

Measuring the Benefits of the Cover Crop Practice

One of the goals of conservation planning is to consider the effects of conservation practices and systems on soil quality. A number of assessments tools exist to measure the impact of the Cover Crop practice.

Assessing Cover Crop Value as it relates to Soil Quality Benefits

1. The Revised Universal Soil Loss Equation (RUSLE2) and Wind Erosion Prediction System (WEPS) planning software is used to evaluate the impact of cover crop management decisions have on soil loss levels. In addition, RUSLE2 has the Soil Condition Index (SCI) that determines a relative value for anticipated Organic Matter based on management of the cover crop.
2. A soil health assessment is used to determine existing soil characteristics. Typical soil health assessments include soil organic matter levels, soil respiration rates, soil bulk density, soil penetrometer readings, soil infiltration rates and observation of soil cohesion utilizing the slake test.
3. Observable reduction in soil erosion (sheet, rill, ephemeral, and gully). Cover crops increase vegetative and residue cover during periods when erosion energy is high. The addition of cover crops to low residue cropping systems such as corn silage and vegetables can substantially decrease soil erosion.
4. Observable soil porosity improvements due to an increase of biomass, that when decomposed, increases soil organic matter content promoting increased microbial activity and aggregation of soil particles. As a result, soil porosity is increased and bulk density is decreased. **Caution:** avoid planting cover crops when soils are saturated to avoid compaction, or use alternative establishment methods such as aerial over seeding.
5. Observable soil aggregate stability which results in less soil crusting. Cover crops reduce soil crusting by protecting the soil surface from the direct impact of rain drops. The resulting increase of soil organic matter, improved infiltration, and increased aggregate stability will further reduce soil crusting and improve the uniformity of seed germination.
6. Adequate soil surface cover and the improved aggregate stability will reduce erosion and surface water run-off and increase water infiltration rates. Channels created by cover crop roots and earthworms form macropores that further improve infiltration. Cover crops, especially small grains, can effectively capture and utilize excess nitrogen to prevent infiltration below the crop root zone.
7. Cover crops reduce the volume of surface runoff resulting in reduced nutrient losses. Decomposition of cover crop or green manure biomass provides a slow release of nutrients to the root zone. Legume crops fix atmospheric nitrogen and provide nitrogen for the main crop. Legumes also capture more phosphorus than grass or small grains. Small grains are useful as catch crops to utilize end of season nitrogen, which reduces the potential for nitrogen leaching. Planting cover crops on continuous corn silage fields with a history of repeated manure applications during late summer is highly beneficial.
8. Nutrient Immobilization can be observed when decomposition releases available nitrogen to the next crop.

The carbon-to-nitrogen (C:N) ratio is a relative estimate of the nitrogen necessary to decompose an organic matter (crop residue) source. A C:N ratio of 50:1 or higher will temporarily “immobilize” soil nitrogen. The immobilization is a result of microbes consuming readily available soil nitrogen during the decomposition of crop residue. The nitrogen will remain immobilized until the microbes deplete the crop residue or other organic matter sources.

Young cereal rye plants have a 14:1 C:N ratio as compared to corn stalks with a 60:1 C:N ratio. The C:N ratio for most clover plants is generally 15:1, which allows nitrogen to quickly become available to the following crop.
9. Cover crops can reduce pesticide loss by reducing surface water runoff resulting in reduced pesticide losses. Increased organic matter increases soil biological activity that can increase the breakdown of pesticide residues.



10. Visible reduction in weed pressure is due to reduced light, seed/soil contact and soil temperatures. The release of chemical compounds by the cover crop (allelopathy) may also inhibit weed growth.

The potential for a negative impact on the primary crop can be reduced by killing the cover crop two to three weeks prior to planting and ensuring good seed/soil contact during seed placement.

11. Soil moisture can be improved when cover crops and green manure crops remove excess moisture from wet soils, resulting in reduction of “waterlogging” in poorly drained soils.

Specie Selection and Seed Quality

- » Select species that are adapted to soil, climatic, and ecological site conditions.
- » Select species suited for the planned purpose and specific site conditions.
- » Do not plant species identified as restricted or prohibited by law.
- » Inoculate legumes with the proper Rhizobium bacteria.
- » Non-commercial seed can be used, as long as the seed has been tested for germination.
- » Seeding rates are based on certified obtained from commercial sources.

Seedbed Preparation and Seeding

Site preparation shall be adequate to assure weed suppression and to promote germination and growth of the species planted. Seedbed preparation and seeding methods are determined as a result of the following:

- » Resource concern and/or objective for planting the cover crop
- » Cover crop life cycle (overwintering)
- » Current soil surface conditions, moisture levels, existing biomass (surface cover)
- » Planned harvest date of the primary crop
- » Estimated growing degrees units remaining prior to the average killing frost
- » Availability of labor/time and equipment

Seeding Methods

Wisconsin NRCS Conservation Practice Standard 340 - Cover Crop, supports several seeding and planting options to establish cover crops. Successful cover crop plantings require seeding within the recommended dates, seeding methods that ensure adequate seed to soil contact and sufficient soil moisture to support seedling growth.

Cover crops may be drilled, no-tilled, slurry applied, broadcast inter-seeded, over-seeded or frost seeded with or without incorporation depending on field conditions. Incorporation of seed following planting by light shallow tillage, or use of a ring roller, culti-packer or similar tool to embed the seed will result in a more uniform seedling emergence. The following non-traditional establishment methods can be used to expand the settings where cover crops can be utilized.

