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AGRONOMY TECHNICAL NOTE

COVER CROPS

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Figure 1. Cover crop mix of sorghum-sudangrass, German millet, safflower, corn, turnip, sunflower, soybeans, and canola. Sheridan County, MT. September 2, 2011 (MT NRCS).

Special thanks to the following people for their help in creating this technical note:
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Definition and Purpose

A cover crop is any plant grown to provide living ground cover within or between rotations of the primary cash crops. Most cover crops are grown for the protection and enrichment of the soil and can be an important tool for improving soil health in an annual crop rotation. Cover crops can support soil health by providing residue to keep the soil surface armored, minimizing disturbance, keeping a living root in the soil, adding diversity to the crop rotation, and encouraging the integration of livestock by providing supplemental forage.

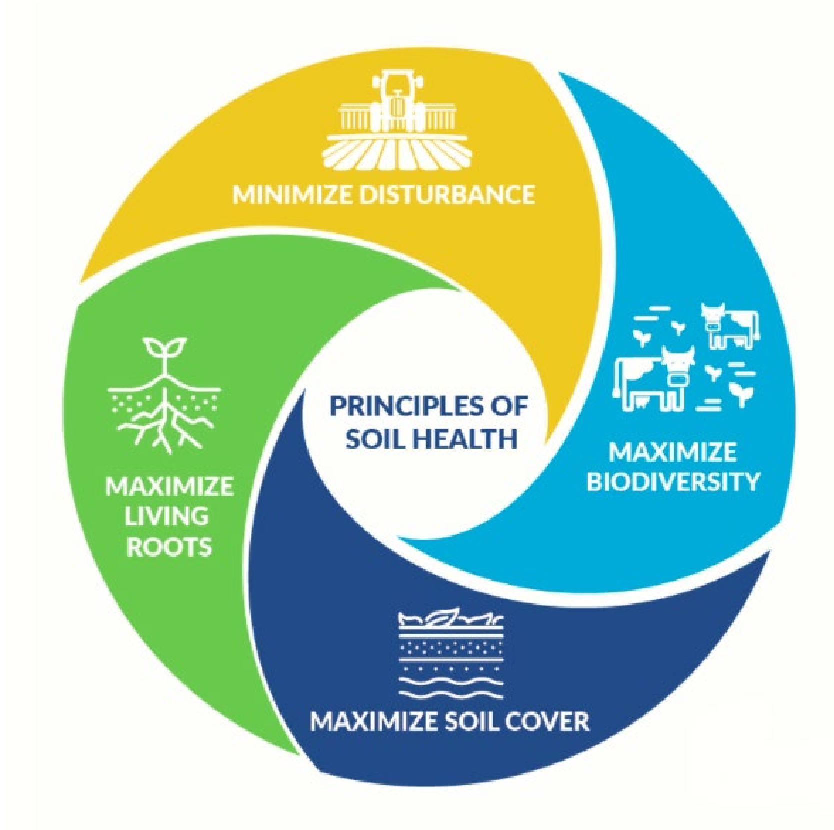

Figure 2. The principles of soil health (USDA NRCS).

Cover crops are most commonly annual species and are best suited for use on crop and pastureland during periods when the field would otherwise have no vegetation, such as a fallow period, after harvest of a cash crop, or during the renovation phase of a pasture or hay field. They can also be used as nurse crops for perennial plantings and interseeded into the understory of cash crops for nitrogen fixation or ground cover. Annual cover crops are not meant to replace otherwise healthy perennial vegetation in range or pasture settings.

This technical note is specific to Montana and is to be used by the conservationist for all stages of cover crop use including planning, installing, and monitoring. Topics covered include identifying resource objectives, site inventory, design, installation, management, grazing, and example seeding mixes.

Resource Concerns and Objectives

Cover crops can be planted for a variety of reasons. Care should be taken to first consider the resource concerns and landowner objectives before beginning the design process. Cover crops mixes must be correctly selected and managed to address the planned purpose. A dryland cover crop planned for nitrogen fixation will look very different from an irrigated cover crop planned for livestock grazing. Common objectives and resource concerns for cover crop use include:

- reducing wind and water erosion
- maintaining or increasing soil health and organic matter
- suppressing weed and pest pressure
- providing nitrogen fixation
- increasing biodiversity
- capturing and cycling nutrients
- managing soil moisture
- minimizing soil compaction
- providing supplemental forage for grazing
- attracting beneficial insects
- providing food and habitat for pollinators and other wildlife

Reduce Wind and Water Erosion

Growing plant vegetation and dead plant residue serves as armor to protect the soil against wind and water erosion. Even soils under no-till or reduced-till management are vulnerable to erosion if not enough vegetation and residue covers the surface. Cover crops can protect against wind and water erosion by providing both vegetation and residue to cover the soil surface during Montana's most erosive winter months (November to April). Both cool and warm season annual grass species, such as small grains, millet, and sorghum-sudangrass have a high carbon to nitrogen (C:N) ratio, which provides the most durable, weather-resistant residue of all the cover crop species. In addition, the fibrous root structure of these crops holds soil together during high wind and water events. These grasses can be particularly valuable when planted as a cover crop after the harvest of a low C:N cash crop with easily degraded residue, such as peas, lentils, or chickpeas.

When planting a cover crop for erosion control, prioritize the use of grass species and ensure that any termination method leaves enough high carbon residue prior to the critical erosion period. The amount of residue needed (pounds per acre) will vary by soil type, crop rotation, and climate. Ideally, no bare ground is seen through the residue prior to the critical erosion period.

Cover crop practices for reducing wind and water erosion include:

- Plant a cover crop that includes at least 50% grass species. The high carbon grass residue will provide greater erosion protection than low carbon residue from other species (legumes, brassicas, etc.) due to its greater resistance to decomposition and superior ability to slow soil particle movement.
- Ensure the maximum amount of cover crop residue is left on the field prior to the most erosive months of November to April.
- Plant an over-winter cover crop such as winter triticale and hairy vetch to provide living vegetative cover over the winter. Make sure the cover crop has enough time to grow and produce adequate canopy cover prior to November.

- Leave standing cover crop residue as tall as possible from November to April. Vertical residue is at least 3 times more effective at controlling wind erosion than horizontal residue and also will catch more snow.
- Boost cover crop biomass production to peak vegetative growth by maximizing the length of the growing season and optimizing soil fertility.
- If grazing the cover crop, use a grazing plan that leaves at least 50% of the cover crop biomass on the field after grazing.
- Plant a winter small grain cover crop in the fall to control ephemeral gully erosion at 1.5 to 2 times the recommended amount. A minimum of 50% canopy cover, 200 stems per square foot, and 6 to 8 inches of crop growth is recommended to provide enough protection against water erosion prior to the critical erosion period of November to March (USDA-NRCS, 2007, National Agronomy Technical Note 2).
- Consider using the most recent USDA NRCS wind and water erosion modelling tools to determine minimum residue amounts and tolerable soil erosion levels.

Maintain or Increase Soil Health and Organic Matter Content

Soil organic carbon is the main building block of organic matter and soil health. In the last century, prairie conversion to cropland caused an approximate 50% loss of soil carbon in the top foot of soil (DeLuca and Zabinski, 2011). This carbon loss has caused decreased soil health throughout the Great Plains, including Montana.

When coupled with little to no soil disturbance, cover crops can help replace this lost soil carbon by intensifying the crop rotation. Crop intensification involves growing more plant material within a given time frame and can be achieved several different ways, including:

- adding a perennial to an annual rotation
- increasing crop yields in an existing rotation
- eliminating fallow in a dryland rotation by continuous cropping or adding a cover crop to the fallow period
- double cropping (two crops in one year)
- growing a cover crop during a season that otherwise would have no crop growth, such as after harvest of a cash crop or overwinter

Root biomass is the key to carbon capture, as carbon from root biomass stays in the soil 2.5 times longer than carbon from shoot biomass (Rasse et al., 2005). Consider terminating cover crops at peak root biomass or later for optimum carbon capture. For small grains, peak root biomass occurs at the boot stage. For oilseeds and legumes, peak biomass occurs at the late flower stage (Gan et al., 2009; Liu et al., 2011).

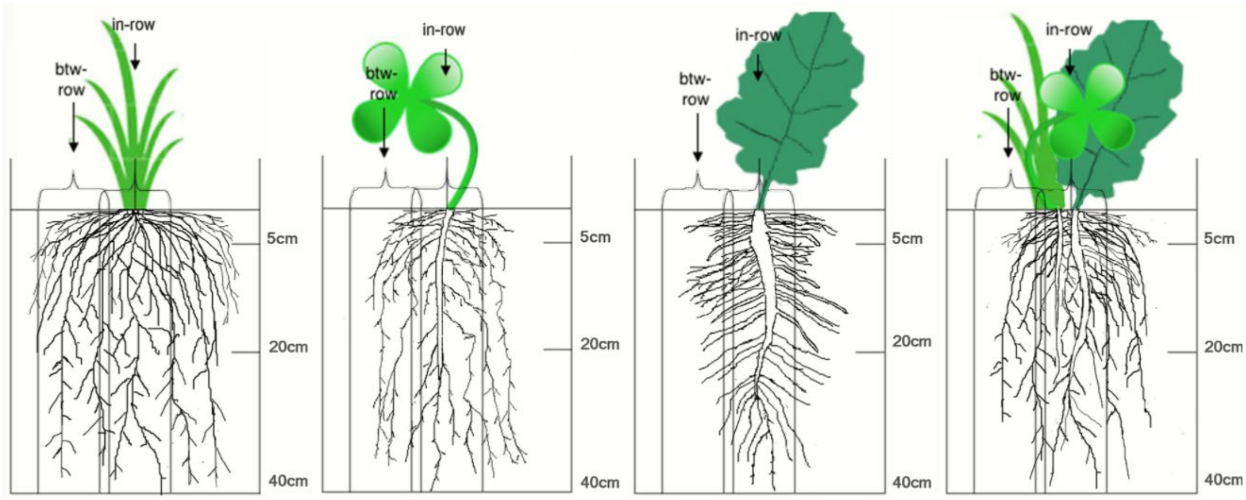

Figure 3. Cover crop root distribution patterns of triticale, clover, forage collard, and a mix of all three (Amsili and Kaye, 2020, used with permission).

Long-term research in dryland regions of both Montana and Saskatchewan has found a close relationship between soil carbon accumulation and average annual dry biomass production (Engel and Miller, 2017) (Shrestha at al., 2013). More biomass produced results in more soil carbon accumulated. Interestingly, this is irrespective of the biomass quality (C:N ratio). These studies also showed that perennial systems accrue more soil carbon than annual systems, therefore the inclusion of perennial species (forages, perennial grains, etc.) in an annual rotation should be considered in addition to annual cover crops when increasing soil carbon is the main management objective.

The research discovered that the minimum biomass required to simply maintain soil carbon levels in an annual crop system on a silt loam soil in a 16-inch annual precipitation zone is 1.8 tons of dry biomass (residue) per acre per year. Residue production must be above this level to increase soil carbon. Less may be required in lower precipitation zones, or where part of the rotation is in perennial crops due to the high root volume of perennials and their increased ability to build soil carbon compared with annuals.

This average residue target can be difficult to achieve in dryland settings. Many dryland crop rotations regularly use a fallow period, and research has shown that a wheat-fallow rotation in Montana will lose soil organic carbon over time, regardless if it is tilled or no-till.

