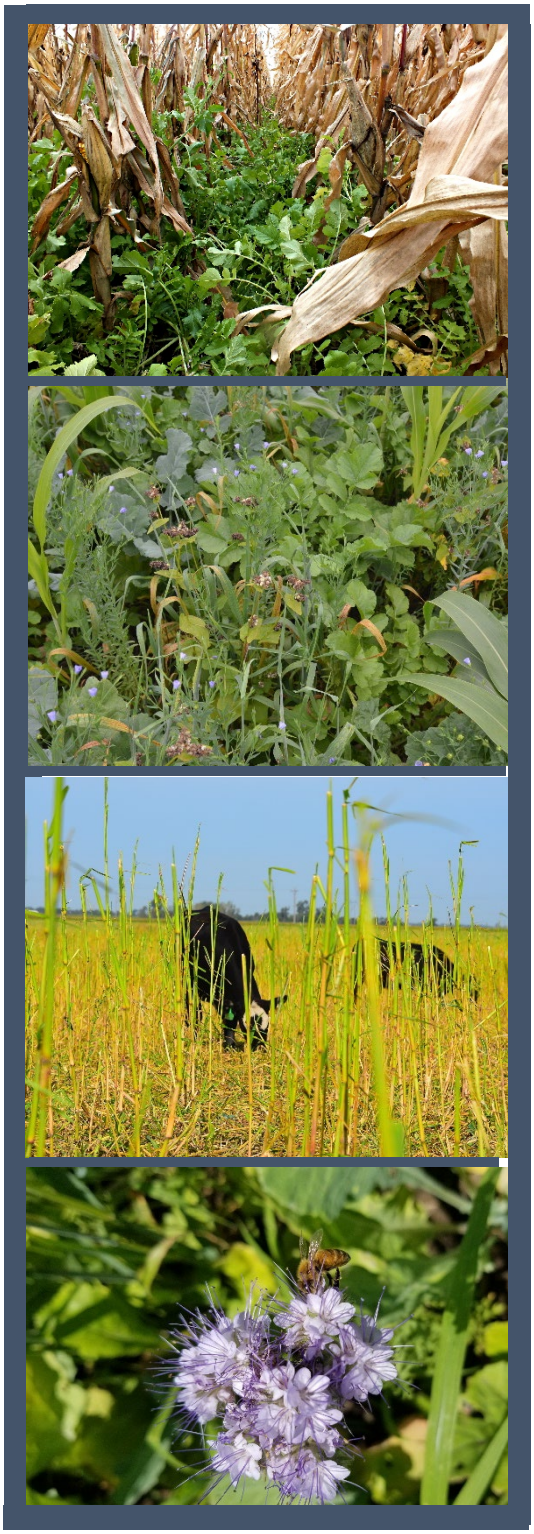
USDA United States Department of Agriculture



TECHNICAL NOTE

COVER CROP TECHNICAL NOTE NO. 16

Revised 7/6/2021

This technical note is to serve as a guide for installing cover crops according to the practice standard found in the South Dakota (SD) Natural Resources Conservation Service (NRCS) Technical Guide.

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Cover Crops

Cover crops are grasses, legumes, and other forbs planted for erosion control, improving soil structure, moisture management, nutrient cycling, increasing beneficial soil biota, suppressing weeds, providing habitat for beneficial predatory insects, facilitating crop pollinators, providing wildlife habitat, and as forage for farm animals. Furthermore, cover crops can provide energy savings both by adding nitrogen (N) to the soil and making more soil nutrients available, thereby reducing the need to apply fertilizer.

Seedbed Preparation

Seedbed preparation shall be adequate to promote germination and growth of the cover crop species planted. A properly prepared seedbed will be free of competing vegetation and not subject to excessive erosion. It also will be firm, so the seed is can be placed at the correct depth.

Seedbed preparation often begins during harvest of the previous crop. Harvest equipment that spreads the crop residue (straw and chaff) evenly across the field improves seedbed uniformity. Drill performance can be impeded by concentrated rows of residue remaining after combine harvest. When residue is more uniformly spread across the header width, stand establishment improves. If the straw is to be removed, it is still important to spread the chaff to prevent issues with seed placement and emergence.

When harvesting small grains, instead of cutting the plant off as a traditional header does, some farmers elect to use a stripper header. A stripper header catches the small grain head and strips the kernels off leaving the rest of the plant standing.

In many cases, harvest is the only seedbed preparation needed. The untilled seedbed will be firm, which is essential to providing good seed-to-soil contact. Experience shows drilling cover crops directly into the undisturbed residue of the previous crop often results in the best success.

Tillage is generally identified as an unnecessary component of seedbed preparation for establishing cover crops. Tillage breaks soil aggregates apart, disturbs soil biology, and compacts soil over the long term. When tillage is employed, avoid tilling soil when it is too dry (I.e., dusty) or too wet (I.e., smears or sticks to equipment). Use the least aggressive tillage method possible to achieve the intended outcome. Ensure too much time does not pass between the final tillage pass and seeding the cover crop as delaying seeding several days may result in a weedy cover crop due to tiny weed seeds germinating below the soil surface.

Seeding Methods

Cover crops may be established using a variety of methods but generally includes either drilling or broadcast seeding. Each method has its own set of advantages and limitations; therefore, it is important to use a method best-suited to meet the intended cover crop goals.

Drill Seeding

Drilling cover crops results in the most uniform seed distribution. With accurate metering, depth control, and spacing, drills offer good seed placement and excellent seed-to-soil contact, which leads to high cover crop establishment rates. Good seed-to-soil contact is also important for fast, consistent emergence. Drilled cover crops will produce denser stands more quickly than other planting methods, which helps with weed suppression. Drilling also generally uses less seed than other cover crop seeding methods, making it more economical. One of the biggest drawbacks of drill seeding is that corn and soybean harvest delays cover crop planting beyond ideal planting dates.

In general, there are two broad classes of seed drills, box drills, and air drills/seeders. The "drill" portion of both are essentially the same – seed tube, furrow opener, press wheel, and furrow closer. Much of the success of a seeding depends on how well these components function to place the seed in contact with the soil at the optimum depth for the species or mix being planted. Opener disks should be kept sharp and should receive adequate down pressure to reach the desired depth. They should cut (rather than hairpin) the residue. Depth-gauge wheels, depth-bands, or other mechanisms prevent planting too deep. All settings should be readily adjustable to maintain planting consistency from field-to-field and across changing soil conditions.

Box drills and air drills/seeders differ mostly in where their seed reservoir is located, and in how the seed is delivered to and from the metering mechanisms. The seed reservoir (seed-box) of a box drill is mounted directly to the frame of the implement and depends on gravity flow to deliver seed to the adjustable openings at the bottom of the hopper shaped seed box. It is metered through fluted gears attached to a rotating shaft powered by a ground-drive wheel. Seed falls into the seed tube and through the furrow openers to the bottom of the seed furrow.

Air seeders/drills use air to blow the seed to the seeding unit. The seed reservoir can either be located on the seeding unit itself, or contained on a cart, either pulled in front (tow between configuration) of the seeding machine, or behind it (tow behind).

Multi-species mixes can be challenging to plant because they often include combinations of seed from different functional groups. Cover crop species generally fall into three functional groups: cereals, legumes, and brassicas. Species with very different sizes and weights may sift or separate in the seed box as the drill operates across the field. To reduce this problem, do not fill seed-boxes to capacity, and closely monitor the seed mix as planting proceeds across the field. If sorting occurs the seed should be manually stirred, (especially with fully filled seed-boxes). Most grain box drills can be outfitted with an additional seed hopper, often referred to as a small seed (or alfalfa) attachment, to address issues associated with planting seed mixtures. They allow for the larger seed to be delivered from the main seed-box through the row openers to the bottom of the furrow at their optimum planting depth. The seed tubes from the small seed-box should be configured to place the seed on the loosened soil behind the openers and pressed into the soil by the following press wheels. Air seeders can also be fitted with multiple seed carts (or multiple compartments per seed cart) to facilitate seeding species with different sizes and weights.
Adding cover crops between full season crops in rotations, such as corn and soybeans, presents problems because of the lack of a good planting window. Research at South Dakota State University (SDSU) indicates cover crops planted at or just before corn competes with the corn much the same as weeds, lowering production. However, if the cover crop was inter-seeded

between rows during the middle or near the end of corn's critical weed free period (V6 or later), the cover crop did not reduce the corn yield (Bich et al.,2014). Many types of equipment have been retrofitted/purchased to inter-seed cover crops. Commercial inter-seeders have been designed specifically to drill cover crops in standing row crops.

Broadcast Seeding

Broadcast seeding can be used when soil conditions are not conducive to using a drill. Some farmers also broadcast cover crops to help them cover large acreages in a relatively short time period. Broadcasting by ground may be done using spinners, drop tubes or air pressure. The most critical factor is accurately metering seed before it is spread and making sure the seeding pattern is appropriate for complete and even ground cover. Different seeds have varying spread patterns based on their respective weights, and heavier seeds spread further than lighter seeds. Broadcast seeders may also be mounted on tractors, combines, high boy sprayers, tillage tools, or other implements. Floater type application equipment may also be capable of operating in conditions too wet to use normal drilling equipment. Caution must be used to ensure wheel tracks and compaction do not negate the cover crop benefits.

Tillage Incorporation

Broadcasted cover crop seed may be followed with light incorporation to increase seed-to-soil contact. Rotary harrows, coulter harrow type vertical tillage tools, or similar tools can be used to aid in fluffing or cutting residue to allow improved contact with the soil. Air delivery seeders can be mounted to these tools to deliver the seed to the soil as the residue is lifted or cut. Typically, the tillage implement is set to run no deeper than one inch and is not designed to invert the soil or bury the crop residue. Coulters should be set to run straight and not be cupped or concave. Tools with multiple operation gangs should only utilize the coulters with the rear harrow gangs raised or detached. This prevents excessive soil disturbance which reduces the benefit of the cover crop and ideally is a single-pass operation.

Broadcast seeding, even with tillage, does not allow seed to be pressed into the soil and covered at an optimum depth which promotes quick, vigorous emergence. Even after tillage, much of the seed will remain on the surface of the soil, exposed to predation by birds and other animals. Success of broadcast plantings is also highly dependent on timely precipitation. Lack of rainfall may prevent germination and inadequate rain may allow germination only for seedlings to dry out and die. Therefore, seeding rates for broadcast seedings will be increased by 50 percent (%) (full rate times 1.5). An exception is cereal rye, in which seeding rate is based on seeding date.

To improve establishment, cover crops have been mixed with fertilizer and broadcast applied with dry fertilizer applicators. Problems with the seed separating from the heavier fertilizer can occur and may result in uneven seed placement. This problem occurs more with spinner type spreaders and may be reduced by using boom mounted air-flow application equipment. Cover crop seed has also been mixed in suspension fertilizers and broadcast with liquid fertilizer application equipment. Cover crop specie(s), fertilizer source, and soil environment all affect how much fertilizer can be safely applied with seed.