Slurry Seeded Cover Crops - Slurry-enriched seeding is a process that combines low-disturbance tillage, manure application and the seeding of cover crops into one operation. This technique is efficient and effective in un-tilled crop fields. Cover crop seed is mixed directly with liquid manure in the manure tanker. Cover crop species best suited to plant with this system include; cereal rye, wheat, annual ryegrass, oil seed radish, red, ladino and crimson clover.

For additional details on slurry seeding refer to the following link: <http://www.mccc.msu.edu/SlurrySeeding.html>.

Frost Seeding is categorized as broadcast or aerial seeding occurring mid to late March through early April during the active freezing and thawing cycle. Warm daytime temperatures combined with low overnight temperatures cause the surface of the soil to freeze and crack. Frost seeding takes skill in determining the exact conditions that are favorable and in assuring the crop will not freeze after emergence.

Guidelines when frost seeding cover crops:

1. Seedbed conditions must favor good seed to soil contact: a) un-tilled winter wheat or soybean residue fields are ideal seedbed conditions, b) frost seeding SHALL NOT occur on un-disturbed heavy residue corn fields or similar conditions, c) when seedbed preparation is necessary to prepare a uniform seedbed in the fall prior to freeze-up and maintain 30-70% residue surface cover.
2. Frost seeding SHALL NOT occur on areas covered with solid ice or snow cover depth greater than 2 inches.
3. Frost seeding shall be completed before the end of the freeze and thaw cycle. Note: Ideal frost seeding conditions vary from year to year, and in certain years the window for seeding may amount to a few days.

CAUTION: Because the risk for failure is high, this practice requires a variance from the Area Resource Conservationist or State Agronomist except for the red clover inter-seeded into dormant winter wheat.



Refer to UW-Publication— “Frost Seeding Red Clover in Winter Wheat” for additional details: <http://ipcm.wisc.edu/downloads/nutrient-managment/>

Broadcast inter-seeding or over-seeding without incorporation may be used to establish a cover crop into a fully mature crop scheduled for harvest in the near future. The terms inter-seeding and over-seeding, are used interchangeably defining seeding techniques where the cover crop is seeded over the top of an un-harvested crop without incorporation into the soil.

When broadcasting cover crops, seed germination depends on the presence of adequate moisture at the soil surface or within the crop residue layer. Dry conditions will result in poor germination due to limited seed to soil contact. The following guidelines will reduce the risk of seeding failure, when cover crops are broadcasted.

Guidelines for broadcasting cover crops:

1. Assess site for one or more of the following conditions: a) moist, friable soil surface, b) 30% soil surface residue cover to conserve surface moisture for seed germination and c) high probability of rainfall after seeding.
2. Seeding as early as possible within the recommended seeding dates will improve stand density and vigor.
3. Select species known to have the highest germination rate may favor broadcast methods. Below are specie groupings in numeric order beginning with the highest probabilities of successfully germinating:
 - » Group 1: small grains
 - » Group 2: annual/perennial rye grass
 - » Group 3: small seed brassicas
 - » Group 4: small seed legumes

Note: Large legume seed crops are not recommended for aerial seeding.

Additional guidelines when broadcasting cover crops into standing crops:

1. **Corn for grain:** Do not over-seed cover crops when corn is immature or green. Cover crops should be over-seeded after the corn has begun to dry down, silks are brown and leaves are dried up to the ear and turned down. This timing will minimize the potential for seed to be trapped in leaf whorls and will allow sunlight to reach the ground between the rows.
2. **Corn for silage:** Cover crops should not be over-seeded into corn that will be harvested as silage, more than 21 days prior to the planned harvest date.

3. **Soybeans:** Over-seed cover crops into standing un-harvested soybeans when 50% of the leaves are yellow and/or prior to 50% leaf drop.
4. **Red clover into winter wheat:** Over-seed red clover into dormant winter wheat by frost seeding during the active freeze and thaw cycle (late February to mid-March).
5. **Red clover into snap beans:** Over-seed red clover during the last cultivation of snap beans.

Fertilization

Cover crops usually follow heavily fertilized crops and do not require fertilization. Fall-planted fibrous rooted grasses or small grains will scavenge leftover nitrogen from the previous crop. Legume cover crops will add nitrogen to the system for the following crop. For these reasons, fertilizer is not required unless the site condition warrants it.

Seed Mixtures for Cover Crops

The seeding mixture used will depend on the objective and identified resource concern. Cover crops can include a diverse mix of grass, non-legume broadleaf and legume plants. The seed mixture should create a balanced stand of above ground biomass and root structure to enhance soil building. Seed mixtures that develop a full canopy will maximize snow retention, soil surface coverage, reduce soil erosion and may be utilized for livestock forage. A mixture of grasses, non-legume broadleaf (brassicas, buckwheat, etc.) and legume plants will improve the soil's biological activity. A mixture of plant species will feed beneficial organisms, improve soil structure, reduce compaction, improve water infiltration/water holding capacity and increase the amount of available nutrient exchange sites in the soil.

Cover crop mixtures are often recommended when the goal is to address multiple objectives and resource concerns. When considering multiple species mixtures, consider the effects of; specie growth characteristics, anticipated growing conditions, nutrient needs, planned seeding rate and the termination method and date.

