of soil mineralizable nitrogen are low, consider fertilizing the cereal rye or applying manure to maximize biomass and ground cover. In the Mid-Atlantic region, cereal rye regularly produces 5,500 lb/acre of biomass but can exceed 10,000 lb/ac under more intensive management. Cereal rye can be effectively terminated with a roller-crimper when it is between 50% anthesis and early milk stages (Figure 3) and by making one or two passes with the roller crimper. In Penn State research, more consistent control of cereal rye was achieved by making two passes with the roller-crimper about one week apart. Soybean were planted on the same day as the second pass. The combination of rolling and planting does a much better job at terminating the cover crop than simply rolling. No-till planting soybean into roller-crimped cereal rye has produced yields similar to conventionally tilled organic soybean in experiments across the Mid-Atlantic.
Soil Building Practices in Organic Annual Grain Systems

**Figure 3.** Cereal rye in anthesis.

**Hairy vetch before corn.** Cover crops before corn need to be managed to control weeds but also to provide a source of N to the following cash crop. Hairy vetch is a legume capable of producing 5,500 lb/ac of biomass and providing as much as 180 lb/ac of nitrogen to the following crop. Hairy vetch biomass production, N fixation, and residue persistence can be increased by growing it in a mixture with a small grain such as cereal rye or triticale (Figure 4). Seeding rates of 20 to 30 lb of hairy vetch in combination with 30 lb/acre of triticale or cereal rye is needed to achieve maximum N content and low C:N ratios. Hairy vetch and triticale mature about the same time, while cereal rye matures ahead of hairy vetch making termination timing more challenging. However, when selecting mixture seeding rates also consider initial field conditions. Sites with low residual soil fertility will favor the growth of the legume(s) in a mix due to the ability of legumes to fix atmospheric N, whereas grasses in a mix are likely to dominate on high fertility sites due to their rapid growth and ability to scavenge N. Therefore, seeding rates should be adjusted according to the primary needs of the site (e.g., N-fixation, weed control, etc.), minimize seed costs, and maximize the benefits provided by the cover crops.

**Figure 4.** Hairy vetch triticale mixture ready to be rolled

Delayed termination and higher seeding rates can also increase hairy vetch biomass accumulation prior to termination. Control of hairy vetch with a roller-crimper is most effective when it is at full bloom to early pod set (Figure 5, stages 6 – 7). However, despite improvements in assessing hairy vetch maturity, control of hairy vetch cover crops with a roller-crimper can range from complete to variable and poor. This range in control represents not only a potential risk to corn yields, but also to future crops if hairy vetch produces seed. To help overcome this challenge, roll the hairy vetch twice to maximize the chance of effective termination. There are two possible approaches to do this: roll the hairy vetch twice and then plant corn (roll-roll/plant approach) or roll the hairy vetch, plant corn and roll the cover crop again (roll/plant – roll) before corn emergence (3-10 days after the first rolling). This latter
approach usually results in better outcome and lowers the risk of delaying corn planting due to a rain event between the first and the second rolling. As with cereal rye, the combination of rolling and planting more effectively terminates the cover crop than simply rolling. For more information about cover crop termination with a roller crimper, see our article on optimizing termination timing. Yields of no-till planted corn can be less consistent than yields of soybean no-till planted into a cover crop mulch because of the constraints to fertility management. Even if legumes can provide some N, supplemental N from approved sources are often required to meet corn needs. Organic fertility amendments are generally more difficult to apply than synthetic fertilizers and can be also more tightly regulated in the Chesapeake Bay watershed.

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Figure 5. Hairy vetch phenology. For effective termination with the roller crimper, wait until early pod set (stage 7). From Mischler (2009).

1.2. Cash crop establishment in heavy residue

Establishing a good cash crop stand into heavy cover crop residue can be challenging. Plant cash crops in the same direction as roller-crimping (ideally in a single pass) so that the coulters on the no-till planter can part the residue rather than be forced to cut through cover crops rolled perpendicularly to the direction of planting. Even with this precaution, cover crop residue may be difficult to cut and can be pushed into the seed furrow (i.e., hair-pinning, Figure 6), which can impede placement of seed into the soil. Cereal rye specially can be problematic if lodging occurs prior to cash crop planting. Row cleaners (trash wheels) can reduce hair-pinning by moving cover crop mulch away from the seed row, however, their use results in uncovered soil that may be prone to weed infestation. There are several commercially-available trash wheels, but units must have a narrow blade angle and ideally overlap to adequately cut and move residue. A relatively new (mid 2010’s) planter attachment, known as a residue slicer, has shown promise to help cut through rolled cover crop and improve uniformity of seed placement by the planter units where row cleaner disturbance of the rolled cover crop is undesirable. The slicer is essentially a smooth coulter equipped with rubber-coated wheels on both sides of the coulter. The attachment is mounted in place of a no-till coulter. The improvement provided by the slicer is realized when the wheels hold the residue tight against the soil at the moment the smooth coulter contacts the residue. The result is better residue slicing and less residue hairpinning, while minimizing the creation of residue-free areas in the field.

