Wisconsin Agronomy Technical Note 7

Cover and Green Manure Crops Benefits to Soil Quality

Soil Quality and Resource Management

Soil is one of the five resources (soil, water, air, plants, and animals) that the Natural Resources Conservation Service (NRCS) addresses during conservation planning. Soil is intimately related to the other four resources, and its condition can either negatively or positively impact the other resources. For example, if the soil surface condition is well managed, the soil will allow water to infiltrate, thus reducing the potential for erosion and increasing the amount of water stored for plant use. The condition of the soil affects water quality, plant growth, and the health of animals. In addition, protection of the soil surface layer will result in wind erosion reductions, thus protecting the air resource. Soil quality is a critical factor in the management of natural resources and the protection or enhancement of soil quality is the key component of all conservation planning activities.

What is Soil Quality?

Soil quality is the capacity of a specific soil type to function within natural or managed ecosystem boundaries to:

- Sustain plant and animal productivity,
- Maintain or enhance water and air quality, and
- Support human health and habitation.

As defined, the terms soil quality, soil health, and soil condition are used interchangeably.

Effects of Conservation Practices

One of the goals of conservation planning is to consider the effects of conservation practices and systems on soil quality. This technical note is designed to complement local or statewide information on the soil quality benefits of cover crops.

Assessing Soil Quality Benefits

The Revised Universal Soil Loss Equation and Wind Erosion Prediction System planning software can be used to evaluate the sustainability and soil health benefits of alternative methods of seedbed preparation, seeding method, cover crop specie selection, growth characteristics, method of termination and all ground disturbing activities prior to planting the next crop.

A soil health assessment to determine the existing soil characteristics shall be carried out when an objective of the cover crop is to improve soil health. 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.

Cover and Green Manure Crop Benefits to Soil Quality

Reduced Erosion

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. Innovative planting methods such as aerial over-seeding may be necessary when harvest of the primary crop typically occurs after the cover crops recommended planting date.

Reduced Sediment Deposition

An increase of soil cover reduces upland erosion, which in turn will reduce sediment deposited by surface water runoff and wind.

Increased Soil Porosity

An increase of biomass, 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.

Soil Aggregation at the Surface

The addition of soil organic matter and subsequent decomposition by microorganisms will increase in soil aggregate stability.

Improved Infiltration

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. **Caution**: macropores can result in an increase in leaching of highly soluble materials such as manure and pesticides by preferential flow if a heavy rainfall event occurs immediately after application. When low to moderate rainfall events occur or mitigation practices are utilized, these soil amendments will uniformly infiltrate into the surface soil after application, and the risks for preferential flow are minimized. Cover crops, especially small grains, can effectively capture and utilize excess nitrogen to prevent infiltration below the crop root zone.

Reduced Soil Crusting

Cover crops reduce soil crusting by protecting the soil surface from the direct impact of rain drops. Use of conservation tillage to establish the primary crop will extend this protection into the growing season. 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.

Reduced Nutrient Loss or Imbalance

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. The ability of legume plants to utilize phosphorus is useful in planning for animal waste utilization and can further reduce commercial fertilizer costs. 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.

Nutrient Immobilization

Cover crops that are terminated two to three weeks prior to planting of the main crop will produce adequate biomass and reduce the risk of a negative yield impact on the primary crop due to soil moisture depletion or the tie-up of nutrients. The rate at which cover crops decompose determines the availability of 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.

Reduced Pesticide Loss

Cover crops reduce the volume of surface water runoff resulting in reduced pesticide losses. Increased organic matter improves the environment for soil biological activity that will increase the breakdown of pesticide residues.

Increased Soil Biological Activity

Cover and green manure crops increase the available food supply for microorganisms resulting in increased soil biological activity.

Reduced Weeds and Pathogens

Increased vegetative cover can reduce weed populations 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 (Reeves, 1994).

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.

Soil Moisture Management

Cover and green manure crops may remove excess moisture from wet soils, resulting in reduction of "waterlogging" in poorly drained soils.