Use the following references to evaluate cover crop species for growth characteristics and conservation benefits: [Table 2](#) “Identification and Comparison of Cover Crop Performance and Benefits by Species”.

[Table 3](#) “Morphology, Physiology and Growth Requirements”. “Midwest Cover Crop Decision Tool” <http://mccc.msu.edu/index.htm>.

Single and Multiple Species Seeding Rate Calculation

When designing cover crop seed mixtures, the seeding rate recommendation is based on the seeding method selected. Cover crops that are drilled, no-



tilled, or broadcast and incorporated, the minimum recommended seeding rate or higher can be planned. Cover crop seeding methods such as broadcast over-seeding or inter-seeding, slurry seeded, frost seeded and other methods, where seed to soil contact is of concern, a higher recommended seeding rate is required. When designing multiple cover crop seed mixtures, multiply the minimum seeding rate for each selected plant species by the planned percentage of each species. The “planned percentage” represents a general proportion of the seed to be planted per species and is not a direct calculation of seeds per square foot or an estimate of canopy cover or plant dominance of a given species. Refer to [Table 1](#) “Cover Crop Species Recommended for Planting in Wisconsin” for the recommended seeding rate per species.

A waiver from the State Agronomist or Area Resource Conservationist for NRCS is required when:

1. Less than **one pound** of seed per plant species is required when designing seed mixtures.
2. More than 4 species are included in the seed mixtures.
3. Cover crops are planted later than the recommended ending seeding date.

Calculating Seeding Rates and Mixes:

Minimum [Table 1](#) seeding rate range or higher per species multiplied by the planned percentage of each species will determine the pounds of seed per plant species to be planted per acre.

***Round up to the next full pound of seed if the seeding rate calculation results in a decimal of 0.5 or larger.**

Example Seeding Mixture Calculation Results

Spring Mix—Cover crop will be drilled into soybean stubble. The landowner selected the seed mixture below:

40% oats...minimum seeding rate 30 lbs./ac. ([Table 1](#))

40% oilseed radish 4 lbs./ac. ([Table 1](#))

20% field pea 65 lbs./ac. ([Table 1](#))

Actual seeding rates:

Oats= 30 lbs X 40% = 12 lbs for the mix per acre

Radish=4 lbs X 40%= 1.6 which rounded up is 2 lbs for the mix per acre

Pea=65 lbs X 20%=13 lbs for the mix per acre

Cover Crop Attributes

The following summary of cover crop attributes provides additional information (advantages and disadvantages) regarding the species listed in [Table 1](#).

Refer to [Table 2](#) for performance and roles of cover crops.

Alfalfa (Medicago sativa)

- » **Advantages:** nitrogen fixer, crude protein: 14-22%, forms arbuscular mycorrhizal associations, attracts pollinators, good at scavenging nitrogen from the soil, and break up compaction.
- » **Disadvantages:** produces autotoxicity and will not tolerate wet sites.

Annual Ryegrass (Lolium multiflorum)

- » **Advantages:** quick-growing non-spreading bunchgrass, establishes quickly even in gravelly or wet soils, excellent for trapping nitrogen, dense shallow root system improves water infiltration and enhances tilth, improves early season weed control, attracts few insect pests and generally can help reduce insect pest level, can be over-seeded into corn or soybeans after leaves turn yellow, self-pollinating, and forms arbuscular mycorrhizal associations.
- » **Disadvantages:** can host high densities of Penetrans Root-Lesion Nematode.

Barley, Spring/Winter (Hordeum vulgare)

- » **Advantages:** produces a deep fibrous root system, produces more biomass than any other small grain crop, will scavenge significant amounts of nitrogen, releases allelopathic chemicals that help suppress weeds, drastically reduces root-knot nematode populations, has a higher nutritional value than oats or wheat, works well in cocktail mixtures, prefers mesic soil conditions.
- » **Disadvantages:** fusarium head blight can be a problem when other small grains are planted within one year and disease problems (especially with tan spot) can be problematic, avoid planting barley after winter wheat.

Berseem Clover (Trifolium alexandrinum)

- » **Advantages:** extremely vigorous tall annual white clover, tolerant of wet conditions, crude protein: 27-29%, excellent nitrogen fixer, forms arbuscular mycorrhizal associations, flowers attract bees, excellent weed suppressor.
- » **Disadvantages:** none.

Buckwheat (Fagopyrum esculentum)

- » **Advantages:** provides quick soil cover, excellent weed suppressor, provides nectar for pollinators and other beneficial insects, loosens topsoil, rejuvenates low fertility soils,



dense fibrous root cluster in the top 10 inches of soil providing an extensive root surface area for nutrient uptake, extracts soil phosphorus from the soil better than most grain-type cover crops, residue decomposes quickly releasing nutrients to the next crop, excellent choice to follow early vegetables, popular honey bee pollinator.

- » Disadvantages: sets seed quickly, will reseed and may become a weed if flowers mature, frost sensitive, will not germinate/thrive in cold soils, and highly attractive to Japanese Beetles.

Canola/Rape (Brassica napus)

- » Advantages: flowers attract pollinators, good at scavenging nitrogen from the soil, crude protein: hay 16%, grain 21%, silage 12%, pasture 17%.
- » Disadvantages: susceptible to sclerotinia, host for Penetrans Root-Lesion Nematode.

