Wisconsin Agronomy Technical Note 7

Cover and Green Manure Crop 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) deals with in 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 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 interchangeable.

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 compliment local or statewide information on the soil quality benefits of cover crops.

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, especially when the primary crops do not furnish adequate cover. Innovative planting methods (such as aerial seeding or interseeding with other non-traditional equipment) may be needed when the harvest of the crop delays conventional planting of cover crops during recommended planting dates. Cover crops following corn silage are highly beneficial if planted early using minimal or no tillage methods.

Reduced Sediment Deposition

An increase of soil cover reduces upland erosion, which in turn reduces sediment deposited by floodwaters and wind.

Increased Soil Porosity

An increase of biomass, when decomposed, increases soil organic matter promoting increased microbial activity and aggregation of soil particles. This increases soil porosity and reduces bulk density. Caution: avoid planting cover crops when soils are saturated to avoid compaction, or use other methods such as aerial seeding.

Soil Aggregation at the Surface

An increase in soil aggregate stability will result from the addition of and the decomposition of organic material by microorganisms.

Improved Infiltration

Adequate soil surface cover reduces erosion and run-off. Channels created by cover crop roots and animals, such as earthworms, form macropores that increase aggregate stability and improve infiltration. Caution: macropores can result in an increase in leaching of highly soluble materials (manure and pesticides) by preferential flow if a heavy rain occurs immediately after application. However, if moderate rainfall occurs or mitigation practices are utilized, the materials 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 will provide protection prior to planting the main crop. If conservation tillage is used, benefits will continue after planting of the main crop. The resulting increases of soil organic matter, improved infiltration, and increased aggregate stability will 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 utilize a higher amount of phosphorus than grass or small grains. This is useful in planning animal waste utilization and management strategies. Small grains are useful as catch crops to utilize excess nitrogen, which reduces the potential for nitrogen leaching. Cover crops will tie up nitrates which can reduce leaching. The most vulnerable sites for nitrogen loss include continuous corn silage fields with a long history of repeated manure applications during late summer. Cover crops following corn silage are highly beneficial.

Nutrient Immobilization

Decomposition of increased biomass results in more organic matter. Research shows cover crops killed two to three weeks prior to planting the main crop results in adequate biomass and reduces the risk of crop losses from soil moisture depletion and tie-up of nutrients. The rate at which cover crops decompose reflects on the availability of nitrogen to the growing crops. The carbon-to-nitrogen (C:N) ratio reflects the relative time organic matter takes to break down. A 50:1 C:N ratio or higher "immobilizes" soil nitrogen to break down the carbon and causes the nitrogen to not be available to crops. Young rye has a 14:1 C:N ratio as compared to corn stalks 60:1. Clover C:N ratio is generally 15:1 which makes nitrogen quickly available to the crop.

Reduced Pesticide Loss

Cover crops reduce the volume of surface 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 cover will reduce weed populations. Reductions are attributed to interference from residue (reduced seed/soil contact), cool soil temperatures, increased soil-borne pathogens, and increased insects and other pests. The harmful effects of cover crops caused by the release of chemical compounds of one plant to another plant (allelopathy) are possible. Losses can be reduced by killing the cover crop two to three weeks prior to planting the primary crop and achieving good seed/soil contact with proper crop seed placement. Cover crops have shown some allelopathic effects on weeds reducing weed populations in conservation tillage systems (Reeves, 1994).

Reduction of Excessive Wetness

Cover and green manure crops may remove excess moisture from wet soils, resulting in reduction of "waterlogging" in poorly drained soils. Caution: transpiration of water can be detrimental in dry climates. Planners should consider the need to adjust the kill date of cover crops to manage soil moisture levels.

SEEDBED PREPARATION AND SEEDING

Prepare a suitable seedbed adequate for the species to be planted and method of planting. This may vary

from conventional planting to no-till. If seeding the cover crop prior to harvest of the primary crop, no seedbed preparation is needed. Early no-till seeding into standing residue provides the greatest soil condition score utilizing RUSLE2 technology.

Seeding Method

If seeding the cover crop prior to harvest of the primary crop, seed can be broadcasted at the same time or immediately following the last row crop cultivation, or aerial seeded into the growing crop later in the growing season.

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 aerial seeded and incorporated with light, shallow tillage to cover the seed.

Rate and Date of Seeding

To produce maximum growth, fall-seeded crops should be planted just as soon as possible after crop harvest. Spring seeded cover crops can be seeded as early as possible depending on the primary crop to be planted. A growth rate of 10 plants per square foot is considered a successful seeding. See Table 1 for seeding rates and dates. Seeding rates are based on Pure Live Seeds.