Caution: excessive transpiration of water can be detrimental during periods of below normal precipitation and/or on soils with low available water capacities. Planners should consider the need to adjust the termination date of cover crops to maintain adequate soil moisture levels. See the current "NRCS Cover Crop Termination Guidelines" for additional information.

Specie Selection and Seed Quality

- Species shall be adapted to soil, climatic, and ecological site conditions.
- Species planted shall be suitable for the planned purpose and site conditions.
- Species identified as restricted or prohibited by law shall not be planted.
- Legumes shall be inoculated with the proper Rhizobium bacteria.
- Non-commercial seed can be used, as long as the seed has been tested for pure seed (purity), germination, and other mechanical qualities, such as inert matter and other crop or weed seeds.
- Seeding rates are based on pure live seed obtained from seed tag information or lab test results. Seed obtained from commercial sources may be assumed to be the equivalent of 100% Pure Live Seed unless a review of the seed tag indicates less than acceptable seed quality.

Actual seeding rates for non-commercial seed sources MUST be adjusted to compensate for non-viable seed. Computations to reflect the adjusted pure live seed seeding rate shall be submitted to NRCS with the practice certification materials.

Seedbed Preparation and Seeding

If seeding after the harvest of the primary crop, in the fall, or prior to the planting of the next crop in the spring, the cover crop may be drilled, broadcast or aerially seeded and where possible incorporated with light, shallow tillage to cover the seed.

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),
- Existing surface biomass cover,
- Current soil surface conditions and antecedent moisture conditions,
- Planned harvest date of the primary crop,
- Estimated growing degrees units remaining prior to the average killing frost,
- Availability of labor/time, and equipment and
- Access to specialized services and equipment.

Prepare the seedbed to meet the germination characteristics of the plant species to be established and the planting equipment/method to be used. When over seeding the cover crop prior to harvest of the primary crop, seedbed preparation is not required. No-till seeding into standing residue provides the greatest soil condition benefit.

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 specific management techniques including; 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 untilled crop fields. Cover crop seed is mixed directly with liquid manure in a manure tanker where a bypass flow system is available to provide tank agitation and seed mixing. The manure-seed mixture is deposited in soil cracks and fissures created by the manure incorporation implements. Cover crop species best suited to plant with this system include; cereal rye, wheat, annual ryegrass, oil seed radish, red, ladino and crimson clover.

Seeding rates of 70-100% of the maximum seeding listed in Table 1 "Common Cover Crops Recommended for Planting in Wisconsin" are recommended. Research data has documented a yield response to manure applied with a winter cover crop.

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

CAUTION: A variance from the Area Resource Conservationist or State Agronomist is required when a slurry seeding system is utilized to establish cover crops.

Frost Seeding is categorized as broadcast or aerial seeding occurring in late February through mid to late March during the active freezing and thawing cycle. Low overnight temperatures cause the surface of the soil to freeze and crack. Warm daytime temperatures thaw the surface, sealing the cracks causing the small legume seeds to naturally embed at ideal planting depths.

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: A variance is required from the Area Resource Conservationist or State Agronomist when frost seeding cover crops, except for the red clover inter-seeded into dormant winter wheat and red clover over-seeded into snap beans during the last cultivation.

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 a cover crop is seeded over the top of an un-harvested crop without incorporation into the soil.

When over-seeding 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 over-seeded.

Guidelines for seeding cover crops when seed is not incorporated (after crop harvest or over seeding prior to crop harvest):

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 rates shall be based on the midpoint or higher of the NRCS seeding rate recommendation in Table 1 "Common Cover Crops Recommended for Planting in Wisconsin", and Table 4 "Seeding Rate Adjustments".
3. Seeding 7-10 days or more before the recommended end dates will improve stand density and vigor.
4. Select species known to have the highest probability to germinate readily on the soil surface without incorporation. 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 over-seeding 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.