Cereal Rye, Winter (Secale cereale)

- » Advantages: tremendous biomass production, can be seeded later in the fall than other cover crops, germinate at temperatures as low as 34°F and produce vegetative growth at 38°F, reduces nitrate leaching, excellent weed suppressor, secrete compounds that will inhibit germination of weeds such as lambquarters, redroot pigweed, dandelions, and Canada thistle, few diseases affect rye as compared to other small grains, can be over-seeded in field crops, can be grown on a wide range of soils and will increase the concentration of exchangeable K near the surface by means of its fibrous root system, tolerates triazines herbicides, excellent for scavenging nitrogen, medium water use.
- » Disadvantages: may become a weed when terminated too late, not recommended before corn in rotation, host for Penetrans Root-Lesion Nematode.

Chicory (Cichorium intybus)

- » Advantages: rapid growth, excellent forage crop, crude protein: 20-32%, attracts pollinators, rooting depth 4 to 5 feet, forms arbuscular mycorrhizal associations, used in mixtures, grows well under droughty conditions.
- » Disadvantages: none.

Cow pea (Vigna unguiculata)

- » Advantages: provides 50 to 100 pounds of nitrogen, attracts pollinators, forms arbuscular mycorrhizal associations.
- » Disadvantages: none.

Crimson Clover (Trifolium incarnatum)

- » Advantages: grows well on poorly drained soils, use as a winter kill annual, utilize as hay, pasture, favored legume of organic farmers, attracts pollinators, grows well in extreme heat.
- » Disadvantages: host for root knot nematode and Penetrans Root-Lesion Nematode.

Field Pea (Pisum sativum)

- » Advantages: residue breaks down and releases nitrogen quickly, provide nitrogen at a rate of 50 to 100 pounds per acre, mix well with oats and barley, excellent for soil building and water use is low.
- » Disadvantages: can lead to aphanomyces problems when in rotations with alfalfa, susceptible to sclerotinia.

Forage/Oilseed Radish (Raphanus sativa)

- » Advantages: deep root crop, excellent for compaction control, crude protein: 26-30%, good for scavenging nitrogen from the soil, flowers attract pollinators and excellent for grazing.
- » Disadvantages: winter kills at 25°F, odor during decay, host for root knot nematode, Penetrans Root-Lesion Nematode, and sugarbeet cyst nematode.

Forage Turnips (Brassica rapa)

- » Advantages: root crop, crude protein: leaf tops 16%, root 12-14%, forms arbuscular mycorrhizal associations, rated good for scavenging Nitrogen, flowers attract pollinators, excellent for grazing.
- » Disadvantages: can become a serious weed if allowed to go to seed, host for root knot nematode, Penetrans Root-Lesion Nematode, and sugarbeet cyst nematode.

Hairy Vetch (Vicia villosa)

- » Advantages: provides 60 to 120 pounds of nitrogen, attracts pollinators, used in a cocktail mixtures, only vetch species that can be fall seeded and reach maturity the next year, can withstand trampling from grazing animals during May and June, adapted to a wide range of soil types, but prefers loamy and sandy soils.



- » Disadvantages: stems are weak and have a tendency to lodge, when seeded with a small grain, the weak stems are supported by the tangling of the tendrils with the small grain stalks, do not plant hairy vetch with a winter grain if you desire to harvest grain for feed or sale, fall seeded hairy vetch will winterkill with temperatures less than 15 degrees with no snow cover, certain species of nematodes increase with hairy vetch, Spring/summer seeding is less successful.

Japanese Millet (*Echinochloa frumentacea*)

- » Advantages: fast growing annual grass, tolerates frequent clipping, makes excellent forage and hay, tolerate both droughty and wet soils, excellent feed source, good choice for converting land to vegetable production.
- » Disadvantages: will not germinate/thrive in cold soil, host for Penetrans Root-Lesion Nematode.

Oats (*Avena sativa*)

- » Advantages: provide quick weed suppressing biomass, naturally occurring compounds in roots and residue can hinder weed growth, excellent nutrient catch crop, improves productivity of legumes when planted in mixes, inexpensive to establish.
- » Disadvantages: slow to release nitrogen to following crops, unless growth is terminated in mid-vegetative stage (12 to 18 inches), host for Penetrans Root- Lesion Nematode.

Pearl Millet (*Pennisetum glaucum*)

- » Advantages: forms arbuscular mycorrhizal associations, excellent for grazing, low water use requirements, self-pollinator.
- » Disadvantages: slower to establish than sorghum or sudangrass, will not germinate/ thrive in cold soil.

Red Clover (*Trifolium pratense*)

- » Advantages: provides 70 to 120 pounds of nitrogen, crude protein: 15%, flowers attract bees and can be used in cocktail mixtures.
- » Disadvantages: host for root knot nematode and Penetrans Root-Lesion Nematode.

Sunflower (*Helianthus annuus*)

- » Advantages: deep rooted, effective in mining mobile nutrients deep in the soil profile, attracts pollinators, forms arbuscular mycorrhizal associations, can be used cocktail mixtures.

- » Disadvantages: may increase sclerotinia inoculum.

Sorghum-Sudangrass Hybrids (*Sorghum bicolor x S. bicolor var. Sudanese*)

- » Advantages: tall fast-growing heat-loving summer annual, suppress some nematodes species, seedling, shoots, leaves and roots secrete allelopathic compounds that suppress weeds, has an aggressive root system that relieves compaction, mowing stalks increases root mass 5 to 8 times compared with unmowed stalks and forces the roots to penetrate deeper making the root system an excellent subsoil aerator, drought tolerant, will tolerate a pH range of 5 to 9, nutrient uptake increases on sandy soils, self-pollinator, medium water use required, forms arbuscular mycorrhizal associations.
- » Disadvantages: requires fertile soils, mature plants terminated by frost-killed become quite woody.

