WHY INCLUDE COVER CROPS IN WISCONSIN CROP ROTATIONS?

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What Is A Cover Crop?

A cover crop is a crop grown to benefit the soil and other crops in the rotation and is usually not intended for harvest. The term cover crop is really a catchall phrase for numerous uses ranging from soil conservation, nutrient retention and environmental protection, improving soil quality and reducing use of purchased inputs. As such, a cover crop is usually planted to provide soil cover during otherwise idle intervals, or fallow periods, in a given crop rotation – that is, between harvest and planting of commodity or feed crops. In some cases, “living covers” may be inter-planted to grow with the commodity crop.

Cover crops are widely recognized as an integral component of organic production systems but also have great potential in conventional agriculture where several cover crops systems have been successfully implemented by producers. The right cover crop can provide multiple benefits while other uses and benefits are mutually exclusive. For example, a green manure crop grown to provide nitrogen (N) will not increase soil organic matter because it’s biomass must rapidly decompose to release N to the following crop.

Examples of Cover Crops for Use in Wisconsin

Legumes

- Hairy vetch
- Chickling vetch
- Sweet clover
- Red clover
- Berseem clover
- Crimson clover
- Field pea

Non-legumes

- Oats or barley
- Annual ryegrass
- Winter (cereal) rye
- Buckwheat
- Tillage/Forage radish

Fast growing legumes, such as annual clovers or vetches, can be planted after short season crops such as small grains or peas. With adequate top and root growth, and associated root nodulation, legume species will fix atmospheric nitrogen into their biomass for microbial release to a following N-demanding crop such as corn, potatoes or snap bean. This is in addition to protecting the soil against erosion and suppressing weeds that may otherwise grow and produce seed, following harvest of these commodity crops.

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In Wisconsin, some producers have found success planting relatively fast establishing species such as berseem clover, chickling or hairy vetch following small grains in late July to mid August. But the soil moisture required for acceptable growth can be less predictable at this time. Medium red clover has shown better consistency in biomass and N yield, but must be planted in early spring with spring seeded small grains or frost seeded into winter grains.

While legume covers are primarily used as biological N producers, non-legume species have slightly different niches. Small grain species such as winter rye, barley, oats or winter wheat tend to be used more for soil conservation, field runoff prevention and soil nutrient retention. In southern Wisconsin, annual small grain species probably need to be planted by September 1 for significant growth and soil protection going into winter (Stute, 2000). Winter (cereal) rye or winter wheat are popular choices to follow corn harvested as silage or early maturity soybeans. Both crops leave relatively little crop residue after harvest and manure is often applied following corn silage. The winter annual grass crops can provide some soil cover, slowing runoff, and have fibrous root systems that help to recycle N and P for next year's crop reducing runoff and leaching losses.

Other non-legumes, such as buckwheat or sorghum-sudan grass hybrids, planted in mid-summer after peas or early snap beans, can be used primarily as weed suppressors and/or soil builders. Their ability to grow quickly at this time, producing several tons of biomass per-acre, can smother, by competition, persistent perennial and other weeds and add recalcitrant organic matter to aid soil conditioning (structure and quality). Sorghum-sudan and winter (cereal) rye, produce allelochemicals (sorgeleone and diboa, respectively) that function as natural herbicides for some following crops if managed accordingly. Another non-legume cover growing in popularity is forage (or tillage) radish which potentially produces a very long taproot selected to penetrate sub-surface soil compaction, thus providing a so-called "bio-tillage." The UW-Extension (*UWEX*) Cover Crops workgroup is beginning to evaluate this species in on-farm and research station trials.

Cover crops work by capturing unused solar energy and storing it as carbon and fixed N (if the cover is a legume) in their biomass along with associated soil derived nutrients. This energy is released to the soil by microbial decomposition of the residue. The amount of unused or wasted energy in some cropping sequences can be substantial. Figure 1 shows growing degree day (GDD) accumulation in Southern Wisconsin from July 1 through October, a period often fallowed after harvest of short season crops. Fully one-half of GDD accumulation occurs during this time.

Purposes and Functions of Cover Crops

Soil Conservation

This use is where the term cover crop is derived. Rapid growing species with spreading stature provide cover on soil with low residue cover, preventing soil and nutrient movement and maintaining soil productivity. By reducing erosion, they can help maintain conservation program eligibility and cropping flexibility on highly erodible land (HEL).