To determine if a cover crop will help maintain or build organic matter, the conservationist can calculate residue production of the complete crop rotation by converting crop yields to residue with a residue calculator such as the Washington State University online crop residue calculator.

Tables 1 and 2 give an example of this calculation. In Table 1, a three-year crop rotation of pea-winter wheat-fallow has an average residue production of 1.08 tons per year. This is not enough to maintain organic matter levels. In Table 2, the rotation has changed to a four-year rotation of pea-winter wheat-canola-cover crop with an average residue production of 1.86 tons per year. This level will maintain soil organic matter.

Table 1. Crop rotation with inadequate residue production to maintain organic matter.

Rotation Year	Crop	Grain Yield	Aboveground Residue* (pounds per acre)
1	Pea	2,000 pounds per acre	2,122
2	Winter Wheat	55 bushels per acre	4,368
3	Fallow	0	0
		Total	6,490
		Average Annual (pounds per acre per year)†	2,163
		Average Annual (tons per acre per year)‡	**1.08**

Table 2. Crop rotation with adequate residue production to maintain organic matter.

Rotation Year	Crop	Grain Yield	Aboveground Residue* (pounds per acre)
1	Pea	2,000 pounds per acre	2,122
2	Winter Wheat	55 bushels per acre	4,368
3	Canola	1,500 pounds per acre	4,395
4	Warm-season cover crop	2 tons per acre	4,000
		Total	14,885
		Average Annual (pounds per acre per year)†	3,721
		Average Annual (tons per acre per year)‡	**1.86**

*Use a conversion calculator to convert grain yield to residue amount.
†Average annual (pounds per acre per year) = Total residue production / number of years in rotation
‡ Average annual (tons per acre per year) = Average annual (pounds per acre per year) / 2000 pounds per ton

A few things to note from this example:

- Producing 4,000 pounds per acre of a dryland warm-season cover crop depends on timely precipitation and may not be realistic every year. Likewise, all dryland yields will vary based on precipitation. Use previous 10-year county average yield data for the basis of these residue calculations.
- Notice that the pea crop produces relatively low residue compared with other crops and decreases the average residue value. The addition of both canola and the cover crop to the rotation adds additional residue to increase the average residue value.

Another way to verify if the cover crop practice meets the objective of increasing soil organic matter is to calculate the Soil Conditioning Index (SCI) and Organic Matter subfactor (OM) in the most recent wind and water erosion modelling tools and compare the planned crop rotation with the baseline rotation. Both the SCI and OM must be positive in the planned rotation and greater than the baseline rotation to indicate an improved condition.

Building soil organic matter takes time in Montana's semi-arid dryland locations. Dryland sites cannot produce as much root and shoot biomass as irrigated sites and will take longer to build soil organic matter. In general, sites with more precipitation (or irrigation), cooler climates, and finer soils (clay) will build organic matter faster than sites with less precipitation, hotter climates, and sandier soils.

Cover crops are only one tool in the soil health toolbox and are most effective at building soil carbon and organic matter when used with a complete soil health system of:

- zero or minimal tillage
- maximum residue cover throughout the year
- a continuous living root in the soil (crop intensification)
- a diverse crop rotation with multiple crop types
- the addition of livestock to the system when possible

Specific cover crop practices for increasing soil carbon and organic matter include:

- Intensify the crop rotation by growing an annual cover crop during a time that otherwise would have no growth (fallow, shoulder season, after harvest).
- Select species with high root and shoot biomass production, such as small grains, millets, and sorghum-sudangrass.
- Terminate cover crops after or at peak root biomass if conserving soil moisture is not of concern. This often corresponds with peak vegetative growth, prior to any reproductive growth.
- Be patient. Organic matter increases slowly in Montana's semi-arid dryland locations, even with the best management. Anecdotal stories from producers indicate they notice soil improvements after a minimum of 6 or 7 years.

Suppress Excessive Weed Pressures and Break Pest Cycles

Cover crops can break pest cycles and reduce weed pressure in commodity crops, reducing the need for pesticides, herbicides, and tillage through the following methods:

- out-competing weeds for water and nutrients when planted into a clean seedbed
- reducing light reaching the soil surface through dense canopy cover, slowing weed seed germination
- releasing root exudates to provide a natural fungicide or nematicide effect
- hosting beneficial microbial life that discourages disease
- functioning as a trap crop for plant pests
- attracting beneficial insects which help break pest cycles

Cover crops planted during a fallow period can help smother weeds and potentially decrease the need for herbicide application (Kumar, et al., 2020). Over time, the decrease of herbicide application could slow the development of herbicide-resistant weeds. However, this approach depends on adequate biomass production of the cover crop to out-compete the weeds. For example, researchers in Kansas found that a fall-seeded cover crop reduced kochia biomass by 90% if the cover crop produced a minimum of 1050 pounds of biomass per acre (Petrosino et al., 2015).

Changing the cover crop season of use can also provide multiple windows for weed control in a forage or pasture system prior to seeding a new perennial mix. Table 3 shows the renovation schedule of an old crested wheatgrass pasture in northern Stillwater County, using two years of annual cover crops prior to dormant seeding a new, diverse perennial stand. Notice that planting a warm-season cover crop in Year 1, followed by a cool-season cover crop in Year 2, allows for varying herbicide application windows for weed control. Likewise, the cover crop in Year 1 was limited to a single species sorghum-sudangrass to allow for the option of an in-crop broadleaf herbicide application.

Table 3. Pasture renovation schedule using annual cover crops.

Year	Month	Operation
1	Late May	Spray crested wheatgrass (CWG) pasture and weeds with glyphosate. Late May spray date allows for optimum kill of CWG.
1	Early June	Plant warm-season cover crop of sorghum-sudangrass. Single species cover crop allows for in-crop application of broadleaf herbicide if needed.
1	Late August	Graze cover crop
1	Early September	Spray pasture for weed control
2	Early April	Spray pasture for weed control
2	Early April	Plant a cool-season cover crop mixture.
2	Mid to Late June	Graze cover crop
2	July	Spray pasture for weed control
2	September	Spray for weed control
2	October	Dormant seeding of diverse perennial pasture mix

Cover crop practices for suppressing weeds and breaking pest cycles include:

- Identify weed and pest species prior to cover crop design and understand their life cycles and timing of emergence.
- Timing is critical. Plant the cover crop prior to the emergence of the weed species of concern.
- Select cover crop species with strong early growth, dense plant architecture, and quick canopy closure. Grasses and brassicas are the most competitive. Legumes are the least competitive.
- When using herbicide, spray weeds 2 or 3 days prior to planting the cover crop. Waiting longer to plant only encourages weed regrowth.
- Consider planting an all-grass cover crop when attempting to control broadleaf weeds, or an all-broadleaf cover crop when attempting to control grassy weeds. This will allow for possible in-crop herbicide application options.
- Change the cover crop season of use to allow for different herbicide control windows.
- Never let weeds go to seed! Graze or terminate the cover crop prior to weed seed production.
- Select broadleaf cover crop species with nectar and bloom times to attract beneficial insects.
- Consider using mustard in a cover crop mix for soil fumigation against soil-borne diseases prior to potato and sugar beet crops. Mustard may also contain allelopathic qualities to suppress weed germination and growth.
- In areas where Wheat Stem Sawfly (WSS) is a concern, do not include wheat as the cool-season grass component of a cover crop. Instead, include oats, which act as a potential trap crop for WSS. Barley is a second option but is less effective than oats as a trap crop.

Provide Nitrogen Fixation

Figure 4. Active root nodules on vetch roots. Note the reddish pink color (Derek Tilley, USDA NRCS).

Legumes are the only cover crop species that fix nitrogen from the atmosphere with the help of rhizobia bacteria. Annual and perennial single-species legume green manures (LGM) cover crops are commonly used in organic crop production for nitrogen fertility and hold potential for greater use in no-till systems as an alternative nitrogen source to mitigate the impact of soil acidification from commercial nitrogen fertilizer application.

The amount of nitrogen fixed by a legume cover crop is highly variable and depends on:

- amount of biomass produced
- nodulation
- percentage and type of legume species in the mix
- maturity of plants at termination
- amount of pre-existing nitrogen in the soil

In general, more nitrogen is produced by legumes and returned to the soil when more legume biomass produced, the percentage of legumes in the cover crop mix is high, and the plants are younger (Housman, 2016). Available soil nitrogen also plays a role, as annual legumes will scavenge existing soil nitrogen before fixing nitrogen from the atmosphere. Nitrogen fixation from legumes grown in a nitrogen-rich soil will be minimal.

Research from Washington and Oregon has shown that plant available nitrogen (PAN) is greatest when legumes are 75 to 100% of the cover crop biomass, and minimal or negative when legumes are 25% or less of the cover crop biomass. Consider using a minimum of 40% legumes biomass in a cover crop mixture to prevent nitrogen tie-up in the following crop (Sullivan, Andrews, and Brewer, 2020).

Cover crop practices for promoting nitrogen fixation include:

- Use at least 75% legumes in a cover crop mix to maximize N production, and no less than 40% to minimize N tie-up.
- Add legumes to any cover crop mix on low N soils to improve the productivity of the mix. Even if legumes appear at less than 40% of the biomass and do not provide N for the following crop, they can provide N for the other cover crop species in the current year.
- Think carefully about crop residue and soil erosion when using a legume cover crop. Legume residue has a low C:N ratio, breaks down quickly over winter, and provides little protection from wind and water erosion. Avoid using a 100% stand of legumes when possible. Consider adding a minimum of 25% grasses to a legume cover crop mixture to increase over-winter erosion protection.
- Understand the N-fixing potential of the annual legume species used. When given enough precipitation, fava bean fixes the most amount of N of all cool season annual legumes, followed by pea, then lentil (Olson and Bowness, 2016).
- Warm-season legumes such as mung bean, cowpea, and sunn hemp have not been as reliable as their cool-season counterparts in cover crop mixes in Montana. When grown with warm-season grasses they tend not to compete very well. In addition, they can be quite expensive. They may have potential in an all-broadleaf warm-season mix, or possibly with reduced amounts of warm-season grasses and tend to do better under irrigation than in dryland. Ask for local advice prior to using these species and make sure the local climate will support the use of warm-season legumes before using them. Areas near the Canadian border have a shorter growing season and are not good locations for these species.
- Soybean is the one warm-season legume that has had some success in Montana cover crops, both dryland and irrigated.
- Terminate legumes at flat pod stage for maximum N-fixation if conserving soil moisture is not of concern (McCauley, et al., 2012).
- Terminate legumes at first bloom when conserving soil moisture is a concern.
- Legumes are not as competitive as other cover crop species, especially grasses. Choose less-competitive grass species, such as triticale or millet, in a mixed cover crop to reduce competition with the legume species. If using highly competitive grass species such as sorghum-sudangrass or barley in a mix with legumes, use them at reduced seeding rates.
- Monitor the cover crop stand and weigh plant species separately to determine if legumes appear in sufficient quantity. Adapt the seeding rates and species for the following year if needed.
- Soil test as close as possible to planting a cash crop following a cover crop to accurately estimate N credits. Refer to the PNW publication "Estimating Plant-Available Nitrogen Release from Cover Crops" for more information (Sullivan, Andrews, and Brewer, 2020).
- Include legumes in the rotation several times to maximize their impact. Legumes can improve wheat protein after one appearance in the rotation but require several appearances in the rotation to improve wheat yield (Jones, et al., 2020).
- Perennial legumes can contribute more nitrogen to the system than annual legumes. While alfalfa is not by conventional (or traditional) definition a cover crop because it

is repeatedly hayed and removed, soil tests in MT indicate dryland alfalfa can contribute up to 150 lb N per acre in the soil after three to four years of growth. This is enough to provide the N crop needs for the next year's winter wheat without applying commercial fertilizer (USDA-NRCS MT, 2020).