Sudangrass (*Sorghum bicolor*)

- » Advantages: tall fast-growing heat-loving summer annual, suppress some nematodes species, seedling/shoots/leaves and roots secrete allelopathic compounds that suppress weeds, has an aggressive root system that relieves compaction, mowing stalks increases root mass 5-8 times compared with unmowed stalks and forces the roots to penetrate deeper, making the root system an excellent subsoil aerator, drought tolerant, will tolerate a pH range 5-9, nutrient uptake increases on sandy soils, self-pollinator, medium water use required, forms arbuscular mycorrhizal associations.
- » Disadvantages: requires fertile soils, frost damaged plants can cause prussic acid poisoning in livestock, drought stressed plants can cause nitrate poisoning, host for Penetrans Root-Lesion Nematode.

White Clover (*Trifolium repens*)

- » Advantages: crude protein 24-30%, forms arbuscular mycorrhizal associations, flowers attracts bees.
- » Disadvantages: will not tolerate droughty soils and has a shallow root system.

Triticale, Winter (*Triticum x Secale*)

- » Advantages: crude protein: hay 9-16%, grain 17%, self-pollinator, forms arbuscular mycorrhizal associations, excellent weed suppressor and excellent for grazing.



- » **Disadvantages:** seed is more expensive than wheat or rye.

Wheat, Winter/Spring (*Triticum aestivum*)

- » **Advantages:** excellent weed suppressing crop, can be over-seeded into corn or soybeans, produces a tremendous amount of biomass, excellent nitrogen scavenger.
- » **Disadvantages:** host for Penetrans Root-Lesion Nematode, when planted in rotation with other small grains within a year there can be disease problems (especially with tan spot).

Termination of Cover Crops:

Cover crops will be terminated by frost, harvest or grazing for forage, roller crimping, tillage, and/or with proper herbicide selection. Timely termination of in season cover crops is required to reduce soil moisture depletion, nitrogen immobilization, allelopathy and to prevent unwanted re-seeding. Timing of cover crop termination must meet the purpose of the cover crop as specified in the conservation plan. Manage cover crop surface residue and biomass production to meet objectives specified in the conservation plan. In vineyards and small fruit operations, grow cover crop in aisles, mow as necessary for mulch cover and maintain as short stubble. Adjust nitrogen application rates for the subsequent crop based on nitrogen credits for specific cover crop species from University of Wisconsin nutrient guidelines.

(a) Herbicide Termination:

Herbicide selection for termination must be made by a Certified Pesticide Applicator, Certified Crop Advisor or qualified Extension Specialist following pesticide labeling and must be compatible with the following main crop to grown.

(b) Winter Kill Termination:

Insure that planned cover and biomass production levels can be achieved for the specific cover crop purpose from the conservation plan when using cover crop species that terminate by frost or winter kill. When the objective of the conservation plan is to allow fall manure applications to in high Nitrogen Leaching soils, winter kill termination is not an option and winter hardy cover crops must be used.

(c) Grazing/Haying Termination:

Cover crops grazed or harvested for forage as a termination method will have a specified amount of target residual biomass left in the field to meet the cover crop objective(s) outlined in the conservation plan. Employ additional termination methods as needed once grazing/haying has concluded and target biomass is achieved and documented. When cover

crops are grazed, potential adverse reactions from cover crop consumption by grazing animals must be monitored at all times.

(d) Tillage Termination:

Use inversion type tillage implements that will adequately bury and kill the cover crop.

(e) Roller/Crimper Termination:

Rolling/crimping will take place at the proper cover crop growth stage to limit regrowth potential. For small grains this stage is at the boot or grain head stage, for legumes the flowering stage. Direction of rolling/crimping will coincide with planting direction when no-till planting the subsequent crop. Crimpers must break the plant stems in three or more places to be effective. Crimping must be done prior to seed set stage in order to prevent tillering or reseeding of the cover crop.

For additional NRCS cover crop termination criteria refer to: "NRCS Cover Crop Termination Guidelines". <http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/landuse/crops/>

References

USDA, NRCS Wisconsin Biology Technical Note 8, Pollinator Biology and Habitat.

Reeves, D.W. 1994. Cover Crops and rotations. p. 125- 158 In J.L. Hatfield, and B.A. Stewart (eds.) Crops Residue Management, Adv. Soil Science.

Schertz, D.L. and W. D. Kemper. (1994) Crop residue management systems and their role in achieving a sustainable, productive agriculture. ISCO94 Conference. New Delhi.

Cover Crops on the Intensive Market Farm, University of Wisconsin - Madison, Center for Integrated Agricultural Systems, College of Agricultural and Life Sciences.

A. Clark 2007. Managing Cover Crops Profitably, 3rd Edition, Sustainable Agriculture Network Handbook Series; Handbook K9.

Magdoff, Fred, and Harold Van Es. Building Soils for Better Crops - Sustainable Soil Management, 3rd Edition, Handbook Series Book 10.