Broadcast Seeding Without Incorporation

Expect only fair seed-to-soil contact when seed is broadcast on the soil surface with no incorporation. The broadcast with no incorporation seeding method relies on rain, freeze/thaw cycles, and/or snow to

incorporate the seed. Broadcasting by air is often done in situations where it is not practical to use other seeding methods. For example, low lying areas where planting a commodity crop was prevented due to soil wetness. In those conditions soil moisture is more likely to permit seed germination and establishment. Although broadcasting seed in wet conditions can allow for more timely applications, most cover crops will not perform well if broadcast on to a compacted or crusted surface.
Aerial seeding into existing vegetation or standing crops may be desirable to add additional functional plant groups to low diversity crop rotations (i.e., corn/soybeans). A narrow seeding window is sometimes available in late summer and early fall when crops have reached physiological maturity and are no longer using available soil moisture. Aerial seeding into standing row crop success has been inconsistent. Generally, results have been better on the eastern third of the state during periods of high rainfall.

Because seeding is occurring into a standing crop, there is the potential for cover crop seeds to get caught in the crop canopy and not make it to the soil surface. There is also the potential for insects, rodents, or birds to eat seeds on the soil surface or for seed to mold with moisture from heavy dew. Thus, the nature of aerial seeding suggests seeding rates be increased to ensure enough seed is on the ground to get a good cover crop stand. Grasses are more adapted to germination on the soil surface, therefore cereal grains (e.g., wheat, rye, triticale) have the greatest potential for success. Irrigated fields also have increased success rates.

Cost associated with flying-on the recommended cover crop seed rate can sometimes be prohibitive. Some farmers have reported success using lower seeding rates for cereal rye, but outcome has been highly dependent on moisture, surface conditions, residue amounts, and growth prior to frost. Small seeded brassicas (e.g., mustards, rape, canola, turnips, radishes) are sometimes added to the mix to reduce weight. To be effective, brassicas must have at least six weeks of growth following germination. If the cover crop seeding is under contract with Natural Resources Conservation Service (NRCS), do not lower the seed rate without prior approval, reducing the seeding rate may impact cost-share eligibility.

The South Dakota (SD) NRCS has developed guidelines for fall aerial seeding into these standing crops.

Guidelines for success when aerial seeding cover crops into standing soybeans:

- Start aerial application of cover crops when the soybean plant is showing 25-50% yellowing of leaves.
- Aerial apply seed cover crops when 40-50% of the sunlight can reach the ground between the rows. (Walk in the field a few rows to determine this.)
- For success, do not fly cover crops into immature soybeans (still very green). The seeds will most likely germinate and then mold (not enough sunlight to conduct photosynthesis).

Guidelines for success when aerial applying cover crops into standing corn:

- Choose a corn variety with more vertical leaf structure.
- Aerial apply cover crops when the corn plant is dried approximately to the ear.
- Aerial apply cover crops when approximately 50% of the sunlight can reach the ground between the rows. (Walk in the field a few rows to determine this.)
- For success, do not fly cover crops into immature corn (still very green). The seeds will most likely germinate and then mold (not enough sunlight to conduct photosynthesis).

Species Selection

Cover crops have several advantages, but there isn't a single species that does it all. Species selection should be driven by the specific goals of the farmer. Single species provide a narrower spectrum of

benefits but can be a simpler way to get started. Cover crop mixtures, although more complex to manage, generally provide a more diverse array of benefits.

When designing a single species or multi-species cover crop mix, there are several plant characteristics and traits to consider. These characteristics are evaluated on how well they achieve a particular benefit or address a problem. This information is compiled into the SD Cover Crop Table 1. SD uses a "good", "fair" and "poor" rating system. "Good" meaning plants with this rating will consistently achieve the identified purpose or provide an intended benefit. "Fair" implies there are some limitations in achieving a purpose or in some situation's plants will perform better than in others. Plants with a "poor" rating do not have a significant contribution toward achieving the desired condition. Plants with a poor rating may still be providing some benefit, but to a much lesser extent and if planted alone would not be expected to achieve the desired results.

Table 1 guides the user to select plants known to achieve a particular outcome. Often, it is desirable to address more than one problem or get multiple benefits with the same mix. When this is desired, how do you ensure the additional benefits you are trying to achieve do not negate the primary problem you were trying to solve initially? The NRCS uses information contained in the conservation practice standard to identify minimum criteria to achieve a benefit or solve the identified resource concern. For example, if the goal was to address compaction, the criteria to do this, states: "Select cover crop species with the ability to root deeply and the capacity to penetrate or prevent compacted layers." The SD Cover Crop Table 1 identifies species grown in SD known to achieve these criteria.

Designing the Mix

When designing a cover crop mix, it is best to draw from multiple functional groups. These functional groups differ in the types of benefits they can provide to a system. Cereals have higher carbon/nitrogen (C/N) ratios compared to legumes. Because of this, they decompose more slowly and generally provide greater weed suppression in the succeeding cash crop. However, a high C/N ratio can tie up plant available N as microbes work to decompose residue. Legumes fix atmospheric N, meaning they can provide a N credit at termination. Depending on termination timing, they can also provide an excellent nutrient source for foraging pollinators. Because they have a lower C/N ratio, legumes will decompose more quickly than cereals resulting in a shorter period of effective weed suppression. Brassicas, such as radish and rapeseed have a unique tap root which can help break up soil compaction. Brassicas can also be allelopathic, meaning the roots exude chemicals that can prevent weed germination and/or reduce soil dwelling pathogen populations.

General guidelines for designing a cover crop mix include:

- Select cover crop species adapted to soil, climatic, and ecological site conditions.
- Select cover crop species suited for the planned purpose, maximize the desired benefits, and appropriate for the specific site conditions. Refer to Table 1, Cover Crop – Common Species and Properties, for more information.
- Utilize cover crops to enhance crop diversity by adding crop types missing from the cash crop rotation (cool-season grass, cool-season broadleaf, warm-season grass, warm-season broadleaf).
- Select species adapted to the desired planting date with ample time to germinate and reach an acceptable growth stage prior to a killing freeze or adequate root growth to survive the winter.
- Species identified as restricted or prohibited by law shall not be planted.
- Legumes should be inoculated with the proper Rhizobium bacteria. Inoculation helps legumes produce nodules which fix atmospheric N into plant available N.

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 growth characteristics, anticipated growing conditions, nutrient needs, planned seeding rate, and the termination method and date. The seed mixture should create a balanced stand of above ground biomass and root structure to enhance soil building. Seed mixtures with a full canopy will maximize snow retention, soil surface coverage, reduce soil erosion, and can be utilized for livestock forage. A mixture of grasses, non-legume broadleaf (flax, buckwheat, etc.) and legume plants 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 nutrient exchange sites in the soil.

To produce maximum growth, late-summer seeded cover crops should be planted as soon as possible after harvest of the primary crop which are usually cereal crops. Typically topsoil moisture is adequate immediately following cereal crop harvest due to the ripening canopy still shading the soil surface and reducing soil moisture evaporation. This will allow cover crop species to quickly germinate and out compete volunteer cereal growth. Spring seeded cover crops may be an option ahead of soybean and sunflower production provided they are planted as early as possible. Season long cover crops can be planted throughout the growing season depending upon producer goals and objectives.

Seed Quality

Seeding rates are based on Pure Live Seed (PLS) obtained from seed tag information or lab test results. To ensure the quality of all planting material, **the minimum bulk seed germination allowed for each species is 85%.** For seed lots testing below the minimum, the seed rate must be based on PLS and not the bulk seed rate. (PLS = Purity * % total viable (germination + hard seed + dormant)/100).

- When total viable percentages fall below 85%, actual seeding rates MUST be increased to compensate for non-viable seed. Non-commercial (bin-run) seed can be used, if the seed has been tested and contains no prohibited noxious weed seed (no tolerance allowed).
- Cooperators using bin seed must be careful to adhere to the restrictions imposed by the federal Plant Variety Protection Act, the SD seed rules and statutes, and laws governing the use of seed from patented plants.
- All seed must meet the requirements of SD State Seed Laws and Regulations. Information on state seed law is available under SD Article 12:36 Seed Inspection (http://sdlegislature.gov/rules/DisplayRule.aspx?Rule=12:36).
- All seed; including homegrown seed, must be tested for purity and germination to determine if the minimum germination has been met or if PLS calculations must be used to determine the proper seeding rate.
- Tests must be made within a nine-month period, exclusive of the test month, prior to seeding. Retesting of seed is required if the nine month period has lapsed as stated in Article 12:36:04:01 (http://sdlegislature.gov/rules/DisplayRule.aspx?Rule=12:36:04:01).
- Species in the Association of Official Seed Analyst (AOSA) Rules for Testing Seeds must be tested according to the AOSA Rules.
- Information on sending the seed lab at SDSU for testing is available at: http://www.sdstate.edu/ps/seed-lab/index.cfm. If Amaranth species is found in the test results, it must be identified on the seed test report. The SD Department of Agriculture (SDDA) requires a genetic test to be done to determine if the Amaranth species is Palmer Amaranth, a prohibited noxious weed seed.

Calculating Pure Live Seed

The PLS can be calculated from information on the seed tag. By state law, seed tags must contain certain information. Specific information on seed tag requirements can be found at http://sdlegislature.gov/rules/DisplayRule.aspx?Rule=12:36.

The PLS is derived by multiplying % pure seed by the % germination (plus % hard seed, if present) and dividing by 100. For example, if a sample of Radish has a purity of 96% and a germination of 74%, PLS would be calculated as follows: (96% X 74%)/100 = 71.04% PLS per pounds (lbs.) of bulk seed.

To calculate the lbs. of bulk seed required, divide the PLS requirement for the seeding by the % PLS (expressed as a decimal). For example, if 1,000 lbs. of PLS of the above Radish is required for the seeding, the amount of bulk seed to purchase and apply to the field is: 1,000 lbs. of PLS/0.7104 = 1,408 lbs. of bulk seed.

Table 1 contains seeding rates for all species approved for use in SD. The percentage of each species in the mix when added together will equal at least 100% in the cover crop seeding plan (SD-JS-340).

Seeding Dates

May 1 through August 5 – warm-season winter kill species
Early spring through August 20 – cool-season winter kill species
August 1 through Winter – species that do not winter kill

Seeding dates fluctuate annually. Seeding dates may be adjusted up to 15 days by the District Conservationist, based on local weather and site conditions. Be cognizant of potential green bridge that could happen if cool-season grass cover crop species such as wheat, oats, barley, or rye are planted near commercially grown winter wheat fields.

Fertilization

Cover crops usually follow fertilized crops and do not require fertilization. Fertilizer is not recommended (this includes N) for the establishment of the cover crop but may be used to increase biomass production on poor or damaged sites, or for grazing. The cover crop may be used to sequester or trap nutrients from manure or fertilizer applied for the subsequent crop. Fall planted fibrous rooted grasses or small grains and brassicas will scavenge leftover N from the previous crop. Legume cover crops will add N to the soil for the following crop. Adjust N application rates for the subsequent crop based on N credits for specific cover crop species from SDSU nutrient guidelines, when available.

A current soil test is recommended prior to planting the following cash crop to determine appropriate fertility requirements. Additionally, some cover crops (brassicas) have a high sulfur demand. Sulfur deficiencies are most common when soil organic matter is low. Because brassicas are good sulfur scavengers, deficiencies may be observed in spring seeded cereals and early season corn, before the crop roots have reached deeper pools of sulfur.