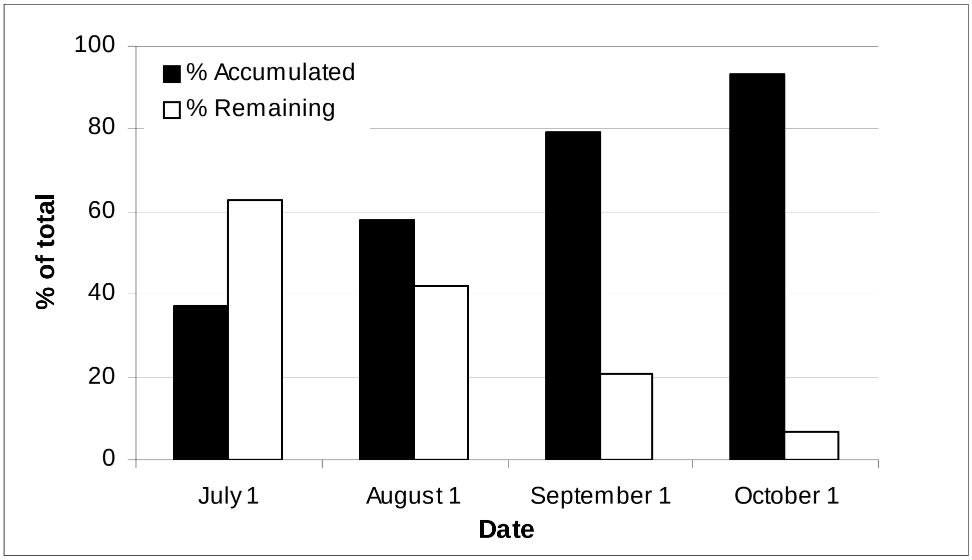

Figure 1. Mean growing degree-day accumulation in Southern Wisconsin, Arlington, (30 year average, AWON).

Some of the more common cover crop systems have been built into the RUSLE2 module of the SNAP Plus nutrient management planning software. This allows a planner to assess the impact of cover crop scenarios on a producer's current conservation plan. Table 1 shows the impact of a red clover cover crop on predicted soil erosion on several soil types and tillage systems.

Soil Building by Adding Organic Matter and Improving Structure

Cover crops can help maintain or increase soil organic matter levels by adding more residue than would be produced by the cropping system alone. To contribute more stable OM, the species selected must produce significant dry matter which is also recalcitrant. In general, grass species have higher C:N ratios than broadleaves (and especially legumes) so they are more resistant to complete decomposition. Lignin content is also important because it resists decay.

Soil quality can be improved by an increase in aggregation and reduced compaction. Since cover crops are often terminated at a vegetative stage of growth, their tissues provide a highly suitable substrate for microbial growth, resulting in greater populations and a more diverse species mix. The resulting increase of biological activity produces microbial gums which glue soil particles together, resulting in better aggregation. Legume cover crops also stimulate mycorrhizal fungi that produce glomalin, a water insoluble glyco-protein that produces more stable aggregates. Even though legumes don't contribute to OM levels, these two aggregate forming processes are important for soil structure.

Root penetration can relieve plow layer and deep compaction and create macro-pores for improved gas exchange and water infiltration. This is important in no-till systems which have no other option, especially when soils are damaged by wheel traffic during wet conditions. Many cover crops are planted at densities which greatly exceed those of routinely grown field crops, increasing the total volume of soil influenced by roots. Species with deep taproots can influence compaction deeper in the soil profile.

Table 1. `Effect of red clover on estimated soil loss (SNAP Plus RUSLE2) based on tillage for corn and soybean (no-till or fall chiseled). Clover seeded into winter wheat as part of a soybean-wheat-corn sequence. Yield levels: 46-55, 81-100, 151-170 bu/a respectively.

			Soybean tillage system			
			No-till		Fall chisel	
			Corn	Corn	Corn	Corn
Soil type	"T"	Clover	NT	CT	NT	CT
			Annual soil loss (ton/acre/year)			
Fox	4					
		-	0.5	2.4	2.0	3.1
		+	0.3	1.9	1.6	2.5
		reduction(%)	40	21	20	19
Kidder	5					
		-	0.5	2.7	2.3	3.5
		+	0.3	2.2	1.8	2.9
		reduction(%)	40	19	22	17
Ogle	5					
		-	0.4	2.1	1.8	2.7
		+	0.2	1.4	1.3	2.2
		reduction(%)	50	33	28	19

6% slope, 500 ft length

Nutrient Management

Adapted cover crops can play a significant role in nutrient management, adding biologically fixed N in the case of legumes, retaining readily lost nutrients or managing soil test levels, especially phosphorus.

Green manure crops fix atmospheric N that can be used to meet a significant portion of the requirements of high N demand crops such as corn. Nitrogen credit information for various legumes can be found in UWEX publication A2809, Nutrient Application Guidelines for field, vegetable, and Fruit Crops in Wisconsin. The amount of credit is based on total biomass which is related to length of growing season and above-ground herbage management.