Figure 6. Hair-pinning of cereal rye results in soybean seeds (white arrows) on soil surface.
1.3. Effective weed control for cash crops planted into heavy residue

Rolled cover crop residue can provide in-season weed suppression in corn and soybean by reducing weed germination and by physically interfering with seedling recruitment and establishment. However, a short growing season, weather-related interference with field operations, or inconsistent cover crop growth can result in below-targeted cover crop biomass residues. Therefore, other tactics may be needed to manage weeds within the cash crop growing season. Effective blind cultivation (rotary hoe or tine weeding) is not possible in these high residue systems but interrow cultivation can supplement between row control. High-residue cultivators are typically equipped with a single, wide flat sweep (about 20 inches) that is set to operate 1- to 3- inches below the soil surface, resulting in minimal soil disturbance (Figure 7). The sweep severs the roots of weeds from the aboveground portion of the plant and thus is effective in managing weeds after they have established. We recommend two passes with the high-residue cultivator at 4 and 6 weeks after planting to improve weed control efficacy. The second pass is needed to dislodge weeds that survived the first pass and increase control of weeds species that germinate after the first cultivation. The high-residue cultivator can be especially effective in controlling early-emerging summer annual species such as common ragweed.

2. Relay cropping

Relay cropping refers to growing two crops or, in the cases explained here, a cover crop and a cash crop simultaneously during selected times during the crop rotation establishing a cover crop into a standing cash crop can provide benefits to the cash crop, such as increased N availability when a legume cover crop is used and can increase the likelihood of successfully establishing a cover crop in situations where establishment after cash crop harvest is challenging. Here, we present two examples of relay cropping with cover crops: 1) Frost seeding a cover crop into a standing winter annual grain, and 2) interseeding a cover crop into standing corn

2.1. Frost-seeding cover crops into a small grain

Frost-seeding cover crops into an annual winter grain is a common interseeding practice for organic growers. Legume cover crops are usually seeded into winter wheat or spelt in late winter when the soil is still frozen. As the temperatures rise, the freeze and thaw cycle helps to incorporate the seed into the soil, which enhances establishment. Benefits of this approach are that the legume provides nitrogen to the growing cereal grain and the cover crop is already established when the grain is harvested. This practice is also sometimes used for spring seeded cereals like oats as well.

2.1.1. Choosing the right cover crop for frost-seeding

The most common cover crop frost-seeded is medium red clover (Trifolium pratense) broadcasted or drilled at approximately 10 lb/A. Seeds should be inoculated prior to seeding with a non-GMO inoculant if red clover hasn't been grown in this field recently. Mammoth red clover has also been successfully established by frost-seeding in research plots in the Upper Midwest.

2.1.2. How to frost-seed cover crops?
Cover crops are often frost-seeded by spinning the seed on using a tractor or ATV in the spring, usually during March when the ground is still frozen. However, seeding using a no-till drill is a way to more consistently establish frost-seeded cover crops (Figure 8). As the weather warms, the seeds germinate, and cover crops start to grow. Competition from the clover is minimal as the small grain canopy is consistently taller than the clover and soil moisture is usually plentiful through the completion of grain fill. Further, being a legume, the clover is capable of fixing the N it requires. This practice eliminates the need to till the ground after the cereal harvest in summer to seed a cover crop and can provide enough biomass for up to two summer or fall forage cuttings.

Figure 8. Frost seeding red clover in March (left). Growth of frost-seeded red clover at wheat harvest in July at Summit Valley Farm (right).