Fertilization

Cover crops usually follow heavily fertilized crops and do not require fertilization. A fall-planted fibrous-rooted grass or small grain 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 purpose. Grasses commonly used for cover crops include annual cereals (rye, wheat, barley, oats), annual or perennial forage grasses such as rye grass, and warm season forages like sorghum sudangrass.

COVER CROP ATTRIBUTES

The following cover crop attributes provide 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. Helps break up compaction.
- Disadvantages: Produces autotoxcity. Does not tolerate wet sites.

Annual Ryegrass (Lolium multiflorum)

- Advantages: A quick-growing non-spreading bunchgrass. The cover crop establishes quickly even in poor, gravelly or wet soils. Excellent for trapping nitrogen. Ryegrass's dense yet shallow root system improves water infiltration and enhances tilth. Improves early season weed control. Ryegrass attracts few insect pests and generally can help reduce insect pest level. Can be overseeded into corn after the last cultivation or soybeans after leaves turn yellow. Self-pollinating. Will form arbuscular mycorrhizal associations.
- Disadvantages: Ryegrass can host high densities of Penetrans Root-Lesion Nematode.

Barley, Spring/Winter (Hordeum vulgare)

- Advantages: Barley produces a deep fibrous root system, produces more biomass than any other small grain crop, and scavenges significant amounts of nitrogen. Barley releases allelopathic chemicals that help suppress weeds. Barley can drastically reduce root-knot nematode populations. Has higher nutritional value than oats or wheat. Works well in a cocktail. Prefers mesic soil conditions.
- Disadvantages: Fusarium head blight can be a problem. If other small grains are to be planted within a year, there can be disease problems (especially with tan spot). 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 pollinator and beneficial insects. Topsoil loosener, rejuvenator for low fertility soils. Dense fibrous roots 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. Can provide potential honey income. Prefers mesic conditions.
- Disadvantages: Will reseed and may become a weed if flowers mature. Buckwheat sets seed quickly. Very frost sensitive. Does not germinate/thrive in cold soil. Highly attractive to Japanese beetles.

Canola/Rape (Brassica napus)

- Advantages: Flowers attract pollinators. Rated good at scavenging nitrogen from the soil. Crude protein: hay 16%, grain 21%, silage 12%, pasture 17%.
- Disadvantages: Susceptible to sclerotinia. Canola has less biotoxic activity than rapeseed. Rapeseed is a host for Penetrans Root-Lesion Nematode.

Cereal Rye, Winter (Secale cereale)

- Advantages: Tremendous biomass production. Rye can be seeded later in the fall than other cover crops. It will germinate at temperatures as low as 34°F and produce vegetative growth at 38°F. Decreases nitrate leaching, and is an excellent weed suppressor. May 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 overseeded 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: Can become a weed if tilled at wrong stage. Best if killed early. Not recommended before corn. Host for Penetrans Root-Lesion Nematode.

Chicory (Cichorium intybus)

- Advantages: Rapid growth. Excellent forage crop. Crude protein: 20-32%. Attracts pollinators. Rooting depth 8 to 12 inches in depth. Forms arbuscular mycorrhizal associations. Used in mixtures. Does 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: Good on poorly drained soils. Use as a winter kill annual. Utilized as hay, pasture, and organic farming, pollinator enhancement. Does well in extreme heat.
- Disadvantages: Host for root knot nematode and Penetrans Root-Lesion Nematode.

Field Pea (Pisum satuvum)

- Advantages: Winter pea residue breaks down and releases nitrogen quickly. Can provide nitrogen at a rate of 50 to 100 pounds per acre. Peas mix well with oats and barley. Excellent for soil building. Low water use.
- Disadvantages: Can lead to Aphanomyces problems when in rotations with alfalfa. Susceptible to sclerotinia.

Forage/Oilseed Radish (Raphanus sativa)

- Advantages: Deep root crop. Excellent compaction control. Crude protein: 26-30%. Very good for scavenging nitrogen from the soil. Flowers attract pollinators. 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. Can be used in a cocktail mix. Hairy vetch is the 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. Fall seeded hairy vetch will winterkill with temperatures less than 15 degrees with no snow cover. Do not plant hairy vetch with a winter grain if you desire to harvest grain for feed or sale. Certain species of nematodes increase with hairy vetch. Spring/summer seeding is less successful.

Japanese Millet (Echinochloa frumentaceae)

- Advantages: Fast growing annual grass. Tolerates frequent clippings and makes excellent forage and hay. Tolerate both droughty and wet soils. Excellent feed source. Good choice for converting land to vegetable production.
- Disadvantages: Does not germinate/thrive in cold soil. Host for Penetrans Root-Lesion Nematode.