Moyer, Jeff, Organic No-Till Farming - Advancing No Till Agriculture, Crops, Soil, Equipment. Frost Seeding Red Clover in Winter Wheat" <http://ipcm.wisc.edu/downloads/nutrient-management/ManureSlurryEnrichedseedingCoverCrops> <http://www.mccc.msu.edu/SlurrySeeding.html> Midwest Cover Crop Council: <http://www.mccc.msu.edu/index.htm>



Midwest Cover Crop Decision Tool: <http://mcccdev.anr.msu.edu/>

Planting Winter Cereal Rye after Corn Silage: <http://www.soils.wisc.edu/extension/covercrop.php>

NRCS Cover Crop Termination Guidelines: <http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/landuse/crops/>

National Agricultural Aviation Association website: <http://www.agaviation.org/>

UW Extension Publications: Cover Crop Termination, Forage Herbicide Quick Sheet – Cereal Rye Forage after Corn Silage, Forage Herbicides Quick Sheet – Spring-Seeded Forages after Corn and Herbicide Rotation Restrictions in Forage and Cover Cropping Systems located at the Wisconsin Crop Weed Science Website: <http://wcws.cals.wisc.edu>



Table 1: Cover Crop Species Recommended for Planting in Wisconsin

Species	¹ Minimum Seeding Rate in lbs. bu./ac. (incorporated seed)		² Minimum Seeding Rate in lbs. bu./ac. (non-incorporated seed)		Seeding Date (statewide)	Planting Depth (inches)
	lbs.	bu.	lbs.	bu.		
GRASSES						
Annual Ryegrass (<i>Lolium multiflorum</i>)	15	0.7	20	0.8	4/10-6/1, 8/1-9/1	¼ to ½
Barley, Spring (<i>Hordeum vulgare</i>)	50	1.0	63 to 75	1.3 to 1.6	4/10-6/15, 7/15-9/1	¾ to 1½
*Japanese Millet (<i>Echinochloa frumentacea</i>)	22	0.5	28	0.6	6/1-7/15	½ to ¾
*Sorghum:Sudangrass (<i>Sorghum bicolor</i> x <i>S. bicolor</i> var. <i>Sudanese</i>)	28	0.6	33	0.7	6/1-7/15	½ to 1½
*Sudangrass (<i>Sorghum bicolor</i>)	28	1.0	33	1.2	6/1-7/15	½ to 1
*Pearl Millet (<i>Pennisetum glaucum</i>)	22	0.5	28	0.6	6/1-7/15	½ to ¾
Wheat, Spring (<i>Triticum aestivum</i>)	50	0.8	70 to 90	1.2 to 1.5	4/10-6/15, 7/15-9/1	¾ to 1½
Barley, Winter (<i>Hordeum vulgare</i>)	50	1.0	63 to 75	1.3 to 1.6	8/15-9/15	¾ to 1½
Cereal Rye, Winter (<i>Secale cereale</i>)	60	0.9	90 to 120	1.6 to 2.1	7/15-10/15	¾ to 1½
Oats (<i>Avena sativa</i>)	30	0.9	45 to 60	1.4 to 1.9	4/10-9/1	½ to 1½
Wheat, Winter (<i>Triticum aestivum</i>)	50	0.8	70 to 90	1.2 to 1.5	8/1-10/1	¾ to 1½
Triticale, Winter (<i>Triticum</i> x <i>Secale</i>)	50	1.0	70 to 90	1.3 to 1.9	8/1-10/1	¾ to 1½
NON-LEGUMES BROADLEAF						
*Buckwheat (<i>Fagopyrum esculentum</i>)	20	0.4	35	0.7	5/15-8/1	½ to 1
**Oilseed Radish (<i>Raphanus sativus</i>)	4	--	12	--	4/10-6/15, 7/15-8/15	½ to ¾
*Sunflower (<i>Helianthus annuus</i>) (part of a mix)	1	--	2	--	6/1-7/15	1 to 1½
*Chicory (<i>Cichorium intybus</i>) (part of a mix)	1	--	2	--	4/10-6/1, 8/1-9/1	½ to ¾
Rapeseed/Canola (<i>Brassica napus</i>)	2	--	6	--	4/10-6/15, 8/1-8/15	½ to ¾
Forage Turnips (<i>Brassica rapa</i>)	1	--	5	--	4/10-6/15, 7/15-8/15	¼ to ½
LEGUMES						
Alfalfa (<i>Medicago sativa</i>)	13	--	16	--	4/15-6/1, 8/1-8/30	¼ to ½
Berseem Clover (<i>Trifolium alexandrinum</i>)	9	--	17	--	6/1-8/1	¼ to ½
*Cowpea (<i>Vigna unguiculata</i>)	55	0.9	99	1.7	6/1-7/15	1 to 1½
*Field Pea (<i>Pisum sativum</i>)	65	2.6	100	4.0	4/10-6/15	1 to 1½
Hairy Vetch (<i>Vicia villosa</i>)	15	--	20	--	4/10-6/15, 7/15-9/15	1 to 1½
*Peas, Winter (<i>Pisum sativum</i> subsp. <i>arvense</i>)	65	2.6	100	4.0	8/1-9/1	1 to 1½
Red Clover (<i>Trifolium pratense</i>)	9	--	13	--	4/10-8/15	¼ to ½
White Clover (<i>Trifolium repens</i>)	7	--	9	--	4/15-6/1, 8/1-8/30	¼ to ½
Crimson Clover (<i>Trifolium incarnatum</i>)	11	--	17	--	6/1-8/1	¼ to ½

¹ Incorporated seed—Seeding methods used that provide good seed to soil contact (drilled, no-tilled, or broadcast and incorporated).