Factors Affecting Establishment

When establishing cover crops, farmers must overcome several challenges to get the full benefits. Some of these factors include the short growing season between crop harvest and cold winter weather,

inconsistent rainfall, herbicide restrictions, weeds, and volunteer crop. A key factor is planning. Farmers who plan their cover crop program up to a year in advance of seeding are more likely to be successful and although having a good plan is essential, flexibility in adapting the plan to current conditions also is important.

Herbicide labeling requirements and restrictions continues to be one of the most challenging aspects of adding cover crops to a rotation. Some herbicides maintain long-term residual soil activity for months or years after application and could impact cover crop establishment and/or their use for forage. The persistence of herbicides can be affected by a wide range of management (tillage, application rate, and herbicide application method) and soil properties (moisture, temperature, soil colloid properties, chemical reactions, pH, microbial population, soil texture, and organic matter). Always check the herbicide labels for planting, harvesting, or grazing restrictions. Herbicide application records should be reviewed for at least the past two cropping seasons.

Understanding Herbicide Label Restrictions

Once a herbicide is used in a cropping system, the restrictions on the label must be followed for the original crop it is used on AND the succeeding crops until all restrictions on the label have been surpassed. These rotational restrictions exist for two reasons:

- To protect humans and animals from herbicide residues that a succeeding crop may accumulate at elevated levels prior to entering the feed or food chain.
- To ensure good establishment for the following crops by avoiding herbicide carryover injury.

Identifying the difference between a forage crop and a cover crop in the herbicide label is critical when evaluating herbicide label restrictions. Simply put, a forage crop is planted for animal feed, which can be either grazed by animals or harvested from the field. A cover crop is planted for a variety of reasons—improving soil health, adding nutrients, suppressing weeds—and is not harvested. Typically, the cover crop's biomass stays in the field and may be incorporated into the soil.

In the legal sense, once the biomass of a cover crop is removed from the field for feed (grazed or harvested), it is considered a forage crop or more precisely a crop, according to the Environmental Protective Agency (EPA) registered pesticide label. Label restrictions must still be followed even in situations where cover crops can be grazed or harvested within a crop insurance or cost-share program.

The University of Wisconsin Extension publication "Herbicide Rotation Restrictions in Forage and Cover Cropping Systems" contains a quick reference guide for rotation restrictions for several herbicide products.

Competing Vegetation

To produce maximum growth, late-summer seeded cover crops should be planted as soon as possible after harvest of the primary crop, which are usually cereal crops. Typically, topsoil moisture is adequate immediately following cereal crop harvest due to the ripening canopy still shading the soil surface and reducing soil moisture evaporation. This moisture allows cover crop species to quickly germinate and out compete volunteer cereal growth, which can compete for water and nutrients. If seeding is delayed, it is recommended to control weeds (including volunteer plants germinating from waste grain) prior to or immediately following the seeding of the cover crop. **Volunteer cereal growth will not be credited toward the cover crop full seeding rate.**

Disease Vectors

A good rule of thumb is to not include the same species in the cover crop mix as the cash crop preceding or following the cover crop. Most cool and warm-season grasses (including oats, barley, cereal rye, sorghum, and corn) can act to varying degrees as secondary hosts for the wheat curl mite. Wheat curl mite acts as a disease vector carrying the wheat streak mosaic virus. The mite prefers wheat and will multiply most rapidly on wheat; therefore, control of volunteer wheat is most important for controlling this disease and preventing its spread to nearby wheat crops.

Stand Evaluation

Unlike a cash crop in which stand success is evaluated based on yield at the end of a growing season, determining if a cover crop met its intended purpose can be a little more challenging. Cover crops are not intended to reach maturity, therefore other factors like stand density, surface coverage, and biomass production are used to gauge stand success. To complicate matters, cover crop mixes have a diversity of plants types. The way these plants are arranged influences the resources (sunlight, water, nutrients) they are able to capture. The leaves and roots of each plant define the crop structure they represent, (i.e., an oat seedling does not occupy the same footprint as a turnip). Therefore, when determining cover crops success, seeding rate, plant characteristics, and the intended purpose need to be considered.

General Guidelines to Determine Stand Success

The following guidelines can be utilized as a measure of successful stand establishment in most cases; however, exceptions will exist. Generally, intended cover crop benefits will be achieved when:

- Seeding mixes result in approximately 12-15 plants per square foot. This number should be increased by at least 5 plants per square foot when weed control or excess moisture utilization is the primary purpose; and/or
- Minimum cover crop canopy 40% or greater, and/or
- The above ground air dry weight biomass production is between 1,800 – 2,000 lbs. per acre (east river) and 1,200 – 1,400 lbs. per acre (west river) (6-8 weeks of growth).

Failure to meet these targets does not necessarily mean the stand has failed nor does exceeding these guidelines ensure stand success. For these reasons, seed quality guidelines and seeding rates previously discussed should be followed.

The minimum documentation required to certify the cover crop practice (as identified in the Conservation Practice Standard (CPS) 340, Cover Crop Documentation requirements) includes:

1. A field visit by an NRCS employee with cover crop job approval authority verifying seeding.
2. Seed tag label(s) - the minimum bulk seed germination allowed for each species is 85%. If less than 85%, the seed rate must be based on PLS.
3. Receipt or other documentation of how much seed was purchased.
4. Corresponding acreage of fields where the seed was planted.
5. Date planted.
6. Establishment procedure (drilled or broadcast).
7. Completion of SD-JS-340 (Implementation Requirement).

Seed tags and receipts or other documentation will be used to document the lbs. per acre meet the rate specifications on the Implementation Requirement (IR) sheet. Incorrect planting will be identified by this method. The above documentation can be acquired any time during the cover crop growing season.

If any items 2-6 above are not met, and the stand is questionable, then additional data collection is required to certify the practice. At least one of the following procedures will be used to document the seeding certification as meeting the NRCS standards. If assistance is needed to determine if standards and specifications have been met, please contact your area or state agronomist for help.

Randomly sample a minimum of three locations throughout the field. Sampling can be done using a one square foot (ft^2) frame (12 inches x 12 inches) or a range hoop which is 1.92 ft^2.

- The number of plants can be counted and divided by the number of sampling sites to determine average stand density (plant number/number of sites/frame size).
- Biomass per area can be measured by clipping all plant material within the boundaries of the quadrat. Place harvested material in a pre-weighed paper bag. Air dry samples until weight no longer changes (typically 5 days). To determine lbs./acre using a one ft^2 frame, multiply the grams times a factor of 96. For a 1.92 ft^2 frame multiply by a factor of 50.
- Amount of cover crop can be estimated visually to get a quick approximation. Look straight down at the growing plants and soil surface to determine how much of the surface within the boundaries of the quadrat appears to be covered. Do not look across the field as this results in overestimating the amount of cover as bare soil may be hidden from view. A residue rope can be used in some situations.

Once sample data is collected, utilize the general guidelines for stand success identified above to determine if stand meets the intended conservation practice purpose and the resource concern has been met.

Termination of Cover Crop

An important consideration when incorporating cover crops into the system is their termination. Some cover crops will winterkill while others will require some type of management. Cover crops that need to be terminated in the spring include winter (cereal) rye, winter wheat, winter triticale, red clover, sweet clover, and hairy vetch. A few cover crops may or may not winterkill depending on the severity of winter and degree of snow cover; these include canola, turnips, and annual ryegrass.

Winterkill from frost continues to be the most popular method of terminating cover crops. Farmers who are just beginning to experiment with cover crops or who have limited time and labor resources may consider growing cover crops that do not overwinter. Herbicide use is the next most popular method. The growth stage and height of the cover crop at the time of termination is critical in determining what herbicide and rate will be most effective. As with controlling weeds, cover crops are easier to kill early in the spring while they are small. Crops that are bolting, jointing, or producing reproductive structures can be difficult to control and may require other termination methods. Cover crops allowed to flower and produce viable seed can lead to volunteer cover crops becoming weeds in subsequent years. Consult with your agronomist, crop consultant, or area extension personnel for recommendations concerning volunteer cover crops in the following cash crop.

Herbicide control measures are generally divided into two groups: contact or translocated. Contact herbicides are not transported throughout the plant, they only affect the parts of the plant they come into contact with. Cooler temperatures won't limit contact herbicide activity; however, a successful application will require complete foliar coverage. Complete coverage will be especially difficult in mixed cover crop stands because of the different plant sizes and shapes. Translocated herbicides are transported in plants to their growing points and sites of action. These herbicides rely on plants

transport systems to gain access to the site of action — this eliminates the need for complete application coverage. However, the rate translocated herbicides kill plants depends on the plants metabolism, which tends to be slower in the spring due to cooler temperatures.

Herbicide effectiveness may be reduced when wet soils keep sprayers out of fields delaying spray applications allowing cover crops to reach undesirable heights and growth stages. Check fields for regrowth or skipped areas following herbicide applications.

Mechanical soil disturbance can be a method of cover crop termination, but the negative effects of tillage needs to be considered. If large amounts of cover crop biomass are present, multiple tillage passes may be necessary to terminate the cover crop, which can negate the benefits the cover crop is providing to soil health and could result in erosion. Rototillers can also be used to terminate cover crops when biomass levels are low enough to avoid clogging. Vertical tillage tools are not reliable for cover crop termination.

Mowing is less effective than tillage or herbicides for cover crop termination. Mowing leaves an uneven layer of mulch, which decreases weed suppression capacity. An additional drawback of mowing is that grass species grow back after mowing and may need to be mowed more than once for successful termination.

Rolling or roller-crimping reduces dependency on herbicides during corn and soybean production. Effective termination with this method is dependent upon the proper timing of the crimping for the cover crop species present. For cereal rye, it is recommended to wait until the rye has shed pollen to get a consistent kill with a roller/crimper. A cover crop mix makes control more complicated since the species can be at different growth stages, at the same time. Examples of cover crops controlled with rolling/crimping include hairy vetch (at full bloom), barley, triticale, or cereal rye (all at milk or dough stage).

Regardless of termination choice, it is important to have a plan in place to minimize problems in the cash crop. The proper timing of cover crop termination must be considered on a site and situation specific basis. Cover crops terminated too early in the season diminish associated soil quality and crop production benefits, while delaying termination until closer to cash crop planting dates increases risk associated with crop emergence, particularly in dryland conditions. If spring is exceptionally dry or if the long-range forecast predicts dry conditions terminate cover crops when they are small (six to eight inches tall) to conserve moisture.

Producers considering the growing season, soil moisture, soil temperature, N management, weed suppressive potential, and equipment with respect to timing of cover crop termination can successfully use cover crops to enhance crop productivity while minimizing risk to cash crop establishment.

The 2018 Farm Bill mandated changes to the treatment of cover crops for United States Department of Agriculture (USDA) programs, which add more flexibility to when cover crops must be terminated while remaining eligible for crop insurance. The USDA's Farm Service Agency (FSA), NRCS, and Risk Management Agency (RMA) developed new guidelines and policy provisions to enact these changes, which became available in the 2020 crop year. To learn more about cover crop termination guidelines, see: NRCS Cover Crop Termination Guidelines Version 4

Grazing Considerations

Grazing Potential Following Small Grains

Cover crop mixes planted after small grain harvest can provide high quality forage late into the fall and provide a rest period for cool-season pasture or rangeland. The brassicas (such as turnip, radish, rapeseed) will typically stay green into November and have been sampled with a range in crude protein of 14-19%. Other cover crop mixes can not only provide quality forage but also provide substantial amounts of dry matter production. Typically, mixtures containing warm-season grasses produce some of the highest dry matter results.