Oats (Avena sativa)

- Advantages: Oats provide quick weed suppressing biomass. Naturally occurring compounds in roots and residue can hinder weed growth. This small grain is an excellent nutrient catch crop. Oats improve the productivity of legumes when planted in mixes. Cheap to establish.
- Disadvantages: Slow to release nitrogen to following crop unless growth terminated in mid-vegetative stage (12 to 18 inches). Host for Penetrans Root-Lesion Nematode.

Pearl Millet (Pennisetum glaucum)

- Advantages: Forms arbuscular mycorrihizal associations. Good for grazing. Low water use. Self-pollinator.
- Disadvantages: Slower to establish than sorghum or sudangrass. Does not germinate/thrive in cold soil.

Red Clover (Trifolium pretense)

- Advantages: Provides 70 to 120 pounds of nitrogen fixer. Crude protein: 15%. Flowers attract bees. Can be used in cocktail.
- Disadvantages: Host for root knot nematode and Penetrans Root-Lesion Nematode.

Sunflower (Helianthus annus)

- Advantages: Deep rooted. Effective in mining mobile nutrients deep in the soil profile. Attracts pollinators. Forms arbuscular mycorrhizal associations. Use in mix cocktails.
- Disadvantages: Can 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. Requires fertility. 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 a subsoil aerator, drought tolerant and can tolerate a pH range of 5 to 9. Increase nutrient uptake on sandy soils. Self-pollinator. Medium water use. Forms arbuscular mycorrhizal associations.
- Disadvantages: Mature, frost-killed plants 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. Requires fertility. 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 a subsoil aerator, drought tolerant and can tolerate a ph range 5-9. Increase nutrient uptake on sandy soils. Self-pollinator. Medium water use. Forms arbuscular mycorrhizal associations.

- Disadvantages: Frost damaged plants can cause prussic acid poisoning in livestock and 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: Not adapted to droughty soils and has a shallow root system.

Triticale, Winter (Triticale triticosecale)

- Advantages: Crude protein: hay 9-16%, grain 17%. Self-pollinator. Will form arbuscular mycorrhizal associations. Self pollinator. Excellent weed suppressor. Excellent for grazing.
- Disadvantages: Seed is more expensive than wheat or rye, but it makes better animal forage.

Wheat, Winter/Spring (Triticum aestivum)

- Advantages: Excellent weed suppressing crop. Can be overseeded into corn or soybeans, producing a tremendous amount of biomass. Nitrogen scavenger.
- Disadvantages: Host for Penetrans Root-Lesion Nematode. If 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-tillage organic systems. Crimpers must break plant stems in multiple places (three or more to be effective). They should be used when the plants are in the pollination stage prior to seed set.

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

An ARS study done in Morris, Minnesota, reported dramatically higher carbon losses through $C0_2$ emissions under moldboard plow plots as compared to no-till. The results of the study indicate that carbon was lost as $C0_2$ in 19 days following moldboard plowing of wheat stubble that was equal to the total amount of carbon synthesized into crop residues and roots during the previous growing season.

SUMMARY

Cover and green manure crops as a conservation practice can improve soil health. Soil quality benefits such as increased organic matter, biological activity, aggregate stability, infiltration, and nutrient cycling accrue much faster under no-till than other conventional tillage practices that partially incorporate the residue.

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Table 1
Common Cover Crops Recommended for Planting in Wisconsin

Species	Seeding Rate Drill / Broadcast	Seeding Date (statewide)	Planting Depth (inches)
GRASSES			
Annual Ryegrass (Lolium multiflorum)	22-33 lbs/ac	4/10-6/1, 8/1-9/1	¼ to ½
Barley, Spring (Hordeum vulgare)	55-83 lbs/ac	4/10-6/15, 7/15-8/15	¾ to 1½
Japanese Millet (Echinochloa frumentaceae)	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)	65-165 lbs/ac	4/10-6-15,7/15-8/15	¾ to 1½
Barley, Winter (Hordeum vulgare)	55-75 lbs/ac	8/15-9/15	¾ to 1½
Cereal Rye, Winter (Secale cerale)	60-185 lbs/ac	7/15-10/15	¾ to 1½
Oats (Avena sativa)	33-110 lbs/ac	4/10-9/1	½ to 1
Wheat, Winter (Triticum aestivum)	65-165 lbs/ac	8/1-10/1	¾ to 1½
Triticale, Winter (Triticale triticosecale)	65-165 lbs/ac	8/1-10/1	¾ to 1½
NON-LEGUMES BROADLEAF			
Buckwheat (Fagopyrum esculentum)	50-65 lbs/ac	5/15-8/1,	½ to 1
Oilseed Radish(Raphanus sativus)	11-22 lbs/ac	4/10-6/15, 7/15-8/15	½ to ¾
Sunflower (Helianthus annus) (part of a mix)	1-2 lbs/ac	6/1-7/15	1 to 1½
Chicory (Cichiorum intybus) (part of 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)	17-28 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 pretense)	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(50%)	6-11 lbs/ac	8/1-9/1	¾ to 1
Peas, Winter (50%)	33-50 lbs/ac		
Cereal Rye, Winter (50%)	30-93 lbs/ac	7/15-9/15	½ to 1½
Hairy Vetch(50%)	9-14 lbs/ac		
Annual Ryegrass (60%)	13-20 lbs/ac	4/10-6/1, 8/1-9/1	¼ to ½
Oilseed Radish (40%)	5-9 lbs/ac		
Berseem Clover (50%)	5-9 lbs/ac	6/1-8/1	½ to ¾
Oats (50%)	17-55 lbs/ac		
Oats (60%)	20-66 lbs/ac	4/10-6/15, 7/15-9/1	½ to ¾
Oilseed Radish (40%)	5-9 lbs/ac		
Oats (60%)	20-66 lbs/ac	6/1-6/15, 8/1-9/1	¼ to ½
Peas, Winter (40%)	26-40 lbs/ac		
Oilseed Radish	6-11 lbs/ac	8/1-9/1	¾ to 1
Hairy Vetch	9-14 lbs/ac		