² Non-incorporated seed—Seeding methods used when broadcasting seed without mechanical incorporation (aerial, over-seeding/inter-seeding and frost seeding).

Cover crop seed mixture designs must include a minimum of 1 pound of seed per specie planted.

Note: lbs_bu/ac represent the numbers in sequence in the Table. For example: 15/0.7 refers to 15 lbs. or 0.7 bushel per acre.-

* Species with asterisk are not recommended for aerial seeding. Large seed legumes (cowpea, etc.) and summer annuals (Japanese millet, etc.) require adequate seed to soil contact.

** Spring seeding of oil seed radish must include the termination strategy to prevent the production of viable seed.



Table 2: Identification and Comparison of Cover Crop Performance and Benefits by Species

Species	Use ¹	N-Source	SoilBuilder	Erosion Fighter	Weed Fighter	Pest Fighter	N-Scavenger	Grazing	Quick Growth	Non-Fragile Residue	Pollinator	Deep Rooted
Alfalfa (<i>Medicago sativa</i>) ³	C	4	3	3	3	1	2	3	3	1	3	4
Annual Ryegrass (<i>Lolium multiflorum</i>)	C	0	3	3	2	2	3	4	4	2	0	2
Barley, Spring (<i>Hordeum vulgare</i>)	C	0	3	3	3	1	3	3	3	4	0	2
Berseem Clover (<i>Trifolium alexandrinum</i>) ³	C	4	2	2	2	1	1	4	2	1	3	1
Buckwheat (<i>Fagopyrum esculentum</i>)	C	0	2	3	3	1	3	1	4	0	4	4
Canola/Rapeseed (<i>Brassica napus</i>)	C	0	2	3	2	1	3	4	4	1	3	3
Cereal Rye, Winter (<i>Secale cereale</i>)	C	0	4	4	4	3	4	4	4	4	0	3
Chicory (<i>Cichorium intybus</i>)	E	0	2	2	2	0	2	3	2	1	2	3
Cowpea (<i>Vigna unguiculata</i>)	C	3	2	2	2	0	2	3	3	1	2	1
Crimson Clover (<i>Trifolium incarnatum</i>)	E	3	2	3	2	1	2	4	3	1	4	2
Field Pea (<i>Pisum sativum</i>)	C	2	2	2	1	1	1	2	3	1	2	2
Forage Turnips (<i>Brassica rapa</i>)	C	0	1	3	2	0	3	4	3	1	1	1
Forage/Oilseed Radish (<i>Raphanus sativus</i>)	E	0	2	3	2	1	4	3	3	1	3	3
Hairy Vetch (<i>Vicia villosa</i>)	C	4	2	2	3	2	1	0	2	1	2	4
Japanese Millet (<i>Echinochloa frumentacea</i>)	C	0	3	3	3	3	3	3	4	4	1	3
Oats (<i>Avena sativa</i>)	C	0	3	3	3	2	3	4	4	2	0	2
Peas, Winter (<i>Pisum sativum</i> subsp. <i>arvense</i>)	C	2	2	2	1	1	1	2	3	1	2	2
Pearl Millet (<i>Pennisetum glaucum</i>)	C	0	3	3	4	2	3	4	4	4	1	2
Red Clover (<i>Trifolium pratense</i>) ³	C	4	3	3	3	1	2	4	3	2	4	3
Sorghum-Sundangrass (<i>Sorghum bicolor</i> x <i>S. bicolor</i> var. <i>Sudanese</i>)	C	0	4	4	4	2	4	4	4	4	2	3
Sunangrass (<i>Sorghum biclor</i>)	C	0	4	3	4	3	4	4	4	4	2	3
Sunflower (<i>Helianthus annuus</i>)	E	0	2	2	2	1	3	1	3	3	3	4
Triticale, Winter (<i>Triticum</i> x <i>Secale</i>)	C	0	3	3	3	2	3	4	3	4	0	2
Wheat, Spring/Winter (<i>Triticum aestivum</i>)	C	0	3	3	3	2	3	4	3	4	0	2
White Clover (<i>Trifolium repens</i>) ³	C	2	2	1	1	2	3	3	3	3	2	0

¹ Use: C=Common Use – Considerable state knowledge regarding species use.
E=Emerging Use – Limited state knowledge regarding species use.

² Attribute Ratings: 0=Poor, 1=Fair, 2=Good, 3=Very Good, 4=Excellent

³ Legumes such as alfalfa and red clover may cause bloating of ruminant animals. Take necessary precautions to prevent bloat when grazing cover crops that contain these legumes.