Increase Biodiversity

NRCS groups field crops into four types: cool-season grasses (CSG), cool-season broadleaves (CSB), warm-season grasses (WSG), and warm-season broadleaves (WSB). Broadleaves can be further separated into legumes, brassicas, and other broadleaves.

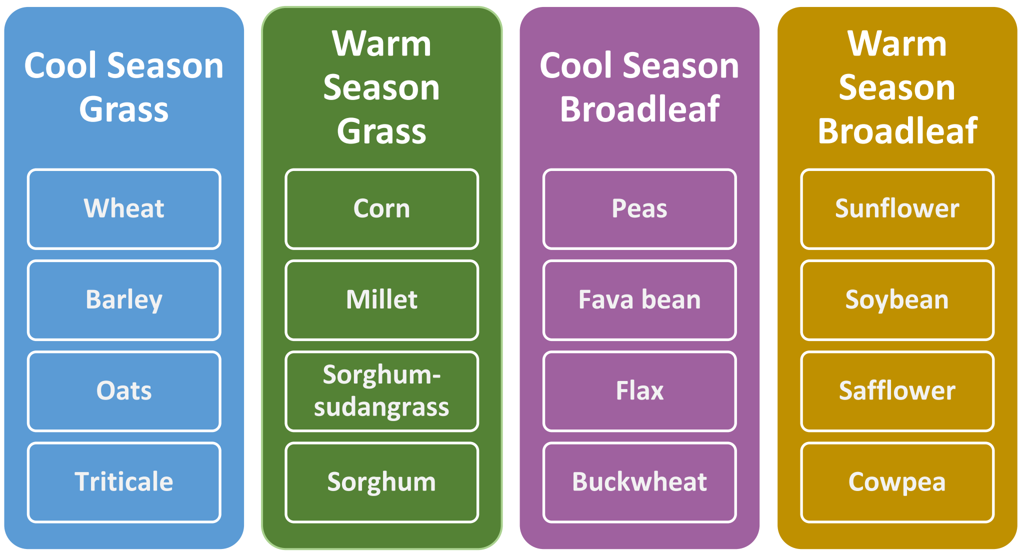

Figure 5. The four crop types for rotation diversity with common examples (MT NRCS).

Cover crops can increase the diversity in a crop rotation. This diversity can promote different pathways of soil biological activity, help break weeds and pest cycles, allow for different herbicide use, and diversify the income stream.

Plant diversity influences belowground soil processes in various ways. Plant litter with lower C:N ratio promotes greater bacterial populations, while plant litter with higher C:N promotes a fungal-based decomposition pathway with slower nutrient mineralization (Wardle and Van der Putten, 2002), reduced N leaching (de Vries and Bardgett, 2012), and increased ability to retain nutrients during wetting and drying cycles (Gordon et al., 2008). Plant root exudates also influence the soil environment, as each plant species has a specific root exudate quantity and composition, which promotes the growth of various microbial communities (Somers et al., 2004).

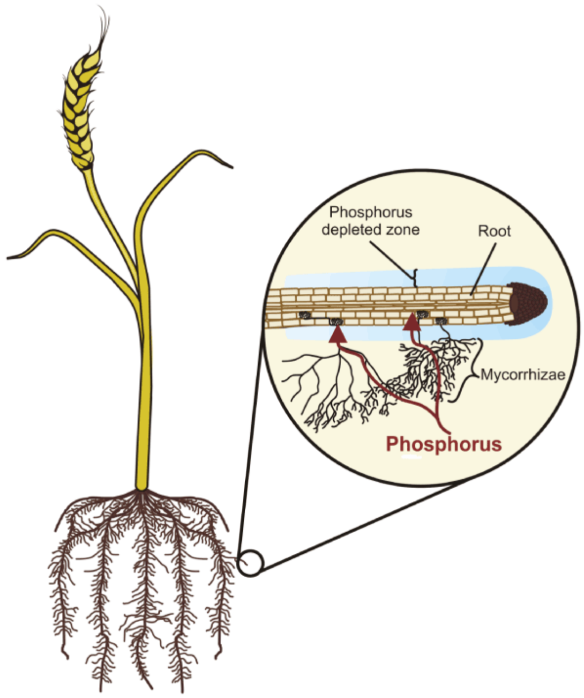

Figure 6. Wheat roots with associated arbuscular mycorrhizal fungi (Roy-Bolduc and Hijri, 2011, used with permission).

Mutualistic relationships are another way in which individual plant species can influence belowground ecology, particularly via rhizobial bacteria and arbuscular mycorrhizal fungi (AMF) associations. Rhizobia are N-fixing bacteria which associate with legumes while AMF are a type of mycorrhizal fungi which grow only in mutual association with a plant root and are not visible with the naked eye. They scavenge nutrients and water for the plant in exchange for carbohydrate. When a living root is not available, AMF remain in the soil in spore form. AMF associate very closely with most cover crop species, except for the brassicas.

Belowground plant diversity also holds the key to the "rotation effect," by which crop yields of a given crop improve when grown in a diverse rotation and not in continuous succession of the same crop (Karlen, 2006) (Bullock, 1992). Cover crops can promote the rotation effect by providing diversity that is otherwise missing in a cash crop rotation.

NRCS recommends a complete crop rotation contain all four crop types (cool and warm season grasses and broadleaves) to increase diversity and break pest and disease cycles. In instances where a crop type can't fit in the main cash crop rotation, use a cover crop to increase diversity in the rotation. For example, a warm-season cover crop of millet, sorghum-sudangrass, and sunflowers in a wheat-pea rotation will add warm season grasses and broadleaves to the rotation. Because the majority of Montana cropland is devoted to cool-season grass production (wheat and barley), most cropland acres will benefit from the addition of a warm-season cover crop if the local climate permits.

Cover crop practices for increasing diversity include:

- Document the current crop rotation and identify which, if any, of the four crop types are absent. Then include the missing or least represented crop type in the cover crop. Consider adding a minimum 30% or more of the desired crop type to the mix so that it shows up in sufficient quantity.
- Understand the local climate and native plant community. Some locations in Montana have no native warm-season plants, indicating they may not be suited to a warm-season cover crop. In these locations, consider using warm-season species with a shorter growing season such as foxtail (German) millet. Also consider that the cover crop is not intended to grow to complete reproductive maturity and may still produce adequate vegetative growth. Local experience and experimentation in these locations are fundamental to cover crop success.
- Add a brassica to any cover crop mix. Brassicas can often be successfully added to both cool and warm-season cover crop mixes, and may promote the rotation effect in a small grain system. As a rule of thumb, brassicas should not be more than a total 2 pounds per acre for all brassica species in a cover crop mix.

Capture, Cycle or Distribute Nutrients

Planting a cover crop that scavenges nitrogen (N) and other nutrients helps to reduce groundwater quality degradation. Fibrous rooted cereal grains are good at scavenging excess nutrients, especially N, which are left in the soil after harvesting a cash crop. Large tap root species such as radish, sunflower, or safflower, can also scavenge deeper nitrogen and reduce the risk of N leaching into ground water. Nitrogen is then held within the plant tissues until they decompose and slowly feed the following crop.

Radish is often used as a cover crop for N scavenging in wetter parts of the US and is planted in late summer or early fall after the cash crop harvest. It scavenges N and grows a large taproot in the fall, holding it in the root over the winter. When the radish starts to decay in early spring, N is released and available for the subsequent cash crop.

Timing is crucial when using radish as a cover crop species. Radish planted before the summer solstice will bolt, produce flowers and a smaller tap root, and provide less nitrate scavenging. Radish planted after the summer solstice will stay in a vegetative state, produce larger tap roots, and provide more nitrate scavenging.

Figure 7. Radish in Gallatin County, MT, Aug. 25, 2019. Angular roots indicate a soil compaction layer at 6” depth (MT NRCS).

Cover crop practices for the capture of nutrients include:

- Select fibrous-rooted (grasses) or tap-rooted species (radish, kale, collards, sunflower, safflower).
- Plant the cover crop so that it establishes prior to the season of greatest potential nitrate leaching and phosphorus movement. This usually correlates with the time of greatest water movement and the least crop vegetation (November to April).
- Plant radish in late summer for fall growth during cooler temperatures and allow it to frost kill over the winter. In mild winters with insulating snow cover, radish may not die off and persist into the spring, set seed, and volunteer in the future.

Manage Soil Moisture

Cover crops can be used to manage areas of extra soil moisture, most commonly when excessive spring rains prevent the planting of the cool season cash crop, or in other Prevented Planting situations. Crop species with high water use, such as corn, sorghum-sudangrass, sunflower, and soybean, are good warm-season choices that can be planted in early summer, after heavy spring rains have subsided, to provide some vegetative growth with grazing potential.

Cover crops can also be used in dryland systems to fully or partially replace a fallow period. Summerfallow began in Montana to increase soil moisture and stabilize grain yields. However, research has shown than most water stored during the summerfallow period is lost to evaporation, with at most 40% of the precipitation collected during the fallow period stored for future crop use (Peterson, et al, 1996). In addition, fallow has serious soil quality disadvantages, including greater soil erosion potential, increased potential for saline seeps and nitrate leaching, decreased soil organic matter, and decreased soil biological activity. Cover crops can add residue as a mulch to armor the soil and minimize soil moisture loss from evaporation during the fallow period. For this technique to be effective, cover crops must produce sufficient biomass to cover the soil surface and the residue must be left as tall as possible over winter to facilitate greater snow catch and moisture retention. Select species with an upright residue architecture when designing cover crops for snow capture.

Continuous cropping and cover crop replacement of fallow can help alleviate the organic matter depletion that occurs in both tilled and no-till dryland fallow systems. However, the production of the additional residue and root material needed to build organic matter must be carefully balanced with the soil moisture used to create it. When soil moisture is managed correctly, the producer can create an upward-moving spiral of soil health in which:

- Soil moisture is used to produce more plant root material.
- This root material is converted to soil carbon and organic matter.
- Increased organic matter results in greater soil aggregation, water infiltration, and soil moisture retention.

Prevented Planting

The USDA Risk Management Agency (RMA) defines Prevented Planting as a failure to plant an insured crop by the final date in the insurance policy's Special Provisions. Visit https://www.rma.usda.gov/en/Topics/Prevented-Planting for more information.

- Increased soil moisture retention contributes to the production of more plant root material. And ideally the cycle continues.