Field observations indicate the amount of forage produced by nonlegume species (specifically the brassicas) is directly tied to the amount of residual N in the field. Producers planting cover crops for grazing should consider soil testing and monitoring the amount of residual N in the profile after small grain harvest. When residual N is not available (or soil nitrate levels are low), the situation may lend itself to planting a mix with a higher percentage of legumes (such as field peas, vetch, clover, or lentils). If, there is residual N, producers could maximize production by using a mix of nonlegume and grass species.

Field observations also indicate if a high biomass cover crop was grown, the residual N was likely was utilized and no longer available. It may be tied up in the residue or may have been taken off by the livestock. If drier conditions prevail the following spring, the breakdown of the biomass produced will be much slower, thus the cycling of nutrients will be delayed and not available the first growing season. Soil tests should be taken following the cover crop in order to account for what the cover crop has sequestered.

Grazing Potential Season-Long

Season-long cover crops can be a great option for building up soil health, provide warm-season grazing for livestock, and can give native rangeland and pastures rest periods during the growing season. Optimum time for planting this type of mix would be late spring (June 1-15). Grazing mix should be predominately warm-season species and typically would be ready to graze around 45 to 60 (preferable) days after planting. If grazed correctly, adequate rest and regrowth could provide another grazing opportunity later in the fall.

When grazing cover crops, grazing heights, and the amount of residue left on the soil surface should be monitored closely. Full season cover crops may also be a great option when transitioning to no-till or recently converted no-till where soil structure is lacking, and water infiltration is low. One limitation is a cold spring or wet soil may hinder getting the cover crop planted. The SD NRCS recommends at least 50% residue or ground cover be maintained after grazing the cover crop, ensuring soils remain covered in the fall, and winter during critical wind periods. Long term no-till fields shouldn't have the infiltration issues; but grazing still need to be monitored and residue or ground cover maintained at or greater than 50%. A grazing stick is a good tool to use to determine amount of forage available and to measure how much has been taken off. Leaving a minimum of three-six-inch stubble height, depending on specie(s) selection, is a good rule of thumb. Refer to Prescribed Grazing, Range Technical Note No. 9 for more details.

Animal Unit Month (AUM): the amount of forage livestock will consume in one month. Standard animal unit (AU) is 1,000-lb. cow with a six month or younger calf by her side.

Kinds/Class of Animals	AUE
1,000 lb. Cow, dry	0.92
1,000 lb. Cow, with calf	1.0
1,200 lb. Cow, with calf	1.15
1,400 lb. Cow, with calf	1.29
Cattle bull, mature	1.40
Weaned Calf, yearling	0.60
Yearling Cattle (600-800 lbs.)	0.70
2-year old cattle (800-1,000 lbs.)	0.90
Horse, mature	1.25
Sheep, mature	0.20
Sheep, ram	0.25

Calculating Stocking Rate:

Formula: _____ X _____ = _____ X _____ = _____

Number of Animals | Animal Unit Equivalent (AUE) | AU | Months (M) | AUM

Calculating Forage Productions (lbs./acre): (Field Clippings 3-5 Samples/Field)*Air-dry forage samples

Formula: 1. Average Dry Weight (grams) X Conversion Factor = Production (lbs./acre)
2. Production (lbs./acre) X Acres in Paddock = Total Production (lbs./acre)

Calculating Carrying Capacity: (Average consumption of an AUM is 913 lbs. of air-dried forage).

Formula: 1. Acres in Paddock X Actual Production (lbs./acre) = Total Production (lb.)
2. Total Production (lb.) X Harvest Efficiency = Consumable Forage (lb.)
3. Consumable Forage (lb.)/913 (lb.) = AUM

Grazing Toxicity Concerns

When planning to graze cover crops, producers should identify risks to livestock. Some crop types are toxic to specific livestock species. Others may become toxic under certain conditions. The following briefly identifies conditions to be aware of. University and extension publications can provide more in-depth information.

Bloat - Some cover crop species are considered toxic to livestock. Bloating has been a consistent producer concern when turning cattle out into any lush cover crop field. Bloat occurs when gases from fermentation get trapped in rumen. Bloating symptoms results in difficulty breathing due to pressure on lungs and nerves. Risk of bloat can be reduced by implementing the following management strategies: 1) not to introduce hungry animals in to a field; 2) introduce animals slowly either through put and take or by restricted access over a 7-10 day period; 3) provide dry matter (hay, millet hulls, dry pasture, or crop stalks) to the cattle when they are grazing in the cover crop field; 4) the cover crop species should be at least 25% grasses and not more than 50% brassicas; 5) strip graze whenever possible to get the best utilization of the cover crop plants; and 6) use bloat blocks where ever practical.

Risk of bloat also increases following a frost. Frost damage in high-quality forages like alfalfa, clover, and fresh small grain shoots, cell walls to rupture and make protein and minerals more readily available for one to two days. These readily available proteins and minerals increase gas buildup in the rumen to the point animals cannot eliminate them by eructation (belching), creating bloat.

Nitrate Toxicity – When excess nitrate is consumed, it is converted to nitrite in the rumen and absorbed in the bloodstream. Nitrate from soil can accumulate in many species (corn, small grains, sorghums, millet, brassicas, weeds such as kochia, and lambsquarter). Not only a drought-related issue; nitrate toxicity also occurs following hail, a hard freeze, chemical damage, mineral imbalance, excessive fertilization, and may result due to previous crop history. Nitrates commonly concentrate in the lower portions of plant stems. Symptoms of nitrate toxicity include abortion, weakness, incoordination, muscle tremors, and blue membranes. Consider sampling and testing for nitrates before haying or grazing. Allow for time to adapt to high-nitrate forages. Give full feed of hay prior to turnout. Consider grazing stockers or open cows. Also, consider energy supplements.

Grass Tetany - Occurs in lush, green, cool-season grasses in spring and fall. Grass Tetany is caused by an imbalance of potassium, calcium, and magnesium. Symptoms may include staggering, twitching, excitability, and death. Supplement with magnesium oxide or magnesium sulfate if risk of grass tetany is suspected.

Ergot - Ergot is a fungus affecting small grains and grasses (wheatgrass, brome, fescue). Sclerotia ergot bodies replace seed heads of infected plants. This can be common when wet conditions persist during boot stage. The greatest risk of toxicity occurs when grazing mature plants. Symptoms include lameness, loss of extremities, heat stress, and decreased milk production. Examine pastures and hay for ergot. Graze before seed heads develop or clip seed heads before grazing.

Sulfur Toxicity (Polio) - Excess sulfur cause buildup of hydrogen sulfide in the rumen and bloodstream. Brassicas, alfalfa, canola, and weeds may be high in sulfur. Symptoms include neurological issues, blindness, head pressing, convulsions, and death. Limit brassicas to no more than 50% of cover crop mix. Remove or limit high sulfur containing feeds from the diet. Replace high sulfate water sources.

Prussic Acid - Certain forage plants, especially sorghums and related species are associated with an increased risk because of prussic acid poisoning. Prussic acid or hydrogen cyanide (HCN) forms during water stress or after frost. It prevents oxygen transfer from blood. Symptoms include rapid breathing, muscle spasms, and other symptoms like nitrate toxicity. To reduce risk, do not graze until plants are 24-30 inches tall. Do not graze for 10 to 14 days following a drought-ending rain. Do not graze regrowth until it is 18 inches tall. Harvest forage as hay or silage. Avoid green chopping.

Sweet clover – Sweet clover contains coumarin, which converts to toxic dicumarol in moldy hay. Symptoms include stiffness, lameness, swellings beneath the skin, and abortions. Ensure hay is dry before bailing. Alternate with non-moldy forage to avoid severe poisoning.

Hairy Vetch - Allergic reactions in cattle and horses can occur from ingesting hairy vetch. Symptoms include swelling, cough, loss of appetite, weakness, diarrhea, and abortions. Limit to less than 15% of mixtures.

Brassicas – These plants are extremely nutrient dense and high in moisture but low in fiber. Therefore, it can be difficult for livestock to eat enough to meet their nutritional requirements. Toxicity concerns

include polio, nitrate toxicity, and bloat. Large bulbs may lodge in the esophagus and lead to choking. Limit brassicas to 50% of mix for best results.

Grazing Compaction

Integrating livestock with cover crops can be very advantageous for long term soil health. The manure and urine from grazing animals have been found to stimulate the soil biology. Caution should be taken when grazing cover crops during wet, non-frozen soil periods as compaction issues could affect crop production the following year. It is best to remove the livestock completely when these conditions occur as decreased yields have been observed.

In an average precipitation year, fall months tend to be drier than spring months. Therefore, grazing in late summer or early fall should not cause soil compaction problems and ample precipitation received in the spring should recharge our soil moisture profile for the following cash crop.

To avoid cash crop yield decreases following cover crops, producers should:

- Moderately graze during dry or frozen soil conditions to avoid soil compaction.
- Minimize residue removal to promote proper soil armor.
- Ensure proper diversity of cover crop mix for grazing.

Producers who implement grazing practices are encouraged to fence off areas in a field and conduct their own yield checks on the following year's cash crop to determine impacts whether positive or negative on their own farm.

Wildlife and Pollinator Benefits

Several cover crop species can provide excellent food for wildlife, including pollinators and beneficial insects. Cover crops can provide important areas to forage, areas of cover from both predators and the elements, and areas in which to breed and nest. Migratory birds passing through the region use cover crop fields to forage and rest. High-quality stopover sites are also important as birds arrive on their breeding grounds earlier in the year, typically have greater reproductive success. Cereal grains and legumes will provide nesting habitat, if allowed to grow over 12 inches tall before termination. Minimizing field disturbance during the primary nesting season (fewer passes, wider row spacing, not using a roller) can increase nest survival for breeding birds. Cover crop fields can provide food in the winter and brood-rearing habitat in the spring for foraging chicks. Including diverse cover crop plant species which flower and bloom, greatly increase insect abundance and type. Thus, a mix of cover crops can be beneficial for young birds that require insects as their main food source in the spring.

By ensuring that fields have green cover, even in idle years, it allows the ground to be used by wildlife. Green cover allowed to bloom is especially valuable for pollinators and other insect species. Fallow fields provide very few benefits to wildlife. Cover crops like clovers, vetch species, and peas can provide great habitat for native pollinator species, which has important advantages for agriculture and the ecosystem. Bee populations have been rapidly declining across the country. This decline has the potential to adversely affect agricultural production, since bees pollinate many commodity crops.

Flowering cover crops can be attractive to pollinators and beneficial insects because they provide pollen, nectar, and shelter. Most brassicas, if allowed to bloom, are an excellent food resource. Many natural enemies of crop pests also benefit from these habitat resources for at least one stage of their life cycle. Attracting pollinators and beneficial insects has the potential to boost yields through increased pollination services and natural pest control. Utilizing a diverse cover crop mixture will maximize beneficial insect activity by generating season-long blooms and variation in vegetative structure.