Rate and Date of Seeding

To produce maximum growth, fall-seeded cover crops should be planted as soon as possible after harvest of the primary crop. Spring seeded cover crops should be seeded as early as possible depending on the primary crop to be planted.

Tested seed shall be used. Cover Crop seed purchased from non-commercial sources shall be tested for pure seed and germination. The planned seeding rate increase shall reflect 100% pure live seed.

When designing cover crop seed mixtures, the seeding rate recommendation shall start at the mid-point of the seeding range per specie. See Table 1 "Common Cover Crops Recommended for Planting in Wisconsin" for seeding rates and dates. Table 4 "Seeding Rate Adjustments" provides a quick reference for designing seed mixtures with the most commonly used cover crop species.

When cover crops are planted later than the ending seeding date listed in Table 1, a variance must be obtained from the State Agronomist or Area Resource Conservationist.

A "as established" plant population of 10 plants per square foot or more is considered a successful cover crop seeding.

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.

Seed Mixtures for Cover Crops

The seeding mixture used will depend on the objective and identified resource concern. Grasses commonly used for cover crops include annual small grains (rye, wheat, barley, and oats), annual or perennial forage grasses such as rye grass and warm season forages like sorghum-sudangrass. 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 or cocktails 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 Performance and Roles of Each Cover Crop Specie".

Table 3 "Specie Morphology, Physiology and Growth Requirements".

"Midwest Cover Crop Decision Tool" http://mccc.msu.edu/index.htm.

Multiple Species Seeding Rate Calculation

When designing multiple plant species mixtures, multiply the mid-point of the per acre seeding rate range from Table 1 "Common Cover Crops Recommended for Planting in Wisconsin" for each selected plant species by the percentage of the total seed mixture planned for each plant - see examples below. The "planned percentage" represents a general proportion of the seed to be planted by species and is not a direct calculation of seeds per square foot or an estimate of canopy cover that each plant will occupy.

Round up to the next full pound of seed if the seeding rate calculation results in a decimal of 0.5 or larger. A minimum of **one pound** of seed per plant species is required when designing seed mixtures.

Mid-point Table 1 Seeding Rate Range X___% seed per species = lbs./ac. of seed per plant species.

Refer to Table 4 "Seeding Rate Adjustments" for the mid-point seeding range for each specie.

Use of this calculation method provides a uniform starting point when designing cover crop mixtures and reducing the potential for a seeding mixture failure due to a plant species being significantly out competed for light and moisture.

A review of seed mixture designs by the State Agronomist or an Area Resource Conservationist is required when:

1. Less than 20% of the Table 1 or Table 4 seeding rate midpoint is recommended for any plant species
2. A seed mixture utilizes 4 or more plant species

Example Seeding Mixture Calculation Results

Spring Mix—Cover crop seeded during the spring following fall harvest of corn or soybeans. The cover crop will remain on the field until planting of the next crop:

- 45% grasses (oats; 20.0 lbs./ac. or barley; 28.0 lbs./ac.)
- 40% Non-legume broadleaf (forage turnips 1.0 lb./ ac. or oilseed radish; 3.0 lbs./ac.)
- 15% legumes (field pea; 12.0 lbs./ac. or cowpea; 12.0 lbs./ac.)

The recommended seeding rate for field pea (17.0 lbs./ac.) and cowpea (15.0 lbs./ac.) species in the example above are less than 20% of the mid-point seeding rate. The seeding rate shall be increased to exceed 20% of the mid-point seeding rate or request a variance from the Area Resource Conservationist or State Agronomist.

A spring cover crop mixture will keep the soil surface covered, maintain the loose soil condition promoted by the winter freeze/thaw cycle and stimulate soil microbial activity. Nitrogen can be added to the soil by including legumes in the mixture.

Summer Mix—Cover crop planted post-harvest of small grain or vegetable crop:

- 10% grasses (annual ryegrass; 2.0 lbs./ac. or spring barley; 6.0 lbs./ac. or, oats; 5.0 lbs./ac., etc.)
- 65% Non-legume broadleaf (oilseed radish; 5.0 lbs./ ac. or forage turnips; 2.0 lbs./ac., etc.)
- 25% legumes (winter pea: 21.0 lbs./ac. or red clover; 3.0 lbs.ac., etc.)