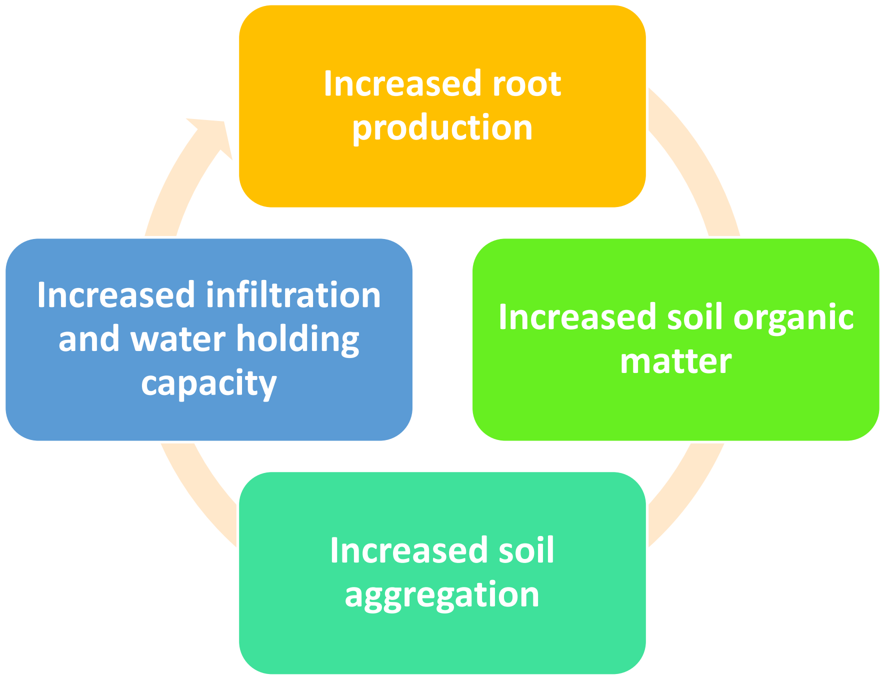

Figure 8. Upward soil health spiral when dryland soil moisture use is correctly balanced with increased plant and root biomass production (MT NRCS).

Care must be taken when using cover crops in a dryland setting for fallow replacement as they can deplete soil moisture, tie up nutrients, and decrease yields in the following cash crop. Past field research in Montana has focused on comparing dryland soil moisture use between cover crops and fallow, with cash crop yields often less following a cover crop than fallow (Miller et al., 2003; Miller et al., 2011). Research has shown that cover crops for fallow replacement are less likely to decrease the following cash crop yields when the cover crop is planted in early spring (April) and terminated prior to June 15th, to match the peak precipitation window in Montana's dryland regions.

The challenge with this approach is that early June is often not desirable for cover crop grazing, as most livestock producers graze established range, forest, and pasture units during this time and instead need additional grazing options in the fall or early spring. To accommodate for grazing, it is better to install a cover crop in early summer for late fall grazing (October and November), which does not fit the research recommendation of an early June termination.

As a result, when using cover crops to replace dryland fallow, producers should initially expect their yields and moisture use to be comparable with a continuous crop system and not a crop-fallow system. This may require a shift in thinking and yield expectations. Rather than focusing on individual crop year yields, which may be less in a continuous system than a fallow system, focus instead on annualized average yields, which may be greater in a continuous system when calculated across the entire rotation.

The following cover crop management strategies are recommended on dryland sites when the objective is conserving soil moisture:

- Leave as much cover crop residue as possible on the soil surface to reduce water evaporation from sun and wind. Ideally, no bare soil should be visible.
- Leave residue as tall as possible (18 inches or greater) in the fall to maximize over-winter snow catch.
- To maximize soil moisture conservation for producers who are most risk-averse, plant cover crops grown for fallow replacement in early April and terminate at first legume bloom (around June 15).
- Cool-season grasses (C3) may use less soil moisture than warm-season grasses (C4). Although if given adequate moisture and growing temperatures, warm-season grasses will produce more biomass than cool-season grasses.
- Do not plant dryland winter wheat in the fall following a warm-season cover crop. Instead consider spring cash crops to allow for over-winter soil moisture recharge and nutrient release.
- Include a legume component in a cover crop mix. While this does not directly impact soil moisture use, it can help alleviate the nutrient tie-up associated with using cover crops as a fallow replacement.

Soil Health Demonstration: Infiltration

For an illustration on how a no-till continuous crop system infiltrates water much faster than a tilled wheat fallow system, head to the Montana NRCS YouTube channel

https://www.youtube.com/watch?v=iTPjLaHLDP4&t=89s

In addition to proper cover crop management, good soil moisture management in a dryland system depends on a complete systems approach from planting to harvest. The following techniques are foundational to preserving dryland soil moisture and will provide increased drought resiliency and more successful cover crops in the long term. These include:

- Use a no-till disc drill at planting to minimize soil disturbance and moisture evaporation.
- Leave the maximum height of standing residue over the winter for increased snow catch. Raise the height of a standard header or use a stripper header for maximum residue height.
- Leave all crop residues on the field after harvest.
- Maximize the amount of high C:N residue cash crops in the rotation to provide enough residue to mulch the soil and minimize soil moisture evaporation. A good rule of thumb is 2/3 to 3/4 of the rotation should be high carbon cash crops (grasses and oilseeds). For example, a wheat-pea-fallow rotation has only 1/3 of the rotation in a high carbon crop (wheat), which is not enough residue to protect the soil. Adding a grass-dominant cover crop to replace the fallow period improves the rotation to wheat-pea-cover crop, with 2/3 of the rotation now in high carbon crops to provide enough residue and mulching effect. See the Appendix of this technical note and the Data tab of the 340 Cover Crop Implementation Requirement (IR) spreadsheet for C:N information of each cover crop species.

Minimize Soil Compaction

Cover crops can be a useful tool to break-up soil compaction. Converting to a no-till system is the first step in healing the plow layer associated with tillage. However, old plow layers take time to disappear and can remain even after conversion to no-till. Brassica species such as canola, mustard, and radish, along with safflower and sunflower, have tap roots which can grow through hardpan soil layers and create pathways for water infiltration, air flow, and soil biology movement and function. Deeper roots also bring nutrients back to soil surface layers, making the nutrients accessible to shallow rooted cash crops.

Cover crops designed for soil carbon and organic matter improvement will also help break up a compaction layer over the long-term. Fibrous-rooted grasses with a high volume of root production help break compaction by building soil aggregates through carbon addition.

Provide Supplemental Forage for Grazing

Grazing is an essential element of cover crop use, as it provides an immediate economic return for the cover crop investment and helps to integrate livestock on cropland. Specific cover crop grazing management strategies are included later in this publication.

Timing of grazing is the most important determinant of cover crop species selection. Determine when the producer needs the forage and if a warm or cool season window is the best option. Warm-season grasses (C4) will yield more than cool-season grasses (C3) when given enough moisture and growing temperatures. Warm-season grasses are ideally grazed in late September through October, after a killing frost and danger of prussic acid toxicity has passed. However, there are more opportunities within a growing year to produce cool-season grasses and they may be a more reliable source of forage in Montana's climate.

Cover crop design is crucial for livestock grazing safety and will depend on the livestock species and plant species used.

- Consider using BMR (Brown Midrib) varieties of corn, sorghum, and sorghum-sudangrass with less cellulose and greater palatability to cattle when grazing these species green. However, if grazing after termination, the BMR varieties may not provide a benefit.
- Sunflowers and forage collards are also preferred by cattle. Sunflowers do best in a warm-season window at 1 to 2 pounds per acre in a mix, while forage collards do best in a cool-season window (especially in the fall) where the total amount of brassicas are no more than 2 pounds per acre.
- Consider not using turnips in a grazing mixture. Turnips at the right size can be a choking hazard for cattle. Use forage collards instead.
- Use caution when including buckwheat and hairy vetch in cover crops used for grazing due to potential livestock toxicity issues. While potential toxicity always must be taken seriously, good grazing management significantly reduces any risk, and reported issues of livestock toxicity from grazing cover crops is rare in Montana.
- Understand potential cover crop toxicity issues prior to designing a cover crop mix for grazing. Consult USDA-NRCS MT Plant Materials Technical Note 124, "Plants Poisonous to Livestock in Montana and Wyoming" (USDA-NRCS MT, 2020) for more information.

Attract Beneficial Insects and Provide Habitat for Wildlife

Cover crops can fulfill their primary purpose of benefitting the soil while also providing forage and cover for wildlife and attracting beneficial insects. Cover crops can provide wildlife food through cover crop biomass, seeds, and insect/invertebrate prey species. Flowering cover crops can be especially important for wild bees and other beneficial insects, especially if insecticides are avoided. Encouraging pollinators and beneficial insects can help decrease crop pests and increase crop yields. For example, parasitoid wasps that prey on the Wheat Stem Sawfly (WSS) benefit from the nutrition provided from plant nectars such as buckwheat, cowpea, phacelia, and flax. Including these species in a cover crop mix may encourage natural WSS control.

When designing a cover crop to attract beneficial insects consider using seeds not treated with neonicotinoids and other insecticides. Flowering cover crop species to consider in a cover crop mix to attract insects include buckwheat, camelina, canola, mustard, phacelia, safflower, sunflower, ramtilla, clovers, flax, cowpea, and vetch. Note that the flowers of some legumes such as peas and lentils are tightly closed and not available to all beneficial insects. Radish will flower if planted prior to the summer solstice but will remain vegetative with no flowers if planted later. Refer to MT NRCS Biology Technical Note MT-20 "Creating and Enhancing Habitat for Pollinator Insects" (USDA-NRCS MT, 2021) and the Appendix of this technical note for information on cover crop flowering species and their bloom periods.

Figures 9 and 10. Ramtilla (*Guizotia abyssinica* L.f.) (MT NRCS), and Proso millet (*Panicum miliaceum* L.) (USDA).

Cover crops also provide wildlife cover for safety from predators and nesting sites. In addition, the practice can address habitat fragmentation and provide habitat corridors and migration stop-over sites, particularly when cover crops are coupled with edge of field buffers. Residue left on the field will provide fall and over-winter cover if left standing as tall as possible, with a minimum height of 10 inches.

Cover crop practices that can help provide food and habitat for wildlife include:

- Consider selecting species that will set seed when planning a cover crop as a food source for upland birds. Proso millet is a good example. Allow enough time and heat units for warm-season grasses to produce seed in the late summer before frost-kill.
- Include both cool season and warm season species to lengthen the period of plant and seed production and provide a longer timeframe of food availability.
- Implement termination with machinery in a linear fashion from one end of the field to the other to allow wildlife to escape. Avoid the primary nesting season (April 15–August 1) to minimize impacts to nesting birds.

Cover crop practices that can help provide food and habitat for beneficial insects include:

- Use a diverse mix of species that have different bloom periods to lengthen the period of available pollen and nectar food sources.
- Consider using native species adapted to local conditions.
- In perennial farm systems such as orchards or vineyards, use low-growing perennial clovers or tolerate non-invasive weeds such as dandelions to provide floral resources for pollinators. It is critical that insecticides not be over-sprayed and allowed to drift down onto flowering plants in the ground cover.
- Use non-insecticide treated seed. For example, if canola is planted as a bee cover, it is important to not have systemic insecticides used in it.
- Avoid application of insecticides to cover crops especially where pollinators and beneficial insects are a goal. Where cover crops are planted in rotation with insecticide-treated cash crops, the residual impact of cash crop insecticides may be a concern. Systemic insecticides can persist in the soil and be reabsorbed by later crops that were not treated.
- Terminate cover crops after the last bloom if possible. Avoid chemical termination or terminate after bloom if using chemical applications. The combination of frost and grazing is an easy way to terminate cover crops to benefit insects.