Table 2: Cover Crops Used by Wildlife, Bees, and Beneficial Insects

	WILDLIFE - BIRDS AND MAMMALS							BEES AND BENEFICIAL INSECTS	
	COVER				FOOD				
Cover Crop	Nesting	Brood	Fall	Winter	Fall	Winter	Green Browse	Native and Honeybees	Predator Parasitoid
Alfalfa		X	X		X		1,2,3,4	High	Moderate
Barley	X	X					1,2,3	None	Low
Brassica hybrids		X			X	X	1	High	High
Buckwheat /5		X			X			High	High
Cabbage, African		X			X	X	1	High	High
Camelina, Winter								High	High
Canola		X	X		X	X	1	High	High
Clover, Balansa		X	X		X		1,2,3,4	High	Moderate
Clover, Crimson		X	X		X		1,2,3,4	High	Moderate
Clover, Red		X	X		X		1,2,3,4	High	Low
Clover, Sweet		X			X		1,2,3	High	High
Collards or Kale		X	X		X	X	1	High	High
Corn			X	X	X	X	1,2,3	None	Low
Cowpeas or Dry Beans		X	X		X	X	1,2	High	High
Fava beans		X	X		X	X	1,2	Moderate	Moderate
Flax							1,4	Moderate	Moderate
Lentils		X					1,2,3	Moderate	Moderate
Millet, hay			X		X	X	1	None	Low
Millet, proso			X		X	X	1	None	Low
Mustard		X	X		X	X	1	High	High
Oats	X	X	X		X	X	1,2,3	None	Low
Peas		X	X		X		1,2,3,4	Low	Low
Phacelia		X			X			High	High
Radishes		X	X		X	X	1	High	High
Rapeseed		X	X		X	X	1	High	High
Rye, Cereal	X	X			X	X	1,2,3	None	Low
Ryegrass, Annual								None	Low
Safflowers					X	X	4	Moderate	Moderate
Sorghum, Forage and Sudan Hybrids			X	X	X	X	1,2,3	None	Moderate
Sorghum, Grain			X	X	X	X	1,2,3	None	Moderate
Soybeans					X	X	1,2	Moderate	Moderate
Sudangrass			X	X	X	X	1,2,3	None	Moderate
Sugar beets		X	X		X	X	1	Low	Low
Sunflowers					X	X	4	High	High
Sunn hemp							1,3	High	Moderate
Teff grass			X					None	Low
Triticale	X	X			X	X	1,2,3	None	Low
Turnips		X	X		X	X	1	High	High
Vetch, Chickling							1,2	High	High
Vetch, Common					X		1,2,3,4	High	High
Vetch, Hairy		X			X	X	1,2,3	High	High
Wheat, Spring	X	X			X	X	1,2,3	None	Low
Wheat, Winter	X	X			X	X	1,2,3	None	Low

Key to Green Browse Use: 1 – Deer 2 – Geese 3 – Small mammals 4 – Grassland/Upland Birds

Cover crop benefits for pollinators and beneficial insects identified in Table 2 occur primarily while in bloom and must be allowed to bloom. Additional pollinator and wildlife habitat information is contained in SD Fact Sheets SD-FS-59 Wildlife Food Plots, SD-FS-94 Honey Bee, SD-FS-60 Pollinators, and Biology Tech Note 15, Wildlife Habitat Management Information.

Soil Health Benefits

The biology of the soil is vitally important to its overall health and productivity. The diverse populations of bacteria, fungi, protozoa, nematodes, earthworms, and arthropods create the hidden food web that affects crop production, nutrient cycling, and water infiltration and retention.

Cover crops provide an opportunity to create more biodiversity into a cropping system and keeps a living root growing season long; which provides exudates (sugars or carbohydrates) for fungi and bacteria to utilize as a food source. A symbiotic relationship develops and in return for the sugars, mycorrhizal fungi exchange water and nutrients to the crop roots, typically from areas the root does not or cannot reach. Like all plants, cover crops use sunlight and carbon dioxide to make carbon. Some is utilized by the organisms, but some eventually becomes humus and helps build soil organic matter.

Moisture Management

A major production concern in eastern SD may be moisture management. Planting corn in a timely manner into last year's small grain stubble, due to excessively wet soil conditions, has been a major issue. Cover crop mixes which canopy early in the fall to improve residue decay and take advantage of fall as well as spring moisture, are the answer to this rotation concern. Species fitting these criteria for fall canopy are cool-season broadleaves like the brassicas (turnips, radish, rapeseed, and brassica hybrids). Species which use early spring moisture and over winter increase trafficability through a living root system. These species are the winter small grains (winter wheat, winter cereal rye, and triticale) and the clovers/vetch (sweet clover, red clover, and hairy vetch). Species with early spring growth characteristics will utilize spring moisture and have been shown in Agricultural Research Service (ARS) studies to increase trafficability by 40-60%. Some of the driest spring planting conditions in the Brookings area ARS studies have been the hairy vetch, clover, and rye treatments.

In areas where lack of moisture is a concern, cover crops help improve water infiltration due to the increase in macropores, both from the roots and increased earthworm activity. The canopy from cover crops will shade the bare soil surface to reduce evaporation and help maintain soil biology. Cover crops can be terminated early to conserve soil moisture but should not be removed.

Weed Suppression

Cover crops can play an important role in suppressing weeds, especially during the fallow period between cash crops. Planting should take place as soon as possible after harvest and species chosen for fast establishment and producing large amounts of biomass to create competition. Drilling the seed provides the quickest and most effective way of establishing the cover crop. Broadcasting is another option but requires a higher seeding rate and good seed-to-soil contact is needed to help with establishment. Field observations in SD have not shown great success in broadcasting, especially where there is heavy residue covering the soil surface.

Some cover crop species (winter wheat, winter cereal rye, and triticale) are allelopathic, which means they produce chemicals, which reduce weed germination. These may be good species to consider in the mix, especially if dealing with herbicide resistant weeds. These species overwinter and can provide early weed control in the spring.

Salinity Concerns

In SD, soil salinity can be a resource concern for a few acres or a major concern across an entire field. Species selection for salt tolerance in a cover crop mix might include species of small grains such as rye, barley, and wheat. Broadleaf plants with good salt tolerance would be species such as canola, rapeseed, or sugar beets. The Saturated Paste (dS/m) electrical conductivity (EC) values for these cover crops are listed below. The threshold value represents the maximum salinity level at which a reduction in performance should not occur. In SD, salt affected fields or portions of fields with ECs greater than five or six are those fields where more intensive long-term solutions may need to be employed. Some of these areas may be devoid of typical salt tolerance vegetation such as foxtail barley and kochia. In such areas, long-term salt tolerant perennial cover should be planted including species such as western or tall wheatgrass. Additional information can be found in the 610 Salinity and Sodic Soil Management Guide Sheet located in the SD Field Office Technical Guide Section IV.

Crop Salt Tolerance Ratings:

Crop	Threshold EC, Saturated Paste (dS/m)	Salt Tolerance Rating
Rye	11.4	T
Barley	8	T
Wheat	6.0	MT
Canola or Rapeseed	9.7	T
Sugarbeet	7	T
Western Wheatgrass	6	MT
Tall Wheatgrass	7.5	T

Source: Annex 1. Crop salt tolerance data

Biomass Production

Anticipating the amount of biomass expected to be provided by the cover crop continues to be challenging. The SDSU data collected in 2007, indicated various cover crop mixes were producing an average of 1.7 tons of dry above ground biomass whereas USDA ARS data at Brookings during the same time period indicated that biomass production was half of this value.

In 2008 and 2009, SD NRCS randomly sampled cover crop fields seeded after wheat harvest. The 2008 survey (Figure 1) found a high degree of variability in cover crop dry matter production on fields sampled throughout east-central SD. Samples collected averaged 1.2 tons of dry matter per acre with values ranging between three fourths and 3.5 tons. The dry matter variability of the survey information in 2008 was reviewed by SD NRCS and ARS with no identified individual cause for the observed variability. Soil characteristics, precipitation events, soil moisture levels, soil fertility, residual N, and cover crop species diversity were all identified as potential sources of variability. Samples collected in 2009 showed similar variability. Although planting later in the growing season can impact the amount of biomass produced, review of the 2009 biomass data (Figure 2) indicated that less than half of the variability in biomass production could be explained by the delay in planting. For this reason, temperature, moisture, and fertility should also be considered when estimating biomass production.

Figure 1.

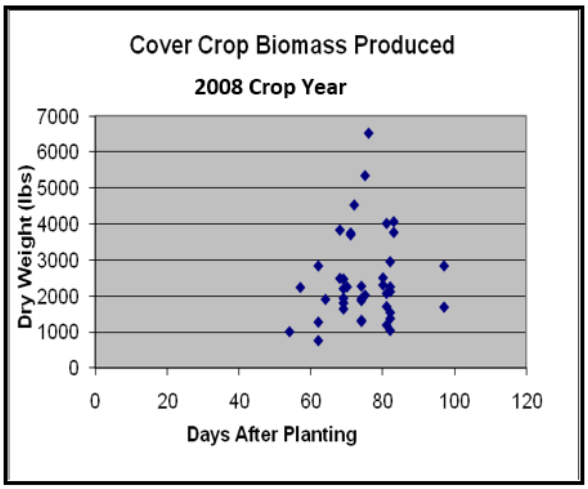


Figure 2.

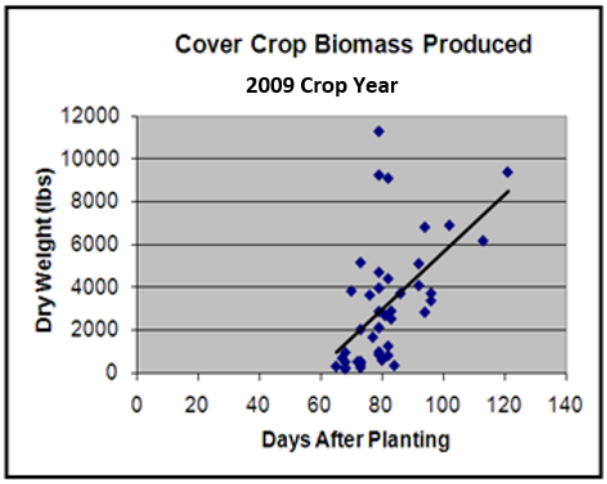


Figure 1. In the fall of 2008, the NRCS randomly sampled fields resulting in the above ground biomass values ranging from ¾ to 3½ tons/acre dry matter.
Figure 2. Fall of 2009 survey data indicates less than half of the variability in biomass production can be explained by planting date.

Nitrogen Recovery and Cycling

Species selection for recovering residual N may include species with a fibrous root system to recover N in the upper-most regions of the soil profile, as well as species with deep tap root systems to recover N below two-three-feet. Warm-season grasses such as sorghum or millet or cool-season grasses such as rye, wheat, barley, or oats, can tie up shallow nitrate in the soil profile. Other species recovering N deeper in the profile may include sunflower or cool-season broadleaves such as rape, canola, or sugar beet. Field observations have shown rape or canola appear to remain greener into the fall when other brassicas are clearly showing N deficiency symptoms. This phenomenon may be due to a deeper recovery of N by canola in the soil profile or possibly other plant characteristics. A more extensive recovery of residual N in the profile may also explain the increases in productivity of crops grown after canola as compared to other cover crops including the legumes, as well as, the observed increased rate of residue break down of crop residue on the soil surface after canola or other brassicas.