Table 3: Morphology, Physiology and Growth Requirements

Species	Life Cycle	Growth Height	Preferred pH	Minimum Germination Temp	Heat Tolerance	Drought Tolerance	Shade Tolerance	Flood Tolerance	Low Fertility Tolerance	Winter Survival Dry Matter Production (lb/ac/yr)	Termination Information	
GRASSES												
Annual Ryegrass (<i>Lolium multiflorum</i>)	winter annual	upright	5.5 - 7.0	40	good	good	very good	very good	good	seldom	1000 - 6000	freeze, tillage, chemical
Barley, Spring (<i>Hordeum vulgare</i>)	cool season annual	upright	6 to 8	38	fair	good	fair	good	very good	never	2000 - 5000	freeze, tillage, mow, chemical, roller crimper
Barley, Winter (<i>Hordeum vulgare</i>)	winter annual	upright	6.0 - 8.0	38	fair	good	fair	good	very good	expected	2000 - 5000	tillage, mow, chemical, roller crimper
Cereal Rye, Winter (<i>Secale cereale</i>)	cool season annual	upright	5.0 - 7.0	34	fair	very good	good	very good	excellent	expected	2500 - 6000	freeze, tillage, mow, chemical, roller crimper
Japanese Millet (<i>Echinochloa frumentacea</i>)	summer annual	upright	4.6 - 7.0	65	excellent	excellent	fair	fair	very good	never	1500 - 3500	freeze, tillage, chemical
Oats (<i>Avena sativa</i>)	cool season annual	upright	4.5 - 6.0	38	fair	good	good	very good	very good	never	2000 - 6000	freeze, mow, tillage, chemical
Pearl Millet (<i>Pennisetum glaucum</i>)	summer annual	upright	5.5 - 7.0	65	excellent	excellent	fair	fair	excellent	never	2000 - 6000	freeze, tillage, chemical
Sorghum-Sundangrass (<i>Sorghum bicolor</i> x <i>S. bicolor</i> var. Sudanese)	summer annual	upright	5.5 - 7.0	65	excellent	excellent	fair	good	good	never	3000 - 8000	freeze, tillage, chemical
Sunangrass (<i>Sorghum bicolor</i>)	summer annual	upright	5.5 - 7.0	65	excellent	excellent	fair	good	good	never	3000 - 8000	freeze, tillage, chemical
Triticale, Winter (<i>Triticum</i> x <i>Secale</i>)	winter annual	upright	5.2 - 7.0	38	fair	good	fair	good	good	expected	2000 - 5000	tillage, mow, chemical, roller crimper
Wheat, Spring (<i>Triticum aestivum</i>)	cool season annual	upright	6.0 - 7.0	38	fair	good	fair	good	good	never	2000 - 5000	freeze, tillage, mow, chemical, crimper
Wheat, Winter (<i>Triticum aestivum</i>)	winter annual	upright	6.0 - 7.0	38	fair	good	good	good	good	expected	2000 - 5000	tillage, mow, chemical, roller crimper
NON-LEGUMES BROADLEAF												
Buckwheat (<i>Fagopyrum esculentum</i>)	summer annual	upright to semi-upright	5.0 - 7.0	50	excellent	good	fair	fair	very good	never	1500 - 2500	freeze, tillage, chemical, mow
Chicory (<i>Cichorium intybus</i>) (part of a mix)	short-lived perennial	upright	5.0 - 7.0	50	very good	very good	good	good	very good	expected	1500 - 2000	tillage chemical
Forage Turnips (<i>Brassica rapa</i>)	cool season annual	upright	5.3 - 6.0	45	good	fair	good	fair	good	seldom	1200 - 3000	freeze, tillage, chemical
Oilseed Radish (<i>Raphanus sativus</i>)	cool season annual	upright	6.0 - 7.0	45	good	very good	good	fair	good	seldom	1200 - 3000	freeze, tillage, chemical
Rapeseed/Canola (<i>Brassica napus</i>)	winter/cool season	upright	5.5 - 8.0	41	good	good	good	fair	good	seldom	1000 - 2500	freeze, tillage, chemical
Sunflower (<i>Helianthus annuus</i>) (part of a mix)	summer annual	upright	5.7 - 8.0	44	excellent	excellent	good	fair	very good	never	250 - 500	freeze, tillage, chemical, mow
LEGUMES												
Alfalfa (<i>Medicago sativa</i>)	cool season perennial	upright	6.5 - 7.0	42	good	good	fair	poor	poor	expected	3000 - 8000	tillage chemical
Berseem Clover (<i>Trifolium alexandrinum</i>)	summer annual	upright	5.0 - 7.0	42	very good	good	fair	fair	fair	never	1200 - 3000	freeze, tillage, chemical
Cowpea (<i>Vigna unguiculata</i>)	summer annual	semi-upright to climbing	5.5 - 6.0	58	excellent	very good	fair	very good	very good	never	2000 - 3600	freeze, tillage, chemical, mow
Crimson Clover (<i>Trifolium incarnatum</i>)	winter annual	upright to semi-upright	5.5 - 7.0	42	very good	good	fair	very good	very good	never	3500 - 5500	freeze, tillage, chemical
Field Pea (<i>Pisum sativum</i>)	cool season annual	climbing	6.0 - 7.0	41	fair	fair	fair	fair	fair	seldom	1200 - 3000	tillage, mow, chemical
Hairy Vetch (<i>Vicia villosa</i>)	winter/cool season annual	climbing	5.5 - 7.0	60	fair	good	good	good	good	expected	1800 - 4000	tillage, chemical, roller crimper
Peas, Winter (<i>Pisum sativum</i> subsp. <i>arvense</i>)	winter annual	climbing	6.0 - 7.0	41	fair	fair	fair	fair	fair	seldom or expected	1200 - 3000	tillage, mow, chemical
Red Clover (<i>Trifolium pratense</i>)	short-lived perennial	upright	5.0 - 8.0	41	very good	good	very good	good	very good	expected	2000 - 5000	tillage chemical
White Clover (<i>Trifolium repens</i>)	cool season annual	upright	5.5 - 6.5	42	fair	fair	fair	good	fair	expected	600 - 1000	tillage chemical