Montana State University Cover Crop Resources

Check out three cover crop bulletins published by Montana State University Extension in 2022, including:

Cover Crops: Soil Health EB0238

Cover Crops: Management for Organic Matter and Nitrogen, EB0237

Cover Crops: Soil Water and Small Grain Yield and Protein, EB0236

Dr. David Weaver's one-hour lecture on Wheat Stem Sawfly management on YouTube:

Ecological Considerations from a Prairie Origin Inform Wheat Stem Sawfly Management

Site Inventory

After determining the objectives of the cover crop, inventory the site, including:

- precipitation amount and timing
- dryland soil moisture storage potential
- irrigation type and availability
- growth windows and frost-free dates
- soil type and soil test results
- weed species and herbicide inventory

Precipitation Amount and Timing

Ninety percent of all cropland acres in Montana are dryland (USDA-NASS, 2020), with most sites receiving 12 to 14 inches of annual precipitation. The local conservationist should know the average annual precipitation for the planned cover crop site as well as the monthly precipitation timing. Most Montana dryland sites receive their peak precipitation from April to mid-June, with very little falling in July and August. The exception to this is the northeast corner of the state near Plentywood, which can receive timely rains in July and August, more like the rainfall pattern of the Dakotas.

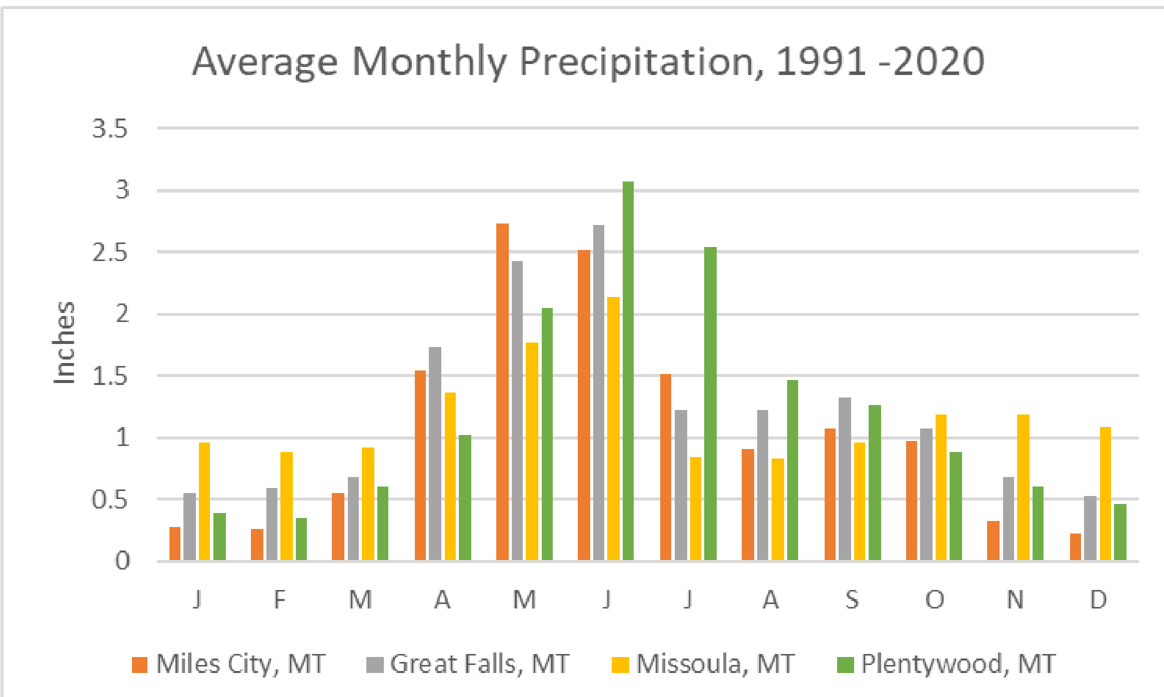

Figure 11. Average monthly precipitation at four Montana locations (NCEI NOAA, data retrieved December 2021).

Dryland Soil Moisture Storage Potential and Management

Planners should identify the primary soil map unit of the field prior to cover crop design along with any limiting soil factors that could decrease soil water availability. Dryland sites with shallow, saline, limey, or sandy soils have less water holding potential than sites without these issues. Consider selecting cover crop species with lower water needs on sites with a limiting soil or in climates with low annual precipitation (< 12 inches). See the Appendix of this technical note and the Data tab of the 340 Cover Crop IR spreadsheet for information on rooting depth and water use of each cover crop species.

Irrigation

Irrigation provides more flexibility for cover crop species selection and season of growth and removes risk of poor crop performance. However, finding a cover crop growth window in an irrigated system can be challenging, as continuous cropping is the norm. A common window exists after the harvest of hay barley in early July, or after malt barley harvest in late July.

Not all irrigation systems have available water early and late in the growing season. The conservationist should know the seasonal limitations of the irrigation system before designing the cover crop. Likewise, irrigation type may influence cover crop design and installation. Cover crops under sprinkler irrigation will receive more even application of water compared with cover crops under flood or furrow irrigation. Broadcast seeding of cover crops will be less successful in flood or furrow systems and is not recommended unless the cover crop can be established without an irrigation set and water is applied after germination and establishment.

Precipitation and Soil Moisture Resources

County-specific precipitation maps are located at NRCS MT FOTG >Section I>Erosion Prediction>Water Erosion>RUSLE Rainfall Factor Maps.

Track monthly precipitation normals at NCEI-NOAA www.ncei.noaa.gov/access/us-climate-normals/#dataset=normals-monthly&timeframe=30&location=MT

Local Mesonet station data are posted at http://climate.umt.edu/mesonet/.

Growth Windows and Frost-Free Days

In general, a cover crop needs a minimum six weeks of growth to produce adequate biomass, ideally with and more time if possible. If a six-week window is not available in the rotation, reconsider if a cover crop is the best tool for the situation.

Cover crop species belong in one of two growth windows: cool-season and warm-season. Cool-season species include small grains, brassicas, peas, lentils, and more. Cool-season grasses begin growth when the soil temperature is between 40 to 45 °F, and grow best between 65 to 75 °F. They become less productive with higher temperatures and longer daylengths and can survive temperatures below 32 °F. Most cool-season species can be planted 6 weeks prior to the last spring frost. They can also be planted in a warm-season window, although their growth will not be robust.

Warm-season species include sorghum-sudangrass, corn, millet, soybean, sunflower, and more. Warm-season grasses begin growth when the soil temperature is between 60 to 65 °F, and grow best between 90 to 95 °F. They become more productive with higher temperatures and longer daylengths and cannot survive temperatures below 32 °F. Warm-season species cannot survive in a cool-season window and should only be planted after the possibility of a spring freeze has passed. The conservationist should identify the first and last frost dates for a given location in the 340 Cover Crop Implementation Requirement (IR) sheet prior to including warm-season species in a cover crop. Warm-season crops should not be planted while the danger of frost still exists.

Table 4. Cool and warm-season growth, planting, and grazing termination windows in Montana. Specific dates are estimates and will vary based on location.

Season	Growth Window	Planting Window	Grazing Termination Window
Cool	Spring	Late March to early April (6 weeks prior to last spring frost)	Early to mid-June (First bloom of legume, boot stage of grasses, prior to heading and seed set)
Warm	Summer	Mid-May to early June (After danger of spring frost has passed)	Plants will die at first fall frost, but grazing can last into late fall/early winter
Cool	Fall	Mid-August to early September (4 to 6 weeks prior to fall frost)	Late October through late December (Wait until no further accumulation of heat units. Plants will remain in a vegetative state until a hard killing freeze and/or snow cover.)
Cool	Overwinter	Mid-August to mid-September (4 to 6 weeks prior to fall frost) OR dormant seeding in late fall after frost if erosion is not a concern	Following spring, summer, or fall

Montana has three cool-season growth windows and one warm-season growth window, as illustrated in Table 4. Cover crops are most productive when planted at the beginning of a specific growth window and terminated after reaching maximum growth. Termination via grazing ideally occurs at peak forage value, which is at the boot stage of grasses. However, this is not always feasible.

All locations in Montana have at least one cool-season growth window and the ability to grow cool-season species. However, not all locations have a window to support sufficient warm-season growth, especially sites at higher elevations. When in doubt, ask local sources about warm-season potential and understand the native plant communities. For example, Meagher County has no native warm-season plants in the rangeland, indicating that warm-season cover crops may not grow well there. Also consider growing a small test plot of warm-season species in marginal warm-season areas before committing to a larger field. Even with a challenging climate, warm-season species may grow well enough to produce adequate vegetative biomass, even though they may not have enough growing season to produce seed.

Summer Cover Crops

Farmers near Great Falls were hesitant to plant their summer warm-season cover crops at the beginning of June 2021, due to severe drought conditions and low soil moisture. Some planted anyway, and the seed remained dormant until almost 4 inches of precipitation fell in August. The resulting forage was a welcome relief for livestock grazing in the fall.

The following considerations should be used when working with specific growth windows:

- When using the spring growth window, terminate cover crops prior to seed production. Since most of Montana's cash crops are cool-season, any cover crops that go to seed in this window can become a weed issue in the following cash crop.
- Warm-season cover crop species in the summer growth window can go to seed with little consequence of becoming weeds in the following crop. Any warm-season volunteer is often controlled by low temperatures or the regular herbicide program. Seed production may be desirable in some species such as sunflower and millet.
- Summer mixed cover crops can be planted into dry soil and lie dormant for 1 to 2 months until timely rains support germination and emergence. This technique is not guaranteed to work every year, but it can be an excellent means of capturing and converting any summer precipitation into biomass.
- When late fall grazing is the objective, consider using spring small grains and not winter small grains when planting at the beginning of the fall growth window. For example, plant a spring triticale and not a fall triticale in mid-August for grazing in November. The spring triticale will not grow a seed head the following year and potentially become a weed issue like the winter triticale.
- When spring grazing is the objective in an over-winter growth window, use winter small grains for greater winter survival.
- When using hairy vetch in an over-winter cover crop, plant it by mid-August at the latest to have enough early root growth to survive the winter.

Soil Testing and Inventory

A standard soil nutrient test in the top 6 to 12 inches for N, P, K, organic matter, pH, and salinity is recommended prior to designing a cover crop as well as deeper sampling of nitrate to 24 or 36 inches. Old Conservation Reserve Program (CRP) or crested wheatgrass sites are often very low in nutrients and need additional N and P to jump-start nutrient cycling before planting a cover crop. Sites with Olsen P levels below 8 ppm are considered deficient and fertilizer addition should be considered. Sites with increased salinity (Electrical Conductivity > 2 dS/m) may require the selection of saline tolerant cover crop species. Likewise, soil acidification is becoming a serious issue in Montana dryland crop sites. Where low pH is suspected, take non-composited soil samples at a depth of 0 to 3 inches. Sites with low pH may need a lime addition prior to cover crop planting or may not be suited to annual cover crop growth. Consider planting acid-tolerant perennials instead.

If the producer is in the beginning phase of improving soil health, the Montana Cropland Soil Health Assessment and an infiltration test can be done to get a baseline assessment. The producer may also want to archive some soil to compare with future soil quality. Place a few representative soil peds from the top 3 inches in a sealed container and compare the visual aggregation and pore space with the same location after several years of implementing an improved soil health system. More sophisticated laboratory tests for soil health in both the baseline and planned condition can be used such as the Haney test, PLFA, microbial respiration test, and more, if the producer has interest. Be aware that these tests may take several years to show improvements in soil health, especially in dryland settings. Producers should not expect to see differences in soil tests and inventories after one year of a cover crop, for example.

Soil Inventory Resources

Soil map units can be found online with Web Soil Survey, NRCS's online soil mapping tool.

Find the Montana Cropland Soil Health Assessment Card online at the MT NRCS website.

Weed and Herbicide Inventory

Visit the site to assess the amount and species of weeds present. Weeds must be controlled to an acceptable threshold prior to cover crop seeding or cover crop species that allow for in-crop herbicide control should be selected. For example, if a significant amount of field bindweed or Canada thistle is present, consider using a cover crop with only grass species to allow for an in-crop broadleaf herbicide application.