The amount of N fixed by cover crops planted for a short portion of the growing season has been a very relevant question for some time. Results suggest legume cover crops planted after wheat may take-up or fix 0 to 75 lbs. of N per acre. Annual legumes such as lentils or field peas would be on the lower end of this range while perennial or biennial species such as the clovers and vetches would be on the higher end. The amount of N fixed will not only depend upon the species grown but also on climatic growing conditions and the amount effective root nodulation. Legumes behave much like grasses when soil N is available, using it before fixing additional N. Well-established legumes fix more N than do seedling legumes.

Cover Crop Challenges

As interest in adding cover to crop systems increases, it is important to acknowledge planting cover crops does have its challenges. Although simple in principle, cover crop management can be quite complicated. Therefore, it is important to plan cover crops using a system approach thinking about the cover crop as a component of the overall cropping system.

Plant Disease

Cover crops can be hosts for both beneficial organisms and pathogenic organisms which cause disease. Cover crops can pose a potential threat as a "green bridge" by providing a host with food and shelter over the winter fallow period when the soil might otherwise be bare. Winter cereal cover crops preceding corn may host pathogens capable of causing corn seedling disease. Winter rye is a host of the same seedling pathogens as corn. Disease risks increase when the interval between killing the rye and planting corn is short. A wider termination window reduces the chance of yield loss. However, not all cover crops act as green bridges. Legume cover crops are hosts for the virus causing soybean sudden death syndrome, but most grasses and brassicas are not. Also, some covers planted back to back, year after year, can result in root and soil disease problems. Continually adding brassicas to the mix may result in pathogens affecting not only the cover crop but also crops like canola.

Insect Populations

Living green material (cover crops and weeds) can attract both beneficial insects and pests. Successfully integrating cover crops into a cropping system must include a commitment to scouting for insect pests on a timely basis and treating when it is needed. Cover crops attract many beneficial insects. Don't harm Beneficial's with an unnecessary insecticide application.

Be on the lookout for potential spring pest issues in cover crop fields, particularly with winter-hardy cover crops. Cover crops can be an attractive egg-laying site for pests like true armyworm or black cutworm and they can be an overwintering site for pests like common stalk borer. The effects of many insect pests can be lessened by terminating the cover crop early; at least two weeks before planting the following crop. Waiting to plant will starve pest insects which require large amounts of food daily to survive before the crop emerges. Displaced insects will be hungry and feed on any available crop. If there isn't enough time for the cover crop to die before the cash crop is planted, pests can move from the cover crop into the cash crop.

Plant Escapes

Cover crops can act as weeds in following cash crops if they are not properly terminated. Hard seed in cover crops may also require control later in the season or the next year. Hard seed is terminology often used to describe dormant seed with an impermeable seed coat, therefore slowing germination. Plant escapes can also be prevented by avoiding seed contaminated with weed seed which could take years to control or eradicate.

Frost

Most cover crops need at least 30 days of growth to be effective and many should have 60 or more days for the full benefits to be realized. Cool-season grass like oats will continue growing after a light frost but will be killed by a hard frost closer to November. A winter annual grass like cereal rye or winter wheat could be seeded later, become established in the fall and continue growing once the spring warms up. It would then be killed before planting the next crop. Cool-season legumes like forage peas or lentils can survive a mild frost in the spring but will be killed by a hard frost. Brassicas are cool-season annuals; they are most effective if they have 45 to 60 days before a killing frost to allow the tap root to penetrate deeper into the soil. Dormant seeding spring annuals including oats, and barley has not worked well in SD. Dormant seeding spring wheat has worked better. Vetches or clovers may also be an option once the temperature drops and the soil firms up. These cool-season cover crops will then germinate and grow in the spring. However, they may start growing early and be killed by a spring frost later because of the lack of residue to help protect them from temperature fluctuations.

Cover Crops Grown for Forage

There are many questions about using cover crops as a grazed or mechanically harvested forage. From an economic standpoint, use of the cover crop is the quickest way to recover some of the production costs associated with establishment. However, if the primary purpose of a cover crop is to keep the soil covered, removing all the biomass produced by the cover crop does not accomplish the intended benefit.

Therefore, when making the decision to use a cover crop for forage, the following guidelines should be used:

- Ensure adequate cover remains regardless of forage defoliation method. The primary purpose of a cover crop is to provide cover; grazing should be a bonus.
- For late summer planted forages and cover crops, the greatest benefit occurs when fall grazing is delayed until 90% of the above ground and below ground biomass growth is complete. At a minimum 6-8 weeks of growth should occur prior to grazing.
- Leave at least 4 inches of residue after grazing or mechanical harvest. This is important to reduce the risk of erosion during critical overwinter periods and improves snow catch.

Annual forages are a viable option to consider in addressing forage needs. Harvest options often include grazing, haying, or silage, depending on the crop. It is however important to realize forages grown only for the purpose of producing feed may not fit cover crop guidelines or some program requirements.

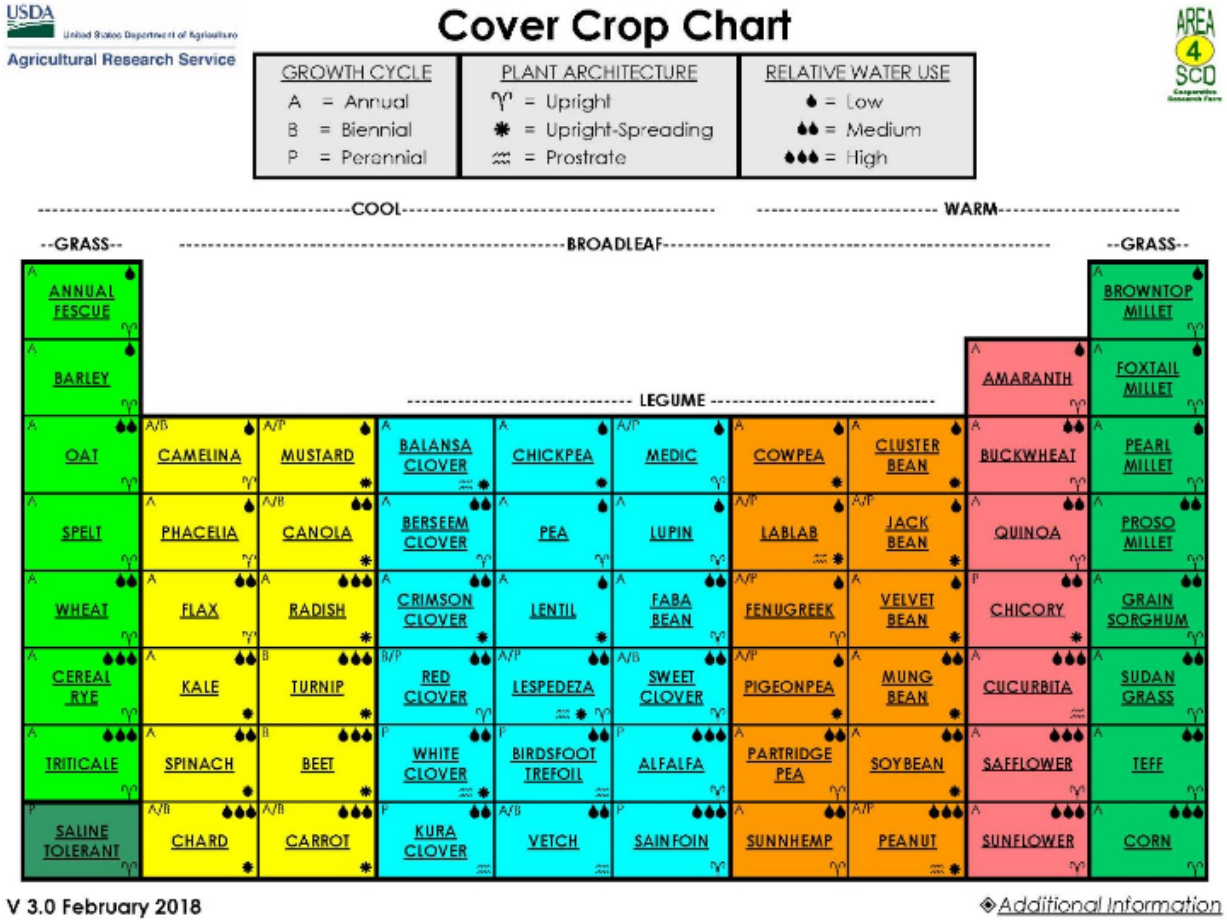
When selecting cover crops to be used as forages, consider growth, and plant characteristics. Covers used for forage may have some additional considerations than those left unharvested. The Cover Crop Chart produced and distributed by staff of the USDA-ARS Northern Great Plains Research Laboratory (NGPRL) in Mandan, North Dakota, is an excellent reference for individual species characteristics.

Cover Crops Chart Download

The Cover Crop Chart, designed by the ARS, can assist producers with decisions on the use of cover crops in crop and forage production systems. The chart, patterned after the periodic table of elements, includes information on 66 crop species which may be planted individually or in cocktail mixtures. Information on growth cycle, relative water use, plant architecture, seeding depth, forage quality, pollination characteristics, and nutrient cycling are included for most crop species.

The Cover Crop Chart is easy to use, requiring only Adobe Acrobat software. Using the chart as a guide, users can select individual crop species by clicking on the name which will direct them to additional information about the selected crop. Icons within each crop page return the user to the chart, easily allowing comparisons of different crops.

The Cover Crop Chart is a very good reference, however, some species contained in this chart may not be suitable for SD or have not been evaluated under growing conditions here at this time. Please see the Cover Crop Table 1 at the end of this document for suitable species. Species not contained in the SD Cover Crop Table 1 may be utilized in a seed mix if prior consultation and approval from the NRCS has occurred. Species listed as a state noxious weed or a county noxious weed will not be planted.



Emerging Technologies

Inter-seeding Into Young Standing Corn

One approach to inter-seeding is seeding cover crops into a standing corn early in the growing season. This management practice requires special or at least modified equipment. When planted prior to canopy closer, to germinate, the cover crop seed must take advantage of sunlight penetrating through the canopy. Planting covers before the canopy closes allows for light interception by young seedlings. This light interception is important for early growth and root development before the rapidly growing crop shades out the covers and puts them into a sort of dormancy, where they must hang out in the understory until late in the season.

One question often asked is when should the cover crop be planted? Corn needs to maintain a competition free timeframe from emergence to around vegetative stage (V), V5-V6. Inter-seeding success is also increased when rainfall occurs within about seven days of seeding. When choosing a crop for inter-seeding, look for species that easily establish and can germinate in low light conditions. Several

grass and legume cover crops fit this description, including annual ryegrass, cereal rye, red clover, crimson clover, and forage radish. These can be planted either singly or in a mixture. The biggest challenge of inter-seeding into standing corn is herbicide application and carryover. Carefully read the label for each herbicide intended for use or previously applied within the last 18 months.