The recommended seeding rate for annual ryegrass (4.0 lbs./ac.), spring barley (13.0 lbs./ac.) and oats (9.0 lbs./ac.) species in the example above are less than 20% of the mid-point seeding rate. The seeding rate shall be increased to exceed 20% of the mid-point seeding rate or request a variance from the Area Resource Conservationist or State Agronomist.

A summer cover crop mixture will break-up compaction, minimize soil erosion, create root channels to reduce compaction and provide nitrogen.

Late Summer Mix—Cover crop is planted prior to leaf drop of soybeans or at least 50% of soybeans leaves have turned yellow:

- 75% grasses (oats; 34.0 lbs./ac. or winter wheat; 53.0 lbs./ac., etc.)
- 25% non-legume broadleaf (canola; 1 lb./ac. or forage turnips; 1 lb./ac., etc.)

A late summer cover crop mixture provides an immediate establishment of cover to reduce soil erosion. The seed mixture will typically be designed with a deep strong root base to break-up compaction capture available soil nitrogen and to provide a quick breakdown of biomass the following spring.

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 autotoxcity 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, topsoil loosener, rejuvenator for 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, may provide potential honey income, prefers mesic conditions.
- 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 satuvum)

- 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 mycorrihizal 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 un-mowed 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 un-mowed 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).

Cover Crop Management

Tillage tools are often used to kill and bury cover crops in conventional tillage systems.

Crimpers may be used to kill cover crops in no-till organic systems. Crimpers must break plant stems in multiple places (three or more to be effective). They should be used following the pollination stage and prior to seed set to prevent tillering.

In conservation tillage systems, cover crops may be killed with chemicals and left on the soil surface or partially incorporated. Research has shown that incorporation of legume cover crops results in more rapid mineralization of nitrogen. **Caution**: a starter fertilizer should be applied at planting of the next grass crop due to a possible delay in availability of nitrogen from legume cover crops in conservation tillage systems (Reeves, 1994).

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

The document provides detailed guidance for termination cover crops prior to planting the primary crop to avoid a crop failure due to insufficient soil moisture.

References

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Table 1: Cover Crop Species Recommended for Planting in Wisconsin