Know the historical herbicide use on a field. Check herbicides being applied in the rotation to ensure they are compatible with both cover crops and cash crops in the rotation. Many pre-emergent herbicides have long residual carryover that may cause seedling failure of a specific plant group. For example, pre-plant applications of broadleaf herbicides with the active ingredients sulfentrazone and sulfosulfuron can persist in the soil for 18 months and 1 to 3 years, respectively, and can injure peas or other species in the subsequent rotation.

Herbicide Carryover Resources

Getting the Most from Soil-Applied Herbicides, MSU Extension publication

Cover Crop Design

Design the cover crop only after determining the resource concerns, understanding the producer objectives, and obtaining the site inventory.

Species Selection

Use the most recent version of the NRCS MT 340 Cover Crop Implementation Requirements (IR) spreadsheet located in Field Office Technical Guide (FOTG) Section IV. Users new to this planning tool should become familiar with the list of cover crop species allowed for use in Montana in the Data tab, also located in the Appendix of this technical note. Note that some species, such as cereal rye and annual ryegrass are allowed for use with Area Office approval only. Species not listed within the spreadsheet are not allowed for use for NRCS planning purposes. Consult the state agronomist if considering species not listed in the 340 Cover Crop IR spreadsheet.

Detailed descriptions of each cover crop species are too numerous to elaborate here. The new planner is encouraged to study the listed Cover Crop Species Resources and spend time in the field with an experienced planner to learn the various characteristics of each species listed in the Data tab of the NRCS MT 340 Cover Crop IR spreadsheet.

Some species are more challenging to select than others. The following information is meant to help provide guidance for the more perplexing species.

Cover Crop Species Resources

USDA ARS Cover Crop Chart

NRCS Wyoming Cover Crop Periodic Table

NRCS MT Evaluation of Cool Season Cover Crop Species in Southern Montana

Plants.usda.gov

Managing Cover Crops Profitably

GreenCover Seed SmartMix calculator

Midwest Cover Crops Council

MT NRCS Flickr site, Cover Crop Species album

Millets. Four types of millet are available for use in Montana cover crops; foxtail (German), Proso, pearl, and Japanese. Foxtail millet is the most common choice and should be used in most situations. It is less likely to set seed and produces good biomass for grazing. Proso millet is more likely to set seed and is a good choice as a food source for upland birds. Pearl millet is more suited to the warmer parts of the state and does best under irrigation. Japanese millet is a good choice for fields with low pH, as it can tolerate levels down to 4.5. See the NRCS Plant Materials Technical Note "Comparison of Five Millet Species for Conservation Use in the United States" (USDA-NRCS, 2014) for more information.

Hairy vetch. Hairy vetch is a cool season legume and can be either an annual or biennial. It is one of the most winter hardy legumes and can withstand temperatures as low as 5 °F with no snow cover. It can be planted in the spring for an annual cover crop, or in late summer for an overwinter cover crop. Plant no later than mid-August for an overwinter growth window with grazing options starting the following spring. Hairy vetch needs more time than a winter cereal prior to fall frost to develop adequate roots to survive the winter. Hairy vetch is known to have a great rooting system, with a tap root that will extend 1 to 3 feet into the soil profile. This taproot will allow the vetch to thrive even in dry conditions. Hairy vetch is also one of the better legumes for N-fixation and weed control.

Hairy vetch can be very persistent. Producers near Great Falls have planted it in a dryland spring-seeded cover crop mix. The cover crop was grazed in June and the hairy vetch regrew after the grazing and provided exceptional weed control through the rest of the summer. During the winter it stayed green underneath the snow and provided winter grazing for cattle. The following spring it grew and provided the producer with 1.5 tons per acre of hay.

This persistence also has a downside. Hairy vetch has 10 to 20% hard seed that can wait in the soil to germinate for one or more years. It also reseeds itself well and can show up in the field years after the initial seeding. Producers with annual legumes in the crop rotation should be cautious when using hairy vetch in a cover crop.

Clovers. Sweet clover is a biennial and most often used for nitrogen fixation in dryland organic or no-till crop systems. It can be seeded with a cereal grain at a rate of 5 pounds per acre. After cereal grain harvest, the sweet clover can take advantage of fall precipitation and grow into the following year where it can be tilled in for nitrogen or hayed for forage. Sweet clover can regrow after haying and help with weed suppression. Care must be taken when grazing sweet clover as it can have anticoagulant effect.

Annual clovers (crimson, Berseem, red, etc.) are not competitive and are not recommended for use in a typical cover crop mix. They perform best when interseeded into a standing cash crop where low light conditions prevail or when used as a single species cover crop under irrigation.

Seeding Rate

Designing a cover crop with an accurate seeding rate is important. Too few seeds per acre results in a thin stand with decreased biomass production and increased weed competition. Too many seeds per acre results in the producer spending too much money on seeds. Likewise, maintaining the proper ratio of the various species in the mix is important. A cover crop mix with more legumes than desired may be more challenging for grazing ruminants. Or a cover crop with too few flowering species will be of no use when attracting beneficial insects.

Cover crop seeding rate depends on species selection and site conditions. Small-seeded species such as annual ryegrass will have much higher seeding rate densities (75 seeds per ft^2) than large-seeded species such as field pea (9 seeds per ft^2). Cover crop mixes with different seed sizes will have a seeding rate that is proportional to the various species in the mix.

To calculate the appropriate seeding rate, use the most recent version of the NRCS MT 340 Cover Crop Implementation Requirements (IR) spreadsheet located in Field Office Technical Guide (FOTG) Section IV. Notice that each individual cover crop species has a recommended full stand seeding rate listed in the Data tab. This rate assumes the cover crop is installed with a drill at a dryland site. Because seed lots and varieties vary in size within a given species, the listed seeding rates should be taken as general guidelines, with natural variation expected.

Planners and producers can approach seeding rate design in various ways. The simplest method of seeding rate determination is to use the desired proportions of the Full Stand Rate, as follows:

1. Start the cover crop design process in the 340 IR Design tab with the Select Species dropdown boxes (Column A). Select the desired cover crop species and enter the cultivar names, if known (Column B).
2. Have in mind an approximate percentage of each crop type desired in the mix, with a total of 100%. In Figure 12 below, the planner wanted 30% legumes, 50% grasses, and 20% brassicas, in a 100-acre irrigated field.
3. Enter an appropriate Planned Rate in pounds per acre for each species (Column C) to obtain the desired percentage in the Percent of Full Stand Rate column (Column D).
4. Check that the Total Percent Full Stand Rate in cell D49 is 100%.
5. Select the appropriate Seeding Method and Site Type from the dropdown in cell C51. In this example, the cover crop is planted with a drill and grown with irrigation, increasing the Total Planned Rate by a factor of 1.25 in the Total Adjusted Rate in Columns J and K. Use these two columns for purchasing seed and cover crop installation and certification. Notice that the Base Rate Summary section does not change with adjustments and is only accurate for a drilled, dryland cover crop.

Table 1. Planned Cover Crop Species, Composition and Seeding Rates

Select Species	Enter Cultivar / Variety	Enter Planned Rate (PLS lb/ac)	Percent of Full Stand Rate (%)	Seeds/lb	Total seeds/ac	Seeds/ft^2	Proportion Total Mix (seeds/ac)	Total Planned Rate (PLS lbs/field)	Total Adjusted Rate (PLS lbs/field)	Total Adjusted Rate (PLS lbs/acre)
LEGUMES	**Totals**				**117,000**	**2.7**	**15%**	**4,500.00**	**5,625.00**	**56.25**
Pea, spring	Arvika	45.00	30%	2,600	117,000	2.7	15%	4,500.00	5,625.00	56.25
GRASSES	**Totals**				**458,750**	**10.5**	**58%**	**2,750.00**	**3,437.50**	**34.375**
Triticale, spring	Trical 141	15.00	25%	16,000	240,000	5.5	31%	1,500.00	1,875.00	18.75
Oat, spring		12.50	25%	17,500	218,750	5.0	28%	1,250.00	1,562.50	15.625
BRASSICAS	**Totals**				**210,000**	**4.8**	**27%**	**120.00**	**150.00**	**1.5**
Forage Collards or Kale	Impact	1.20	20%	175,000	210,000	4.8	27%	120.00	150.00	1.5
BROADLEAVES	**Totals**				**-**	**0.0**	**0%**	**0.00**	**0.00**	**0**

BASE RATE SUMMARY									ADJUSTED SUMMARY	
Number of Species		Total Planned PLS lbs/ac	Total Percent Full Stand Rate (%)		Total Planned seeds/ac	Total Planned Seeds/ft^2		Total Planned (PLS lb/field)	Total Adjusted Rate (PLS lb/field)	Total Adjusted Rate (PLS lbs/acre)
4		73.70	100%		785,750	18.0		7,370.00	9212.5	92.1

Seeding Rate Adjustments: Drill Seeder, Irrigated (1.25x rate)

Figure 12. A four species cover crop design using the Full Stand Rate method in the MT NRCS 340 Cover Crop IR spreadsheet version 4, 2022 (MT NRCS).

In most cases, using the Full Stand Rate target of approximately 100% (+/- 10%) will result in an appropriate seeding rate and is the encouraged method for most MT NRCS cover crop designs. However, all possible species, varieties, and site combinations have not been studied in-depth to determine the ideal seeding rate for every possible cover crop scenario. For this reason, planners with sufficient job approval authority (JAA) can use their professional discretion to alter the target full stand rate to a number other than 100% if there is a justifiable reason to do so. Simply document any discrepancies outside of the target rate in the Notes section of the 340 IR and justify the reason. A common justification could be that the producer has used a known cover crop mix for many years and likes how it performs at her location.

Single vs Mixed Species

Cover crops can consist of a single species or multiple species. Objectives and resource concerns will dictate the number of species to use, with specific advantages and disadvantages to each approach.

Single species. One advantage of a single species cover crop is greater opportunity for weed control. Using a single species allows for in-crop application of either a grass or broadleaf herbicide, depending on the cover crop and weed species of concern. As an example, a single-species sorghum-sudangrass cover crop is a good option in old pasture stands with bindweed infestations in a warm-season planting window. The sorghum-sudangrass field can be sprayed with a broadleaf herbicide during the growing season and again in the fall when the bindweed is translocating herbicide to its roots for an effective kill.

Disadvantages of a single species cover crop include lack of plant diversity and resilience to varying weather conditions and pest pressure, and less forage diversity for grazing and livestock selection. The risk of livestock poisoning and toxicity is also greater when grazing a single species cover crop.

Mixed species. A typical cover crop mix has 5 to 10 species, although some have as few as 2 or as many as 15. There are many advantages to a multi-species cover crop, including increased plant diversity, greater resilience to varying weather conditions and pest pressure, improved forage diversity for grazing, decreased forage toxicity risks, attraction of pollinators, and a more aesthetically pleasing landscape. When compared with a single-species cover crop, mixed-species crops do not necessarily produce more biomass. However, they do provide a more reliable source of biomass due to the ability of the plant diversity to respond to various field and weather conditions (Khan and McVay, 2019).

Competition of species should be kept in mind when designing a mixed-species cover crop as some species are more competitive than others. Grass species selection and amount often influences the amount of diversity in the cover crop. Both sorghum-sudangrass and barley are very competitive when planted in the appropriate growth window. This makes them highly productive for forage and good additions to a mix for biomass production and grazing. However, they can crowd-out other plant species and reduce the effect of a diverse mix. Reduce the proportion of these grass species in a mix or use less competitive grasses such as millet and triticale when aiming for maximum diversity.