Bio Strip-Till

The practice of "bio strip-till" uses cover crops in a progressive way to improve the crop-row environment. Alternating strips of cover crops are seeded allowing one strip to act as a biological strip-tiller (residue decreaser) while the adjacent strip promotes soil health (residue or nutrient builder). The residue decreasing row is typically planted to a tap root species such as forage radish. Planting radishes on the same rows as the subsequent crop accelerates decomposition of crop residue, helps the soil warm up faster, and leave a zone of nearly bare soil. The rows between the cash crop row may consists of a legume, such as forage pea or common vetch or this row could be planted to high residue grass species or a blend of grasses and broadleaves. Bio strip-till facilitates planting of the following year's cash crop into the biologically strip-tilled row without the mechanical disturbance of a strip-till implement.

60-Inch Corn

Sixty-inch corn has gained a lot of interest, especially to farmers who have been trying to inter-seeding cover crops into standing corn. Sixty-inch corn is based on the solar corridor crop system concept. Researchers in Missouri define the solar corridor crop system as "a way to improve crop productivity based on highly efficient use of solar radiation by integrating row crops with drilled or solid seeded crops in broad strips (corridors) which can also facilitate establishment of cover crops for year-round soil cover" (Kremer and Deichman, 2014).

In a 30-inch row system, skipping every-other-row results in a 60-inch configuration. This leaves the corn rows spaced far enough apart to enable sunlight to reach the lower leaves for the entire growing season. The assumption is plants should capture more carbon dioxide to produce more carbohydrates to meet plant demands through maturity.

Weed management in 60-inch rows can be a challenge. The open space between rows gives weeds a great chance to get established. Having good residue and weed management in place is a must. To keep weeds in check, select a cover crop mix that comes up quickly and spreads quickly to make sure weed seed can't get started. Growing a shorter cover crop on the vacated row that completes its peak demand for sunlight before the corn plant begins its increasing demand for sunlight has also been suggested. Things to consider when trying 60-inch rows include:

- Corn Population – maintain the same or similar plants per acre as if corn was planted in normal 30-inch row width. This allows for easy comparison with traditional 30-inch rows.
- Hybrid selection – consider choosing a hybrid with a flex ear trait. All hybrids flex their ear size, but some flex more than others. Hybrids can flex three ways, in length, girth (both of which affect the number of kernels) and depth of kernel. Some hybrids use all three methods; others use only one or two.
- Fertilizer- Banding fertilizer near the corn row is the suggested method of application.

- Herbicide – select fields with a low weed population history. Choose a pre-emerge herbicide with a short residual that will give approximately three weeks of control. Seed the cover crop shortly after a post application.
- Cover crop emergence should coincide with V5-V6 critical weed free period for corn. If cover crop emerges to early, competing cover crop may impact corn yield; too late and risk of weed competition increases.

Planting into Green Cover Crops

Planting green refers to no-till planting a cash crop into a living cover crop and then terminating the cover crop at planting or shortly after. This practice is used to plant a grain crop such as corn or soybeans into a cover crop. This contrasts with planting into a cover crop killed two or three weeks before planting. This method is typically done by planting a winter cereal like rye in the fall but has also been done using spring seeded small grains to avoid the risk of rye contamination in nearby or future wheat crops.

Cereal rye planted in the fall followed by soybeans has been very promising. Cereal rye before corn has been tried, but results have been more variable. Spring seeded oats or barley has also worked well prior to soybeans. Reasons for "planting green", are: 1) Improve trafficability on wet soils, 2) Reduce weed pressure, and 3) Build soil organic matter. It is important to remember planting green isn't risk-free. Soil moisture and insect pests need to be closely monitored. Some farmers have also faced hurdles in qualifying for crop insurance. Much of SD, must terminate their cover crops 15 days or earlier before planting. Farmers intending to plant green, should consult with their crop insurance agent. Farmers who obtain a written opinion from a local expert like an Extension specialist, or certified crop consultant, who endorses green planting can qualify for crop insurance.

Planting green is a newer practice still under evaluation. Some suggestions to consider include:

Beans Planted into Cereal Rye

- Adjust down pressure to field conditions.
- Consider removing residue managers as rye may wrap if greater than 12 inches tall.
- Ensure the desired seed depth is achieved.
- Consider using herbicides to terminate the rye if stand is uneven.
- Roller/crimper is less effective on uneven rye stands.
- Rolling may not be needed; as the rye dies it will break off at ground level.

Corn Planted into Cereal Rye

- Some producers are planting corn two and half to three inches deep to avoid germination injury.
- Consider removing residue managers as rye may wrap if greater than 12 inches tall.
- Consider using an automatic downforce system to control down pressure.
- Consider using spiked closing wheels to ensure seed-vee is closing properly.
- Larger seed corn size appears to result in better emergence.
- Apply a nitrogen starter fertilizer via 2X2 placement in addition to a typical pop-up fertilizer applied in furrow.
- Consider using herbicides to terminate the rye if stand is uneven.

When the decision to terminate the cover crop early is made and "planting green" is discontinued, wait at least two weeks after spraying before planting the cash crop. Decomposing-dying cover can be very

difficult to plant into. Also, N tie-up may occur leaving plants yellow and stressed. Some have also questioned if allelopathic effects could contribute to slower growth and reduced germination.

Seed Mix Design Template

Designing a cover crop mix can be a daunting experience for new planners and producers inexperienced in cover crop mix design. Because no one mix meets every producers' need, a recommendation guide was developed as a template to assist people in selecting species to solve an identified problem. The ranges for each crop type help steer the designer in the right direction while providing flexibility to customize the mix.

Recommended Cover Crop Mixes for South Dakota

Crop Type	Species	Percent
Compaction (surface and subsurface)		
CSG	oats, barley, wheat, cereal rye, triticale, annual ryegrass	10-50%
CSB - legume	field pea, common vetch, chickling vetch, red clover, alfalfa	0-20%
WSB - legume	cowpea, dry bean, sunn hemp	0–20%
WSG	sorghum-sudan, teff	0-40%
WSB	sunflower, safflower	0-15%
Brassica	rapeseed, kale, collards, African cabbage, radish, turnip, hybrids	20-40%
N Fixation and Nutrient Cycling		
CSB - legume	field pea, lentil, common vetch, crimson clover, chickling vetch, balansa clover	40-70%
Brassica	rapeseed, kale, collards, African cabbage, radish, turnip, hybrids	10-30%
WSB - legume	cowpea, soybean, sunn hemp	0-15%
CSG	oats, barley, annual ryegrass	10-20%
Nutrient Scavenger		
CSB - legume	crimson clover, chickling vetch, balansa clover	0-15%
Brassica	rapeseed, kale, collards, African cabbage, radish, turnip, hybrids	10-40%
WSG	millet, teff, grain or forage sorghum, sorghum-sudan, corn, sudangrass	20–60%
CSB	flax, winter camelina	0–10%
WSB - legume	cowpea, dry bean, soybean, sunn hemp	0-15%
WSB	sunflower, safflower	0–20%
CSG	annual ryegrass, barley, cereal rye, oat, spring wheat, triticale, winter wheat	10-20%
Spring Moisture Utilization and N Fixation		
CSB - legume	field pea, lentil, common vetch, crimson clover, chickling vetch, balansa clover	10-25%
WSB - legume	cowpea, soybean, sunn hemp	0-25%
CSG	winter wheat, cereal rye, triticale	50-80%

Spring Moisture Utilization Nutrient Cycling and N Fixation		
CSB - legume	field pea, lentil, common vetch, crimson clover, chickling vetch, balansa clover	0-15%
Brassica	rapeseed, kale, collards, African cabbage, radish, hybrids	15–40%
WSB - legume	cowpea, soybean, sunn hemp	0-15%
CSG	winter wheat, cereal rye, triticale, annual ryegrass	50-85%

Residue Cycling		
CSB - legume	field pea, lentil, common vetch, crimson clover, chickling vetch, balansa clover	20 40%
CSB	flax, camelina	0–15%
Brassica	rapeseed, kale, collards, radish, mustard, African cabbage, hybrids	25–40%
WSG	millet, teff	0–10%
WSB - legume	cowpea, soybean, sunn hemp	0-15%
CSG	oat, annual ryegrass, barley	10-30%

Salinity		
Brassica	rapeseed, winter canola	10-30%
CSG	barley, cereal rye, triticale	70-90%

Soil Health – Increase crop diversity and organic matter		
CSB - legume	field pea, lentil, common vetch, crimson clover, chickling vetch, balansa clover, red clover	10-30%
CSB	flax, winter camelina, phacelia	0–15%
Brassica	rapeseed, kale, collards, radish, mustard, African cabbage, hybrids	5–40%
WSB	sunflower, safflower, buckwheat	0–15%
WSG	millet, teff, sorghum-sudan, sudangrass	0–30%
WSB - legume	cowpea, soybean, sunn hemp	0-15%
CSG	oat, annual ryegrass, barley	10-30%

Cool Season Grazing		
CSB - legume	field pea, lentil common vetch crimson clover, balansa clover	10-30%
Brassica*	rapeseed, kale, collards, radish, turnip, hybrids	0-40%
CSB	flax, winter camelina	0-15%
WSG	millet, teff, grain or forage sorghum, sorghum-sudan, corn, sudangrass	0-5%
CSG	oats, barley, wheat, rye, triticale, annual ryegrass	15-30%

Warm Season Grazing		
WSB	sunflower, cowpea, soybean, buckwheat	0-20%
CSB	flax, winter camelina	0-15%
WSG	millet, teff, grain or forage sorghum, sorghum-sudan, corn, sudangrass	20-60%
Brassica	rapeseed, kale, collards, radish, turnip, hybrids	0-40%

Aerial Seed into Corn going to Soybean		
CSB - legume	crimson clover, common vetch, red clover, balansa clover	0–15%
Brasica	rapeseed, kale, collards, radish, turnips, hybrids	15–40%
CSG	winter wheat, cereal rye, triticale, annual ryegrass	40-70%

Aerial Seed into Soybean going to Corn		
CSB - legume	crimson clover, common vetch, red clover	40–70%
Brasica	rapeseed, kale, collards, radish, turnips, hybrids	10–25%
CSG	winter wheat, cereal rye, triticale, annual ryegrass	10-25%

Wildlife		
CSB - legume	field pea, lentil, common vetch, crimson clover, chickling vetch, red clover, balansa clover	10-30%
CSB	flax, phacelia, winter camelina	5–15%
Brassica	rapeseed, radish, kale, collards, mustard, African cabbage, hybrids	10–50%
WSB	sunflower, safflower, buckwheat	0–15%
WSG	millet, teff, sorghum-sudan, grain sorghum, sudangrass	0–30%
WSB - legume	cowpea, soybean, sunn hemp	0-15%
CSG	oat, annual ryegrass, barley	10-30%

*Brassicas include: Canola, African cabbage, kale, collards, mustard, radish, rapeseed (dwarf essex rape), turnip, and hybrids of these species.

Pre-Designed Cover Crop Mixes

Some people prefer to use pre-designed mixes. Pre-designed mixes eliminate some of the decisions that need to be made. Industry mixes are an example of pre-designed mixes. While there are many good pre-designed mixes available, caution must be used when selecting a pre-designed mix as seeding rates, recommended species, etc. may not meet specification requirements agreed to in a program contract. Always consult with the NRCS prior to utilizing an industry mix or deviating from what is planned on the job sheet also referred to as an implementation guide.