Species	Seeding Rate Drill/Broadcast	Seeding Date (statewide)	Planting Depth (inches)
GRASSES			
Annual Ryegrass (Lolium multiflorum)	15-20 lbs/ac	4/10-6/1, 8/1-9/1	¼ to ½
Barley, Spring (Hordeum vulgare)	50-75 lbs/ac	4/10-6/15, 7/15-9/1	¾ to 1½
*Japanese Millet (Echinochloa frumentacea)	22-28 lbs/ac	6/1-7/15	½ to ¾
*Sorghum-Sudangrass (Sorghum bicolor x S. bicolor var. Sudanese)	28-33 lbs/ac	6/1-7/15	½ to 1½
*Sudangrass (Sorghum biclor)	28-33 lbs/ac	6/1-7/15	½ to 1
*Pearl Millet (Pennisetum glaucum)	22-28 lbs/ac	6/1-7/15	½ to ¾
Wheat, Spring (Triticum aestivum)	50-90 lbs/ac	4/10-6/15, 7/15-9/1	¾ to 1½
Barley, Winter (Hordeum vulgare)	50-75 lbs/ac	8/15-9/15	¾ to 1½
Cereal Rye, Winter (Secale cereale)	60-120 lbs/ac	7/15-10/15	¾ to 1½
Oats (Avena sativa)	30-60 lbs/ac	4/10-9/1	½ to 1½
Wheat, Winter (Triticum aestivum)	50-90 lbs/ac	8/1-10/1	¾ to 1½
Triticale, Winter (Triticum x Secale)	50-90 lbs/ac	8/1-10/1	¾ to 1½
NON-LEGUMES BROADLEAF			
*Buckwheat (Fagopyrum esculentum)	20-35 lbs/ac	5/15-8/1	½ to 1
**Oilseed Radish (Raphanus sativus)	4-12 lbs/ac	4/10-6/15, 7/15-8/15	½ to ¾
*Sunflower (Helianthus annuus) (part of a mix)	1-2 lbs/ac	6/1-7/15	1 to 1½
*Chicory (Cichorium intybus) (part of a mix)	1-2 lbs/ac	4/10-6/1, 8/1-9/1	½ to ¾
Rapeseed/Canola (Brassica napus)	2-6 lbs/ac	4/10-6/15, 8/1-8/15	½ to ¾
Forage Turnips (Brassica rapa)	1-5 lbs/ac	4/10-6/15, 7/15-8/15	¼ to ½
LEGUMES			
Alfalfa (Medicago sativa)	13-16 lbs/ac	4/15-6/1, 8/1-8/30	¼ to ½
Berseem Clover (Trifolium alexandrinum)	9-17 lbs/ac	6/1-8/1	¼ to ½
*Cowpea (Vigna unguiculata)	55-99 lbs/ac	6/1-7/15	1 to 1½
*Field Pea (Pisum satuvum)	65-100 lbs/ac	4/10-6/15	1 to 1½
Hairy Vetch (Vicia villosa)	15-20 lbs/ac	4/10-6/15, 7/15-9/15	1 to 1½
*Peas, Winter (Pisum sativum subsp. arvense)	65-100 lbs/ac	8/1-9/1	1 to 1½
Red Clover (Trifolium pratense)	9-13 lbs/ac	4/10-8/15	¼ to ½
White Clover (Trifolium repens)	7-9 lbs/ac	4/15-6/1, 8/1-8/30	¼ to ½
Crimson Clover (Trifolium incarnatum)	11-17 lbs/ac	6/1-8/1	¼ to ½
RECOMMENDED COCKTAIL MIXTURES			
Forage/Oilseed Radish	3-5 lbs/ac	8/1-9/1	¾ to 1
Peas, Winter	33-50 lbs/ac		
Cereal Rye, Winter	30-70 lbs/ac	7/15-9/15	½ to 1½
Hairy Vetch	9-14 lbs/ac		
Annual Ryegrass	5-10 lbs/ac	4/10-6/1, 8/1-9/1	¼ to ½
Oilseed Radish	3-5 lbs/ac		
Berseem Clover	5-9 lbs/ac	6/1-8/1	½ to ¾
Oats	17-50 lbs/ac		
Oats	20-50 lbs/ac	4/10-6/15, 7/15-9/1	½ to ¾
Oilseed Radish	3-5 lbs/ac		
Oats	20-50 lbs/ac	6/1-6/15, 8/1-9/1	¼ to ½
Peas, Winter	26-40 lbs/ac		
Oilseed Radish	3-5 lbs/ac	8/1-9/1	¾ to 1
Hairy Vetch	9-14 lbs/ac		

*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 contract.