Nutrient retention includes excess nitrate-N which could otherwise leach and phosphorus which could be lost with run-off. Rapid growing species reduce losses by accumulating these nutrients in their biomass, by increasing infiltration and reducing soil movement. Winter rye planted after corn silage is a good example of a cover crop which can accomplish both of these functions. Data from Wisconsin shows a 50% reduction of nitrate-N the spring after manure application when winter rye was grown (Stute et al., 2007). Winter rye is also capable of removing large amounts of soil P if the biomass is harvested for forage (Shelley and Stute, 2008). This research showed that P removal is maximized at N rates which optimized forage yield and confirmed rye is a luxury consumer of P under Wisconsin conditions, meaning that P removal increases with increasing soil test levels. See Shelley and Stute (2008) for a discussion of nutrient management planning implications.

Weed Management

There are three main mechanisms whereby cover crops can provide a weed controlling function:

1. Smothering and competition
2. Allelopathy
3. Enhanced crop competitiveness

Research trials and on-farm experience show that these mechanisms can be effective components of an integrated weed management program, but none are likely to provide consistently acceptable control on their own in agronomic or horticultural crop rotations.

(1) Smothering and competition

Some cover crops can provide a "smother crop" function whereby the cover grows more aggressively than most of the weed species present, and out-compete weeds for water, light and nutrients. Thus, many of the weeds that would otherwise grow are prevented, for this time, from growing and producing seed that would be added to existing soil seed banks. Suppression of some weed species MAY last longer than the duration of the cover crops and into the following production crop. This could be the result of an induced dormancy of weed seeds or from the cover crop's allelopathy. Examples may include buckwheat, sorghum-sudangrass, rye, barley or other small grains, hairy vetch or sweet clover.

(2) Allelopathy

Allelopathy is the ability of some plant species to reduce the growth and development of others via chemical inhibitors. Thus, these plants are producing and releasing their own bio-herbicide as a competitive mechanism. Chemical compounds are released either as root exudates from a living, growing plant, or are released from dead, decomposing plant tissue after the crop is killed with herbicide or tillage. The phytotoxic allelochemicals function to inhibit seed germination or stem elongation of other plants.

The inhibitory effect is usually reduced substantially if the allelopathic cover crop is incorporated into the soil. The dying, decomposing plants need to remain on or very near the soil surface for the compounds to be effective on germinating seeds and seedlings. Also, killing the cover crop at the right stage of growth is important, usually near or after flowering and pollination. This is when the allelochemicals are often at their highest concentration and when the cover crop is less likely to re-grow and become a weed itself. Winter (cereal) rye has been shown in SOME field and laboratory research to be the most effective of the small grains in production of allelochemicals and inhibition of weed seed germination and stem elongation. Sorghum-sudangrass produces sorgeleone, a relatively potent allelochemical as well.

The primary biochemicals involved include:

- Phenolic compounds such as ferulic acid and coumaric acid
- Amine alkaloids (grammines)
- Hydroxamic acids: DIBOA (dihydroxy benzoxazin) and BOA (Benzoxazolin)

Field studies suggest suppression of small seeded annual weeds (and crops) more than larger seeded. Corn, soybeans and wheat have generally been shown as not affected by allelopathic chemicals. Control efficacy is not complete on its own, reported in the range of 20-90% (season long) compared with untreated controls of no cover crop or other controls. Some of the weeds shown to be suppressed by small grains, hairy vetch and sorghum-sudangrass include barnyardgrass, bristly foxtrail, crabgrass, wild proso millet; jimsonweed, velvetleaf and redroot pigweed.

While weed control resulting from allelopathic cover crops is usually not complete, it can be an effective component of either an organic or conventional system. In an organic system, allelopathy can help control early developing weeds, but mechanical cultivation will usually be required to supplement later. In a conventional no-till or reduced till systems, allelopathy can often be used to reduce herbicide requirements by replacing one application in what may otherwise be a two pass herbicide program.

For example, research was conducted at Arlington, WI in 1989 and 1990 by Jerry Doll and Tom Bauer with soybeans no-till planted into rye just after it was killed, either by mowing (sickle bar) or by Glyphosate application (Doll and Bauer, 1991). Results showed that rye killed in early May, when rye was in the tillering stage (10-12"), did not provide season-long weed control, and that a 2nd post emerge application was required. But, when they waited until boot or heading stages to kill the rye, season-long weed control was adequate and yields were competitive with one Glyphosate application for burn-down of the rye (before soybean planting). In treatments where the initial kill was by mowing, weed control and soybean yield were generally comparable (some favorable) when the mowing was at boot or heading stages and followed by one post emerge application of Glyphosate. Soybean yields were, however, maximized in a no-till, 2-pass system without rye in 1990.