2.2. Interseeding cover crops into corn

In an annual grain rotation, cover crops can be established without tillage by directly seeding them into corn or soybean stubble after cash crop harvest. However, corn (and especially corn for grain) and soybean harvest occur late in the fall in much of the Mid-Atlantic and northern Corn Belt, resulting in insufficient time for establishment and growth of a cover crop drilled after grain harvest. Sparse fall and winter cover crop growth usually translates into a poor realization of cover crop goals. Interseeding of cover crops is the process where cover crop seed is broadcasted over fields or drilled into standing grain crops between the rows of grain crop. It can provide field cover that is superior to what might result from drilling late in the fall after grain harvest. This technique has been especially successful in corn, as it does not shade out cover crops as much as soybeans do. In regions where double-crop soybean are grown, interseeding cover crops in late summer has been successful but requires soybean to be planted in wide rows to allow sunlight penetration and operation of the interseeding equipment.

When cover crops are interseeded into standing corn, pay attention to two important factors: 1) the cover crops need to be able to germinate, establish, and survive in the shade of the cash crop until the cash crop is harvested, and 2) the cover crop needs to be seeded at the correct time to prevent it from competing with the cash crop.

2.2.1. Choosing the right cover crop

There are not many species that can establish and survive in the shady environment of a corn crop. Currently, we recommend annual ryegrass, forage radish, medium red clover, crimson clover, and orchardgrass, either alone or in a mixture (Figure 9). Hairy vetch and cereal rye have been successful in double-crop soybeans, but not in corn. Table 1 provides the recommended seeding rates for single species. The lower range is recommended in mixtures. Use legumes if soil N levels are low and use grasses or brassicas if soil fertility is high, to retain N and prevent leaching. Also consider these suggestions if you are planning on using a mixture. Legumes in the mix may not do well if soil N is high and grasses may not do well if soil N is low.

Table 1. Recommended seeding rates for interseeding cover crops into standing corn

<table>
<thead>
<tr>
<th>Cover Crop Species</th>
<th>Rate (lb/ac)</th>
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</thead>
<tbody>
<tr>
<td>Annual Ryegrass</td>
<td>15-20</td>
</tr>
<tr>
<td>Orchardgrass</td>
<td>15-20</td>
</tr>
<tr>
<td>Medium Red Clover</td>
<td>8-10</td>
</tr>
<tr>
<td>Crimson Clover</td>
<td>10-15</td>
</tr>
<tr>
<td>Forage Radish</td>
<td>3-5</td>
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</tbody>
</table>
2.2.2. How to establish a cover crop into standing corn

Cover crops can be drilled or broadcast into standing corn depending on available equipment. Some methods for establishing cover crops into standing corn include:

- Aerial seeding for large areas. Seed losses are high and germination rates usually low with this method, so seeding rates should be increased accordingly (Figure 10A)

- High-boy interseeders that include air seeding equipment and drop tubes hanging from the boom to guide seed down between crop rows (Figure 10B)

- High clearance no-till drills that drill the cover crop seeds in the inter-row (Figure 10C)

- Fertilizer spreaders that spin the cover crop seed on at the last cultivation

Drilling the cover crop provides the best seed to soil contact and therefore, usually results in the best germination rates. If possible, when broadcasting seeds, through aerial seeding or with high-boy type equipment, schedule planting when there is a chance of rain soon after seeding to ensure good cover crop germination. Establishment timing differs depending on the method, see next section for more details.

2.2.3. When to establish a cover crop into standing corn

Timing of interseeding cover crops in corn is crucial. If using high clearance equipment or aerial seeding, broadcast the seeds in mid- to -late season, when corn leaves are senescing and cover crop seeds will have more access to light. Timing of interseeding with a drill is equally important. If cover crops are seeded too early they can compete with the cash crop and behave like a weed. We recommend waiting to interseed cover crops until corn reaches at least the V4-V5 stage (four-five unfolded leaves, with leaf collars formed, figure 11). If cover crops are seeded too late and the corn canopy is already closing, they have a lower chance of germinating, establishing, and surviving until the cash crop is harvested. Even if seeded at the correct time, as soon as the canopy closes, cover crop growth will slow or completely stop, but as corn matures, successfully established cover crops will resume growth. Corn density and variety can also influence cover crop establishment. Corn density greater than 30,000 plants/acre, and longer season varieties (>105 days) that are harvested later are more competitive and the cover crop may not survive the shading.
3. Incorporating a perennial crop into the rotation

Incorporating a perennial such as alfalfa or an alfalfa-grass hay mixture for 2 to 4 years in feed-grain rotations is a common practice in organic agriculture. Perennial crops are often incorporated at regular intervals after a few years of intensive annual grain production. A perennial forage crop that allows mowing or even some grazing of livestock is a powerful tool for combating both annual and perennial weed problems. These crops can also help build soil fertility, improve soil structure after tillage-intensive annuals, and can break disease and insect pest life cycles associated with annual grain crop production.

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