**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	Soil Builder	Erosion Fighter	Weed Fighter	Pest Fighter	N-Scavenger	Grazing	Quick Growth	Non-Fragile Residue	Pollinator	Deep Rooted
Alfalfa (Medicago sativa)[3]	C	4	3	3	3	1	2	3	3	1	3	4
Annual Ryegrass (Lolium multiflorum)	C	0	3	3	2	2	3	4	4	2	0	2
Barley, Spring (Hordeum vulgare)	C	0	3	3	3	1	3	3	3	4	0	2
Berseem Clover (Trifolium alexandrinum)[3]	C	4	2	2	2	1	1	4	2	1	3	1
Buckwheat (Fagopyrum esculentum)	C	0	2	3	3	1	3	1	4	0	4	4
Canola/Rapeseed (Brassica napus)	C	0	2	3	2	1	3	4	4	1	3	3
Cereal Rye, Winter (Secale cereale)	C	0	4	4	4	3	4	4	4	4	0	3
Chicory (Cichorium intybus)	E	0	2	2	2	0	2	3	2	1	2	3
Cowpea (Vigna unguiculata)	C	3	2	2	2	0	2	3	3	1	2	1
Crimson Clover (Trifolium incarnatum)	E	3	2	3	2	1	2	4	3	1	4	2
Field Pea (Pisum satuvum)	C	2	2	2	1	1	1	2	3	1	2	2
Forage Turnips (Brassica rapa)	C	0	1	3	2	0	3	4	3	1	1	1
Forage/Oilseed Radish (Raphanus sativus)	E	0	2	3	3	1	4	3	3	1	3	3
Hairy Vetch (Vicia villosa)	C	4	2	2	3	2	1	0	2	1	2	4
Japanese Millet (Echinochloa frumentacea)	C	0	3	3	3	3	3	3	4	4	1	3
Oats (Avena sativa)	C	0	3	3	3	2	3	4	4	2	0	2
Peas, Winter (Pisum sativum subsp. arvense)	C	2	2	2	1	1	1	2	3	1	2	2
Pearl Millet (Pennisetum glaucum)	C	0	3	3	4	2	3	4	4	4	1	2
Red Clover (Trifolium pratense)[3]	C	4	3	3	3	1	2	4	3	2	4	3
Sorghum-Sundangrass (Sorghum bicolor x S. bicolor var. Sudanese)	C	0	4	4	4	2	4	4	4	4	2	3
Sunangrass (Sorghum biclor)	C	0	4	3	4	3	4	4	4	4	2	3
Sunflower (Helianthus annuus)	E	0	2	2	2	1	3	1	3	3	3	4
Triticale, Winter (Triticum x Secale)	C	0	3	3	3	2	3	4	3	4	0	2
Wheat, Spring/Winter (Triticum aestivum)	C	0	3	3	3	2	3	4	3	4	0	2
White Clover (Trifolium repens)[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 (.b/ac/yr)		Termination Information
GRASSES												
Annual Ryegrass (Lolium multiflorum)	winter annual	upright	5.5 - 7.0	40	good	good	very good	very good	good	seldom	1000 - 6000	freeze, tillage, chemical
Barley, Spring (Hordeum vulgare)	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 (Hordeum vulgare)	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 (Secale cereale)	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 (Echinochloa frumentacea)	summer annual	upright	4.6 - 7.0	65	excellent	excellent	fair	fair	very good	never	1500 - 3500	freeze, tillage, chemical
Oats (Avena sativa)	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 (Pennisetum glaucum)	summer annual	upright	5.5 - 7.0	65	excellent	excellent	fair	fair	excellent	never	2000 - 6000	freeze, tillage, chemical
Sorghum-Sundangrass (Sorghum bicolor x S. bicolor var. Sudanese)	summer annual	upright	5.5 - 7.0	65	excellent	excellent	fair	good	good	never	3000 - 8000	freeze, tillage, chemical
Sunangrass (Sorghum biclor)	summer annual	upright	5.5 - 7.0	65	excellent	excellent	fair	good	good	never	3000 - 8000	freeze, tillage, chemical
Triticale, Winter (Triticum x Secale)	winter annual	upright	5.2 - 7.0	38	fair	good	fair	good	good	expected	2000 - 5000	tillage, mow, chemical, roller crimper
Wheat, Spring (Triticum aestivum)	cool season annual	upright	6.0 - 7.0	38	fair	good	fair	good	good	never	2000 - 5000	freeze, tillage, mow, chemical, crimper
Wheat, Winter (Triticum aestivum)	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 (Fagopyrum esculentum)	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 (Cichorium intybus) (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 (Brassica rapa)	cool season annual	upright	5.3 - 6.0	45	good	fair	good	fair	good	seldom	1200 - 3000	freeze, tillage, chemical
Oilseed Radish (Raphanus sativus)	cool season annual	upright	6.0 - 7.0	45	good	very good	good	fair	good	seldom	1200 - 3000	freeze, tillage, chemical
Rapeseed/Canola (Brassica napus)	winter/cool season	upright	5.5 - 8.0	41	good	good	good	fair	good	seldom	1000 - 2500	freeze, tillage, chemical
Sunflower (Helianthus annuus) (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 (Medicago sativa)	cool season perennial	upright	6.5 - 7.0	42	good	good	fair	poor	poor	expected	3000 - 8000	tillage chemical
Berseem Clover (Trifolium alexandrinum)	summer annual	upright	5 - 7.0	42	very good	good	fair	fair	fair	never	1200 - 3000	freeze, tillage, chemical
Cowpea (Vigna unguiculata)	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 (Trifolium incarnatum)	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 (Pisum satuvum)	cool season annual	climbing	6.0 - 7.0	41	fair	fair	fair	fair	fair	seldom	1200 - 3000	tillage, chemical, mow
Hairy Vetch (Vicia villosa)	winter/cool season annual	climbing	5.5 - 7.0	60	fair	good	good	good	good	expected	1800 - 4000	tillage, chemical, roller crimper
Peas, Winter (Pisum sativum subsp. arvense)	winter annual	climbing	6.0 - 7.0	41	fair	fair	fair	fair	fair	seldom or expected	1200 - 3000	tillage, mow, chemical
Red Clover (Trifolium pratense)	short-lived perennial	upright	5.0 - 8.0	41	very good	good	very good	good	very good	expected	2000 - 5000	tillage chemical
White Clover (Trifolium repens)	cool season annual	upright	5.5 - 6.5	42	fair	fair	fair	good	fair	expected	600 - 1000	tillage chemical