The following mixes have been designed to meet the intended purpose while maximizing environmental benefits. They do not take into consideration the previous crop or crop rotation; therefore, species may need to be modified to fit some rotations.

Protection from Wind and Water Erosion – This mix will provide soil protection and coverage during critical periods when wind and water erosion are likely to occur. Plants must have growth characteristics to cover the soil and hold it in place.

Seed Species	Percent of Full Seeding Rate
Peas	10
Common Vetch	10
Flax	15
Oats or Barley	25
Radishes or Turnips	12
Rapeseed	18
Sudangrass	10

Increase Soil Organic Matter – This mix will produce high volumes of biomass and root mass. Plants should be planted as early as possible and terminated as late as practical.

Seed Species	Percent of Full Seeding Rate
Crimson clover	12
Flax	10
Forage sorghum	15
Millet	15
Oats	12
Radishes	10
African cabbage	16
Annual Ryegrass	10

Improved Soil Aggregation and Soil Organism Habitat (Soil Health) – This mix contains diverse plant species with diverse root systems from different functional groups.

Seed Species	Percent of Full Seeding Rate
Millet	10
Peas	12
Common vetch	12
Flax	14
Oats	20
Radishes	12
Rapeseed	10
Sunflower or Safflower	10

Improved Water Quality by Utilizing Excess Soil Nutrients – This mix contains species known to effectively capture, store, and cycle nutrients. Cover crop should be terminated as late as possible to maximize plant biomass production and nutrient uptake.

Seed Species	Percent of Full Seeding Rate
African cabbage	10
Sunflower	15
Common vetch	15
Flax	15
Oats or Annual Ryegrass	20
Radishes	15
Rapeseed	10

Wildlife, Pollinator, and Beneficial Organism Improvement – This mix contains forbs known to provide habitat, pollen, or nectar to targeted pollinators or other beneficial insects.

Seed Species	Percent of Full Seeding Rate
Phacelia	15
Sunflower or Sunn hemp	15
Common Vetch	5
Peas	10
Cowpea	10
Clover (any)	10
Flax	10
Buckwheat	10
Canola	15

Reduction in Weed Pressure and Suppression of Pest Cycles – This mix contains plants known for their ability to suppress or compete with weeds, interrupt pest life cycles, release compounds to suppress soilborne pathogens or provide habitat for beneficial insects.

Seed Species	Percent of Full Seeding Rate
Cereal Rye	35
Barley	15
Radish	15
Mustard	10
Oats	15
Rapeseed	10

Moisture Management or **Increase Soil Organic Matter** – This mix contains species which utilize excess moisture. If soil moisture becomes limiting, terminate growth earlier, and leave residues on the soil surface.

Seed Species	Percent of Full Seeding Rate
Cereal Rye	60
Barley (forage)	20
Annual Ryegrass	20

Concentration of Salts and Other Chemicals – This mix contains species known to germinate and be tolerant to salts.

Seed Species	Percent of Full Seeding Rate
Barley	50
Cereal rye	40
Rapeseed	10

Soil Compaction Reduction – This mix contains species with the ability to penetrate or prevent compacted layers.

Seed Species	Percent of Full Seeding Rate
Oat	20
Annual ryegrass	20
Sunflower	15
Peas	10
Kale or Collards	10
Radish or Brassica hybrids	15
Rapeseed	10

Nitrogen for Subsequent Crop – This mix contains legumes used to meet a portion of the fertility needs of the subsequent crop.

Seed Species	Percent of Full Seeding Rate
Oat	15
Chickling Vetch	15
Common Vetch	15
Peas	15
Cowpea	10
Radish	10
Clover (any)	10
Kale or Collards	10

Cover Crop Table 1

Table 1: Cover Crop - Common Species and Properties

Cover Crop	Full seeding rate lbs/acre	Seeding depth, inches	Reduce erosion	Increase soil organic matter	Scavenge nutrients	Promote biological nitrogen fixation	Suppress weeds	Provide supplemental hay	Provide supplemental grazing	Rooting depth/Plant water use	Minimize/Reduce surface soil compaction	Minimize/Reduce subsoil compaction	Seed size (Large or Fine)	Crop type and seeding dates	Winter Survival	Salinity Tolerance	C:N Ratio	Mycorrhizal fungi association	Seeds/lb	Shade Tolerance
Alfalfa	6.5	.25 - .75	G	G	G	Y	G	G	F	DH	G	G	F	CB	Y	P	L	M	210,000	F
Barley	50	.75 - 2.0	G	G	G	N	G	G	G	MM	G	F	L	CG	N	G	M	M	14,000	F
Brassica hybrids	7	.25 - .5	F	F	G	N	G	F	G	MM	G	G	F	CB	N	G	L	N	180,000	P
Buckwheat	50	.5 - 1.5	P	P	F	N	F	P	P	SL	F	P	L	WB	N	P	L	N	19,000	G
Cabbage, African	5	.25 - .75	F	F	G	N	F	F	F	MM	G	G	F	CB	N	G	L	N	180,000	F
Camelina, Winter	3	.25 - .5	F	F	F	N	P	P	P	ML	P	F	F	CB	S	P	L	N	400,000	P
Canola	5	.25 - .75	F	F	G	N	G	F	F	MM	G	G	F	CB	S	G	L	N	140,000	F
Clover, Balansa	5	.25 - .75	F	P	F	Y	P	P	F	SL	P	P	F	CB	N	P	L	M	500,000	F
Clover, Crimson	15	.25 - .75	F	F	F	Y	P	F	F	SM	P	P	F	CB	S	P	L	M	150,000	F
Clover, Red	5	.25 - .75	G	F	F	Y	F	F	F	SL	F	F	F	CB	Y	P	L	M	275,000	G
Clover, Sweet	4	.25 - 1.0	G	G	F	Y	G	F	F	MM	G	G	F	CB	Y	F	L	M	260,000	G
Collards or Kale	5	.25 - .5	F	F	G	N	G	F	G	MM	G	G	F	CB	N	G	L	N	175,000	F
Corn	12	1 - 1.5	G	G	G	N	G	F	G	DH	G	G	L	WG	N	P	H	H	2,500	F
Cowpeas or Dry Beans	30	1 - 1.5	P	F	F	Y	P	P	F	SL	F	F	L	WB	N	P	L	M	4,000	F
Fava beans	75	1 - 1.5	F	F	F	Y	F	G	G	DM	F	F	L	CB	N	F	L	P	2,500	P
Flax	30	.25 - .75	F	F	F	N	P	P	P	SM	F	P	F	CB	N	P	H	H	80,000	P
Lentils	30	1 - 1.5	P	P	P	Y	P	P	P	SL	P	P	F	CB	N	P	L	M	20,000	P
Millet, hay	15	.5 - 1.0	G	G	G	N	G	G	G	SL	G	F	F	WG	N	P	M	H	180,000	P
Millet, proso	25	.5 - 1.0	G	G	G	N	G	G	G	SL	G	F	F	WG	N	P	M	H	80,000	P
Mustard	6	.25 - .75	F	F	F	N	G	F	P	MH	G	F	F	CB	N	P	L	N	140,000	P
Oats	70	.5 - 1.5	G	G	G	N	G	G	G	MM	G	F	L	CG	N	F	M	H	16,000	F
Peas	70	1.5 - 3.0	F	P	P	Y	F	G	G	SL	F	F	L	CB	N	P	L	M	3,500	F
Phacelia	4	.25 - .5	F	F	F	N	P	P	P	DH	F	P	F	CB	N	P	L	M	225,000	F
Radishes	8	.25 - .75	F	F	G	N	G	P	G	DH	G	G	F	CB	N	P	L	N	25,000	P
Rapeseed	5	.25 - .75	F	F	G	N	G	F	G	MM	G	G	F	CB	Y	G	L	N	140,000	F

Rye, Cereal planted after Oct.1	60	.75 - 2.0	G	G	G	N	G	G	G	MH	G	G	L	CG	Y	G	H	M	18,000	G
Rye, Cereal planted on or before Oct.1	40	.75 - 2.1	G	G	G	N	G	G	G	MH	G	G	L	CG	Y	G	H	M	18,000	G
Ryegrass, Annual	15	.5 - 1.5	G	G	G	N	F	G	G	MM	G	F	F	CG	S	F	M	M	190,000	G
Safflowers	30	.5 - 1.0	F	F	G	N	F	P	P	DM	F	G	L	WB	N	F	M	M	15,000	P
Sorghum, Forage and Sudan Hybrids	15	.5 - 1.5	G	G	G	N	G	G	G	MM	G	G	L	WG	N	F	M	H	17,000	P
Sorghum, Grain	5	.5 - 1.5	G	G	G	N	G	G	G	MM	G	G	L	WG	N	F	M	H	17,000	P
Soybeans	35	1 - 1.5	F	P	F	Y	F	F	F	SM	F	F	L	WB	N	P	L	M	3,000	F
Sudangrass	20	.5 - 1.5	G	G	G	N	G	G	G	MM	G	G	L	WG	N	F	M	H	25,000	P
Sugar beets	4	.25 - .5	F	P	G	N	F	P	G	DH	G	G	F	CB	N	G	L	N	22,000	P
Sunflowers	7	.5 - 1.0	F	F	G	N	F	P	G	DM	F	G	L	WB	N	F	M	M	8,000	P
Sunn hemp	15	1.5 - 2.0	F	F	F	Y	F	P	F	DM	F	F	L	WB	N	P	L	M	15,000	P
Teff grass	5	.13 - .25	G	G	F	N	F	G	G	SM	G	F	F	WG	N	P	M	H	1M	N
Triticale	60	.5 - 1.5	G	G	G	N	G	G	G	MH	G	F	L	CG	Y	G	M	M	15,000	F
Turnips	4	.25 - .5	F	P	G	N	G	P	G	DH	G	G	F	CB	S	P	L	N	175,000	P
Vetch, Chickling	50	.5 - 1.5	F	F	F	Y	F	F	P	SL	F	F	L	CB	N	P	L	M	2,500	F
Vetch, Common	25	.5 - 1.5	F	F	F	Y	F	F	G	SM	F	F	L	CB	N	P	L	M	8,000	F
Vetch, Hairy	15	.5 - 1.5	G	F	F	Y	F	F	F	SM	G	F	L	CB	Y	P	L	M	14,000	G
Wheat, Spring	60	.5 - 1.5	G	G	G	N	G	G	G	MH	G	F	L	CG	N	G	M	M	15,000	F
Wheat, Winter	60	.75 - 2.0	G	G	G	N	G	G	G	MH	G	F	L	CG	Y	G	M	M	15,000	F

Rooting Depth/Water Use

SL = Shallow rooted/Low water use

SM = Shallow rooted/Medium water use

SH = Shallow rooted/High water use

ML = Medium rooted/Low water use

MM = Medium rooted/Medium water use

MH = Medium rooted/High water use

DL = Deep rooted/Low water use

DM = Deep rooted/Medium water use

DH = Deep rooted/High water use

Shallow = 6 - 18 inches

Medium = 18 - 24 inches

Deep = 24 + inches

Ratings

G = Good

F = Fair

P = Poor

L = Low

M = Medium

H = High

Y = Yes

N = No

S = Sporadic

N/A = Not Applicable

Crop types

CG = cool season grass

CB = cool season broadleaf

WG = warm season grass

WB = warm season broadleaf

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