In contrast, most legumes are not as competitive as grasses and should be at least 20 to 30% of their full stand rate to ensure they are appropriately represented in the final biomass. Clovers have proved to be not competitive in a mix and may be more appropriate for interseeding into standing cash crops as they can tolerate lower light conditions.

When adding species to a mix, take care that all species meet the objective of the planting and will show up in sufficient biomass amounts to justify the additional seed cost.

Rotation Concerns

Take care that cover crops do not promote weeds and harbor pests for the subsequent crops in the rotation. Specific management practices and species considerations include:

- Peas, lentils, and chickpeas in a cover crop can be a source of disease for future cash crops of peas, lentils, and chickpeas. These crops should be grown only every 4 or 5 years in the rotation to reduce disease pressure. Use another cool-season legume in the cover crop such as fava bean, common vetch, or chickling vetch if peas, lentils, or chickpeas are a cash crop in the rotation. These alternative legumes do not promote pea and lentil diseases.
- Hairy vetch and sweet clover have a high percent of hard seed. Be cautious when using these species in a pea or lentil rotation, as they may germinate in the following cash crop and become a weed issue. Consider growing a cereal cash crop after using hairy vetch or sweet clover to allow for herbicide control of any volunteer or re-growth.
- Forage peas grown commercially as a crop or in cover crops can be a contaminant in yellow and green peas grown for food and can result in a price reduction or rejection of peas for human consumption. Ensure that producers are aware of the potential for forage peas to become a contaminant in subsequent pea crops grown for the human consumption market.
- Likewise, common vetch can be a contaminant in future lentil crops. Consider growing a cereal cash crop after using common vetch in a cover crop to allow for herbicide control.
- Encourage producers to use certified seed to avoid contamination issues.
- Do not use a grass-intensive cover crop that leaves large amounts of residue prior to the production of malt barley. Grass residue harbors Fusarium Head Blight, which produces a mycotoxin in the barley kernels and makes the crop unmarketable (Burrows, et al., 2017).
- Both cereal rye (*Secale cereale* L.) and annual ryegrass (*Lolium multiflorum* L.) are annual grasses that can become weedy in cereal grain rotations. The use of cereal rye or annual ryegrass in cover crops requires NRCS Area Office approval in Montana.
- Buckwheat has a high percent of hard seed, volunteers easily in no-till systems, and can become weedy in subsequent crops. Japan has zero tolerance for buckwheat in wheat and requires listing of the presence of buckwheat as an allergen on food products. Buckwheat contamination in wheat shipments to Japan could have significant economic impacts to Montana and other wheat-producing states. Montana NRCS will not recommend planting buckwheat in rotation with or adjacent to commodity wheat production that will be planted to wheat within the next two

calendar years after planting buckwheat. Adjacent is defined as within 30 feet of a wheat field (NRCS National Bulletin 190-16-8 ECS).

Seed Cost, Sources, and Availability

Consider cost limitations of the cover crop seed based on producer feedback. Legumes are typically the most expensive component of a cover crop mixture on a cost per acre basis. The rate and percentage of legumes in a mix can change seed mix costs substantially. This can be at odds with the need to include legumes at a minimum of 20 to 30% of the full stand rate for them to be present in the final biomass. Producers considering an inexpensive cover crop should consider small grains or brassicas. Planners are encouraged to use the Cost Estimate tab in the 340 Cover Crop IR to help producers design a cover crop mix when cost is a concern.

All seed must be tested and labeled in accordance with all Federal and Montana Agricultural Seed Act and Administrative Rules and seed testing must be performed and dated within one year prior to the date of planting. Place a copy of the seed label with the certification documentation in the client folder. Refer to the Montana seed regulations at agr.mt.gov/Seed-Program.

Cover Crop Seed Vendors

A list of cover crop seed vendors for the Western US is provided at NRCS Tech Note WNTSC-3 Cover Crop Seed Vendors for the Western States.

The germination and purity of each species in a mixture must be listed on the seed label, as well as the percentage of each species in the mixture, to verify adequate amounts of Pure Live Seed (PLS). The percentage of weeds and other crop seeds must also be on the seed label. Refer to MT NRCS Plant Materials Technical Note 125 “A Guide to Understanding Seed Labels for Seeding Certification” (USDA-NRCS MT, 2021) for more information.

Use certified seed and recommended species and cultivars whenever available. When certified seed is not available, common seed may be used that is adapted to local soil and climatic conditions. Seed should not be used if the origin is unknown. However, unknown or generic cultivars (variety not specified, or VNS) are allowed.

Figures 13 and 14. Precipitation and site selection strongly influence dryland cover crop biomass production. An 8-species dryland spring cover crop mix of pea, common vetch, oat, Italian ryegrass, safflower, turnip, radish and camelina near Amsterdam, MT, June 2012, produced 0.4 ton per acre dry biomass and was about 10 inches in height. Growing season precipitation was 5.8 inches and the site was on an upland location (top) (MT NRCS). The same 8-species cover crop mix was grown the following year, east of Bozeman, MT, June 2013, and produced 1.7 ton per acre dry biomass and was about 36 inches in height. Growing season precipitation was 7.7 inches and the site was sub-irrigated near a lowland stream bed (bottom) (Susan Tallman).

Installation, Management, and Termination

Seedbed Preparation and Weed Control

The ideal seedbed for cover crops has ample residue, good soil moisture, and is free from weed seedlings. Good seed-to-soil contact is critical for germination and establishment and is best done with a no-till drill with proper row closure and down-force that can cut through any residue.

Weed control is a critical component for the success of a mixed species cover crop. The field must be relatively clean of weeds prior to seeding, as there are no targeted in-crop herbicide options when mixing grass and broadleaf species. The producer should wait for weeds to emerge prior to planting and control with herbicide or mechanical methods immediately prior to cover crop planting (2 to 3 days). Follow all label and plant back restrictions when using herbicide. Before designing the cover crop, visit the field to observe any possible weed issues and understand any weed history that could influence the weed seed bank. Be aware that plants not typically thought of as weeds, such as alfalfa, can become an issue if left unchecked.

Some crops such as corn, soybeans, sugar beets and canola have been developed with resistance to the herbicide glyphosate and are marketed as Roundup Ready®. If these crops are used in a mix, care should be taken to ensure control of volunteer or "escape" plants especially if glyphosate is used to control weeds in the crop rotation.

Seeding Date, Depth, and Inoculation

Match the seeding date to the beginning of the desired growth window (Table 4). Make sure all risk of frost has passed prior to seeding warm-season species. Use the 32 °F threshold for spring and fall frost dates in the Design tab of the 340 Cover Crop IR and note that these dates reflect a 50% probability of no frost.

Seeding depth of a cover crop is very important. Many cover crop seeds are very small and if placed too deep will not germinate and grow. Larger seeds such as the peas and fava bean like to be placed about 2 inches deep. A good intermediate depth if using a mixed cover crop is to sow between ¾ to 1 inch. This allows smaller seeds to break through the soil surface after the larger seeds. Refer to the 340 IR Data tab for seeding depth recommendations for individual or monoculture cover crop species.

Mix inoculant into the box with the seed mix. Refer to Plant Materials Technical Note 5 "Using the Appropriate Legume Inoculant for Conservation Plantings" (USDA-NRCS, 2021).

Seeding Methods

Most cover crops in Montana are seeded directly into the soil using a drill. Row crop precision planters can be used as well and are more commonly found in irrigated settings. When seeding a cover crop mix with a box drill, use a seed-box agitator or fill only 1/3 of the box with the seed mix to enable a more even distribution of seeds without the larger seeds settling to the bottom.

Cover crop seed can also be broadcast on the surface of the soil. This results in marginal seed to soil contact and requires a doubling of the seeding rate. Broadcasting works best with smaller-sized seed such as brassicas and millets. Larger seeds such as peas or sunflowers will not establish well when broadcast and should not be used with this seeding method. Refer to the Seed Size column in the 340 Cover Crop IR Data tab. Small-sized seeds work best for broadcasting, while medium-sized seeds may have mixed results. Large-sized seeds should not be broadcast.

Farmers in the Midwest have had success with broadcast application of cover crops into standing corn, and multiple pieces of innovative machinery exist for interseeding cover crops, including aerial application, high clearance applicators with drop tubes, and an interseeder drill. While these methods are rare in Montana, they may have some use in specific sites and applications.

Interseeding

Interseeding is the practice of seeding a cover crop into an existing cash crop. The purpose is to establish the cover crop early, so that after harvest of the cash crop, the cover crop is released for growth.

Field trials in Montana have shown promise with the technique and have focused on seeding annual ryegrass into silage corn at the V3 stage. The annual ryegrass protects the soil against erosion over the winter months by providing soil cover. Timing is critically important when interseeding, as the cover crop must be seeded only after the cash crop has successfully established. In Montana, the technique works well in silage corn, which is harvested mid-September, giving the annual ryegrass enough time to grow in the fall. In contrast, grain corn is often harvested too late for the technique to be of benefit. Cover crop species with low light tolerance such as annual ryegrass, red clover, and radish, work best for interseeding a cover crop mixture.

Interseeding Resources

Annual Ryegrass Interseeded into Silage Corn, Broadwater County, MT NRCS

Stillwater Interseeding Annual Ryegrass into Silage Corn, MT NRCS

Cover Crop Interseeder: Improving the Success in Corn, Penn State

Fertilizer

Cover crops may benefit from fertilizer addition depending on the species selected and the soil test result. Supplemental nitrogen may be needed if the cover crop immediately follows a crop that is good at scavenging nutrients, such as winter wheat, but may not be needed if the cover crop follows a legume, such as alfalfa. Old pasture stands are often low in fertility and cover crops may benefit from additional nutrients. Base all fertility recommendations for cover crops on a recent soil test and the expected yields for grass production found in the MSU Fertilizer Guidelines for Montana Crops EB161 (Jacobsen, et al., 2005) with 25 pounds of nitrogen applied for each ton of expected cover crop biomass yield, minus any soil test or legume credits. Planners must have the appropriate 590 Nutrient Management job approval authority and use the current MT NRCS Nutrient Management 590 IR sheet when making any fertilizer recommendations.

Termination Methods and Timing

Cover crop termination will depend on the cropping system and producer objectives. Approved methods of cover crop termination include mowing, grazing, chemical application, tillage, roller crimping, or frost. The NRCS 340 Cover Crop standard does not allow cover crops to be harvested for seed or for the burning of cover crop residue. Planners should also be familiar with any specific programmatic constraints (CSP, EQIP, etc.) on termination type prior to design and installation.

Grazing is preferred over haying as a termination method to promote soil health, as proper grazing leaves more carbon in the field through plant residues and animal waste, and the trampling action of hooves brings the plant material in close contact with the soil to allow for microbial degradation. When grazing a cover crop, producers must leave at least 50% of the biomass on the field, with a minimum 6-inch stubble height.

Mowing can be useful when used correctly. Mowing must leave a minimum stubble height of 6 inches and all plant material evenly distributed in the field. Timing is important, as many species will regrow and produce seed if mowed too soon. Grazing a cover crop too early will also result in some regrowth if there is adequate moisture available in the soil.