Table 2
Identification and Comparison of Performance and Roles of Each Specie

Species	Use[1]	Attribute Ratings[2]										
		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	1
Barley, Spring/Winter (Hordeum vulagre)	C	0	3	3	3	1	3	3	3	4	0	1
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	1
Canola/Rape (brassica napus)	C	0	2	3	2	1	3	4	4	1	3	2
Cereal Rye, Winter (Secale cerale)	C	0	4	4	4	3	4	4	4	4	0	1
Chicory (Cichorium intybus)	E	0	2	2	2	0	2	3	2	1	2	3
Cowpea (Vigna unguiculta)	C	3	2	2	2	0	2	3	3	1	2	1
Crimsom Clover (Trifolium incarnatum)	E	3	2	3	2	1	2	4	3	1	4	1
Field Pea (Pisum satuvum)	C	2	2	2	1	1	1	2	3	1	2	1
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	1
Japanese Millet(Echinochloa frumentaceae)	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	1
Pea, Winter (Pisum sativum subsp. arvense)	C	2	2	2	1	1	1	2	3	1	2	1
Pearl Millet (Pennisetum glaucum)	C	0	3	3	4	2	3	4	4	4	1	2
Red Clover (Trifolium pretense)[3]	C	4	3	3	3	1	2	4	3	2	4	3
Sorghum-Sudangrass (Sorghum bicolor x S. bicolor var.-Sudanese)	C	0	4	4	4	2	4	4	4	4	2	3
Sudangrass (Sorghum bicolor)	C	0	4	3	4	3	4	4	4	4	2	2
Sunflower (Helianthus annus)	E	0	2	2	2	1	3	1	3	3	3	3
Triticale, Winter (Triticale triticosecale)	C	0	3	3	3	2	3	4	3	4	0	1
Wheat (Spring/Winter) Triticum aestivum	C	0	3	3	3	2	3	4	3	4	0	1
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
Specie Morphology, Physiology, and Growth Requirements

Specie	Life Cycle	Growth Habit	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 cerale)	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 frumentaceae)	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-Sudangrass (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
Sudangrass (Sorghum biclor)	summer annual	upright	5.5-7.0	65	excellent	excellent	fair	good	good	never	3000-8000	freeze, tillage, chemical
Triticale, Winter (Triticale triticosecale)	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, mow, chemical

Specie	Life Cycle	Growth Habit	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
Chicory (Cichiorum Intybus) (part of 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 annual	upright	5.5 - 8.0	41	good	good	good	fair	good	seldom	1000-2500	freeze, tillage, chemical
Sunflower (Helianthus annus) (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, chemical, tillage
Cowpea (Vigna unguiculata)	summer annual	semi-upright to climbing	5.5-6.0	58	excellent	very good	fair	fair	very good	never	2000-3600	freeze, chemical, tillage, mow
Crimson Clover (Trifolium incarnatum)	winter annual	upright to semi-upright	5.5 - 7.0	42	very good	good	fair	fair	very good	never	3500-5500	freeze, chemical, tillage
Field pea (Pisum Satuvum)	cool season annual	climbing	6.0-7.0	41	fair	fair	fair	fair	fair	seldom	1200-3000	tillage, mow, chemical
Hairy Vetch (Vicia villosa)	winter/cool season annual	climbing	5.5-7.0	60	fair	good	good	fair	good	expected	1800-4000	tillage, chemical, roller crimper
Pea, 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 pretense)	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	creeping	5.5- 6.5	42	fair	fair	fair	good	fair	expected	600-1000	chemical, tillage