Table 4. Seeding Rate Adjustments

Species	MIN seeding rate lbs_bu/ac	MAX seeding rate lbs_bu/ac	MID POINT seeding lbs_bu/ac	< 20% OF MID POINT lbs_bu/ac	70% of MAX seeding rate lbs_bu/ac
Annual Ryegrass	15/0.7	20/0.8	18/0.8	4	14
Barley, Spring	50/1.0	75/1.6	63/1.3	13	53
Japanese Millet	22/0.5	28/0.6	25/0.5	5	20
Sorghum-Sudangrass	28/0.6	33/0.7	31/0.6	6	23
Sudangrass	28/1.0	33/1.2	31/1.1	6	23
Pearl Millet	22/0.5	28/0.6	25/0.5	5	20
Wheat, Spring	50/0.8	90/1.5	70/1.2	14/0.2	63
Barley, Winter	50/1.0	75/1.6	63/1.3	13/0.3	53
Cereal Rye, Winter	60/0.9	120/2.1	90/1.6	18/0.32	84
Oats	30/0.9	60/1.9	45/1.4	9/0.3	42
Wheat, Winter	50/0.8	90/1.5	70/0.9	14/0.2	63
Triticale, Winter	50/1.0	90/1.9	70/0.7	14/0.3	63
Buckwheat	20/0.4	35/0.7	28/0.6	6	25
Oilseed Radish	4	12	8	2.0	8
Sunflower	1	2	1.5	*0.3	1
Chicory	1	2	1.5	*0.3	1
Rapeseed/Canola	2	6	4	*0.8	4
Forage Turnips	1	5	3	*0.6	4
Alfalfa	13	16	15	3.0	11
Berseem Clover	9	17	13	3.0	12
Cowpea	55/0.9	99/1.7	77/1.3	15/0.3	69
Field Pea	65/2.6	100/4.0	83/3.3	17/0.7	70
Hairy Vetch	15	20	18	4.0	14
Peas, Winter	65/2.6	100/4.0	83/3.3	17/0.7	70
Red Clover	9	13	11	2.0	9
White Clover	7	9	8	2.0	6
Crimson Clover	11	17	14	3.0	12

***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 and one number represents lbs. only.