However, more recent trials at Arlington by Dwight Mueller and Jerry Doll (2003-05) showed season-long weed control and acceptable soybean yields by no-till planting soybeans into growing rye in the jointing stage (8-12") with Glyphosate applied shortly after (Stute et al., 2008). Soybeans developed as the rye died and no additional herbicide applications were required. Soybean yields were equal to soybeans planted without rye. Corn yields were reduced in the no-till rye system. This was interpreted as due, not to allelopathy, but, to competition from the rye residue, cooler soil temperatures and delayed planting compared to a no-rye comparison. Nitrogen immobilization from the decomposing rye residue also likely contributed to reduced corn yield. These are all factors soybeans seem to tolerate better than corn.

(3) Enhanced crop competitiveness

As discussed previously, soil quality and nutrient cycling benefits associated with cover crops will serve to enhance the competitive abilities of the crops against weeds as well as other pests.

<u>Supplemental Feed Production</u>

Productive cover crops can be harvested for forage and still accrue many of the conservation benefits they were planted for. Herbage can be harvested either as a planned management practice or in years when forage inventories are reduced by less than optimal growing conditions.

Winter rye is again a good example and is discussed in the NPM publication: Planting Winter Rye after Corn Silage: Managing for Forage. Other options include small grains after short season crops (Oplinger et al., 1997) or red clover interseeded with winter wheat. In on-going research, two years of red clover forage harvest data shows an average DM yield of 2.23 t/a (harvested in early

November) with quality measurement of: 134 RFQ; 16.8% CP; 32.6% ADF and 41.2% NDF (Stute, 2009).

Carbon Sequestration

Because cover crops capture unused solar energy and store it as carbon in their biomass, they have potential to sequester C, especially if their residues resist decay. Little is known about this potential use because it's emerging area of research, but ultimately successful systems may provide an additional revenue source in carbon cap and trade systems.

Risk and Incentive

While cover crops can provide several benefits, their use also has potential risks which need to be considered. These risks include cover crop failure or poor performance and negative impact on the subsequent crop. Failure of the cover crop results in additional costs without the intended benefits. If the cover is intended to reduce input use, for example growing a legume for nitrogen credits, then the added cost is combined with the cost of full rate nitrogen needed to optimize production of the following crop. Potential negative impacts also include soil moisture relations, either depletion or slower drying in spring caused by increased surface residue, potential disease and insect interactions, N immobilization by high C:N residues, allelopathy, competition from escapes or volunteers and crop insurance ineligibility. Any of these has the potential to reduce income by yield reduction or added costs.

Short and long-term economic benefit should be weighed against the risk when deciding to implement the practice of cover cropping. The *UWEX* Cover Crop workgroup has conducted several trials related to successful systems which have identified best management practices to minimize risk and optimize income. Examples include winter rye after corn silage and interseeding red clover in winter wheat. Factsheets outlining these systems and their best management practices are available at: http://ipcm.wisc.edu/Publications/tabid/54/Default.aspx

Cost-share programs may be available, either locally or through the NRCS Environmental Quality Incentive Program (EQIP) to offer short-term financial incentive for using cover crops.

The long-term benefit of cover crop use is improved soil quality which should translate into higher crop yield. Long-term cover crop use is also a performance criterion for the NRCS Conservation Stewardship Program which provides financial reward for using environmentally sound farming practices.

Success with Cover Crops

Cover crops require the same management attention as other crops to be productive This includes selecting the right species, using quality seed and inoculant, making sure soil conditions are right for establishment, calibrated seeding equipment and using the right termination method and timing. Also, look for efficiencies to combine operations for reducing costs such as broadcasting seed with fertilizer. Finally, start with a small area to experiment with before implementing the practice on a large scale.

Information Resources for Cover Crops

Publications

Managing Cover Crops Profitably, Third Edition
http://www.sare.org/publications/covercrops.htm

Cover Crops on the Intensive Market farm, June 2009
http://www.cias.wisc.edu/wp-content/uploads/2003/09/covercrop09final.pdf

Websites

Midwest Cover Crops Council
http://www.mccc.msu.edu/index.htm
Website provides links to a variety of state level publications, resources and expertise.

ATTRA, National Sustainable Agriculture Information Service
http://attra.ncat.org/attra-pub/covercrop.html
This is a national level information clearinghouse.

Seed Sources

Welter Seed and Honey, Onslow IA.
http://www.welterseed.com/default.aspx

Albert Lea Seed House
http://www.alseed.com/

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