Haying is not recommended for cover crop termination as it removes aboveground carbon, makes the soil susceptible to erosion, and removes physical protection, all of which are benefits of a cover crop. In addition, haying of the forage biomass changes the definition from a cover crop to a forage crop. In instances where haying is desired by the producer, the planner should consider using the 328 Conservation Crop Rotation practice instead of the 340 Cover Crop practice.

In rare cases, haying may be of benefit, especially on irrigated sites where the cover crop can regrow after the haying event and then be grazed. Area Office approval is required for any MT NRCS cover crop design which includes haying as a termination strategy. Requests for haying should be rare and approvals should be justified based on estimated biomass production left on the field after the proposed haying event and/or a high amount of cover crop regrowth. All hay cutting must be at a minimum 6-inch stubble height.

Swath grazing of cover crops is a viable alternative to haying and can be means to stockpile forage for later use. Swaths must be grazed on the same field on which the cover crop was grown. Swath grazing requirement are the same as regular grazing. Swaths must be evenly distributed across the field and cut at a minimum 6-inch stubble height. A minimum 50% of the swath biomass must be left on the field after the grazing event.

Chemical termination allows the producer to kill the cover crop before it goes to seed and/or to preserve soil moisture. It is best not to use the same chemical year after year to reduce the risk of developing herbicide resistant plants. The producer should work with their agricultural consultant to determine proper herbicide rotation and timing.

Frost kill is common for cover crops planted for fall grazing. While most annual cover crops will winter kill in Montana, the producer should have a backup plan should some species survive the winter. Some brassicas (radish and canola), legumes (Austrian Winter Peas, vetch, alfalfa, clovers) and winter grains can survive the winter and may need to be controlled the following year.

Mechanical termination is an effective means of control, though tillage is not recommended for soil health purposes. Roller crimping has proven to be a successful mechanical termination method in the Eastern and Midwest United States but is often not effective in Montana, as cover crop biomass production is often too low. A minimum biomass production of about 3 ton/ac is required for the cover crop to effectively lay flat with a roller crimper. This would be possible in irrigated systems in Montana, but not in dryland systems. Finding the right down pressure can also be challenging with this technique, as too little pressure will not kill the crop and too much pressure will cut the stems and trigger regrowth.

Cover crop residue will partially break down over winter, but consideration needs to be given to the equipment used for planting the next crop. Disk drills are much better at cutting through residue than hoe drills but must be maintained during the seeding operation to minimize problems with excess residue. In the event of excessive cover crop residue, the producer may need to find options to minimize plugging issues with drills during seeding. If a hoe drill is used, vining species such as vetches and peas can create problems when seeding the next cash crop, depending on how much of the cover crop residue has broken down.

Further Resources and Websites

Montana Soil Health Project Reports.

Montana NRCS Cover Crop Tips

NRCS Plant Materials Center Cover Crop Performance and Adaptation Trials

Montana State University Cover Crops website

Western Cover Crops Council

Practice Certification

For MT NRCS programmatic purposes, a seed label for each cover crop species must be provided to correctly certify the installation. The seed tag must show percent purity and percent germination to calculate the Pure Live Seed (PLS) for each species. The PLS test date can be no older than 12 months from the time of the seed purchase within the state of Montana, and within the past 6 months for seed purchases outside of the state. Each species must be within ± 10% of the PLS specified in the design sheet for the entire cover crop to meet the certification requirement. Producers and seed dealers should be aware of this certification condition prior to seed purchase. Place a copy of the seed label with the certification documentation in the client folder. Cover crop seed must be purchased and installed based on the PLS requirement and not simply on the pounds per acre in the design sheet. Refer to MT NRCS Plant Materials Technical Note 125 "A Guide to Understanding Seed Labels for Seeding Certification" (USDA-NRCS MT, 2021) for more information.

Crop Insurance for Dryland Cover Crops

When using dryland cover crops, consult the current USDA Risk Management Agency (RMA) guidelines for Good Farming Practices and specific planting and termination date requirements. Because dryland cover crops use soil moisture, this can affect the yields of the subsequent cash crop and crop insurance classifications. Refer to USDA RMA Cover Crop Termination Guidelines Version 4 for more information.

Monitoring and Evaluation

Cover crop monitoring can be a useful tool for understanding what types of cover crops work best at a given location. Information from monitoring can help improve and refine the cover crop design for the following year. Likewise, monitoring provides information on the amount and type of forage present for grazing.

Seedling stand counts can help evaluate the vigor of germinating seedlings for a given site and help determine if re-seeding is desired after a severe weather event.

- Take the count 15 to 30 days after cover crop emergence.
- Use a square foot quadrat and count 5 separate samples across the diagonal length of the field, avoiding headlands and field edges.
- Only count species from the 340 Cover Crop IR Design Tab. Weed and other volunteer species should not be included in the stand count.
- Count whole plants, not tillers.
- Stand counts should be close to the plants per square foot in the 340 Cover Crop IR Design Tab (Cell G49). 10 plants per square foot is also a good minimum rule of thumb.

Cover crop biomass can be monitored prior to termination by collecting, drying, and weighing biomass from at least 3, and at most 5, samples per field along a diagonal transect. Allow biomass samples to air dry for a week in well-ventilated paper bags or spread out on newspaper. A simple monitoring strategy collects the total biomass from each sample and estimates only the total cover crop production. A complex monitoring strategy separates the biomass by species and compares the biomass percentages to the Full Stand seeding rate percentages in Column D of the 340 Cover Crop IR Design Tab. If grazing the cover crop, use the collected biomass numbers to calculate the Animal Unit Months (AUMs). Also note the monthly precipitation, frost-free days from planting to termination, and other cultural practices.

Figure 15. Monitoring hoop after cover crop clipping (MT NRCS).

Grazing

Cover crops can be a great source of high-quality supplemental forage, relieving pressure on native rangeland and pastures early and late in the season. Grazing of cover crops also promotes soil health by integrating livestock into a crop system. Livestock convert the grazed plant material into a lower C:N food source through digestion and waste addition. The manure is then a more readily available food source for microbial life. Likewise, hoof action and trampling increase microbial activity compared with haying by bringing the ungrazed portion of the cover crop into closer contact with the soil where it decomposes faster than standing residue. This decomposition also makes seeding the following crop easier with less residue for the drill to travel through.

Grazing cover crops is of greater benefit to the soil than haying. Haying removes most of the aboveground biomass, leaving the soil exposed to weeds, erosion, and greater soil temperatures. Haying also requires ownership and maintenance of haying equipment, the storage and hauling of hay to the livestock, and the hauling of manure away from any confined feeding areas. In contrast, proper grazing leaves at least half of the plant material with a minimum stubble height of 6 inches on the soil surface, providing protection from erosion, and weed infestation, and decreases soil temperature. Grazing requires the expense of good fencing and livestock water, but expense is also saved with no need to haul and spread both the livestock feed and waste.

Most grazing of diverse cover crops is safe when coupled with good management. Plant species diversity allows livestock to regulate their intake of potentially problematic species and avoid toxicity issues.

Figure 16. Cattle grazing a warm-season cover crop (MT NRCS).

Management

To reduce toxicity risks when grazing cover crops use the following practices:

- Always provide access to clean water.
- Provide roughage, e.g., old hay or access to grass pastures, to help livestock balance their intake between high and low carbon feedstocks.
- To prevent prussic acid poisoning in mixes that contain sorghum, sorghum-sudan, and/or sudangrass, do not graze the cover crop until 7 to 10 days after a killing frost or other damaging event (mowing, hail, etc.)
- Send livestock into the cover crop field full, not hungry. Early afternoon is often a good time, after a morning of grazing elsewhere.
- Monitor livestock closely for early signs of nitrate or prussic acid poisoning.

Risks

Care should be taken when grazing cover crops to protect livestock health and safety. If pesticides are used, follow pesticide label grazing restrictions. Most risks with grazing cover crops pertain to plant species toxicity, specifically nitrates and prussic acid. Consult USDA-NRCS MT Plant Materials Technical Note 124, "Plants Poisonous to Livestock in Montana and Wyoming" (USDA-NRCS MT, 2020) for more information. While all toxicity issues should be taken seriously, it should be noted that with proper design and management, cover crops can be grazed successfully, and the reported frequency of toxicity issues in Montana due to cover crop grazing is rare.

Nitrates. Small grains, brassicas, sunflowers with immature seeds, and other species can accumulate nitrates that are toxic to livestock. Stress, high soil nitrogen levels, and regrowth after cutting or hail can increase nitrate levels, all which generally decrease as plants mature. Nitrates accumulate in the lower one third of plants during stressful conditions.

Practical wisdom on nitrate accumulations in cover crops teaches that generally, all four of the following must be met before nitrate poisoning from grazing is likely to occur:

- The cover crop is a monoculture or has very low diversity.
- Nitrogen levels in the soils are high.
- Dry conditions or other environment factors have stressed the stand.
- Grazing occurs below a stubble height of 6 inches.

Never assume a forage is safe if it has been affected by adverse growing conditions. Take a forage sample to your local Montana State University (MSU) Extension office for a rapid nitrate analysis prior to grazing. However, be aware that a clipped sample may not represent what is actually consumed from a diverse pasture (Rasby, Anderson, Kononoff, 2014).

To avoid nitrate toxicity to livestock when grazing cover crops, rely on good management strategies instead, including:

- Plant a diverse mix that gives livestock choices when grazing.
- Always provide access to clean water.
- Don't overstock pastures.
- Do not use high density grazing on suspected high nitrate pastures.
- Graze the suspected pasture during the day and remove livestock at night to

reduce the amount of pasture consumed and to acclimate livestock.

- If possible, don't graze the suspected forage until one week after a killing frost.
- Avoid feeding suspect forage to very hungry livestock. Put cattle on the suspect forage with full stomachs.
- Monitor livestock closely for early signs of nitrate poisoning including:
    - difficult and rapid breathing
    - muscle tremors
    - low tolerance to exercise
    - poor coordination
    - diarrhea and frequent urination
- Provide access to low quality (low protein) roughage (e.g. old hay, grass pasture) to help livestock balance their intake between high and low carbon feedstocks.
- Soil test regularly and follow fertilizer recommendations to not overapply nitrogen.

Prussic acid. Prussic acid (also known as hydrogen cyanide, HCN) can come from sorghum, sudangrass, and sorghum-sudangrass hybrids. According to Oregon State University Extension, sorghum contains higher quantities of prussic acid than sundangrass, and is unsafe for grazing until the plants reach maturity with no new growth present. In contrast, most varieties of sudangrass pose little danger of prussic acid poisoning when grazed, except from the young growth after any damage such as frost, hail, drought, clipping or grazing (Vough, 1978). Toxicity of sorghum-sudangrass falls somewhere in between sorghum and sudangrass.

Most problems with prussic acid can be avoided with proper management, including:

- Designing and installing a diverse cover crop mix. This will have less potential prussic acid compared to a monoculture stand with sorghum or sorghum-sudangrass.
- Wait to graze sudangrass until it is 18 to 20 inches in height.
- Wait to graze sorghum-sudangrass until it is 24 to 30 inches in height.
- Do not graze new growth of sorghum, sorghum-sudangrass, or sudangrass within 7 to 10 days of stress or damage, such as frost, hail, mowing, grazing, drought, etc.
- Use certified seed to assure varietal purity.
- Select sudangrass rather than sorghum for grazing, as it has less prussic acid potential. A sorghum-sudangrass hybrid falls somewhere in between the two.
- Soil test regularly and follow fertilizer recommendations. High nitrate with low phosphorus and potassium can contribute to high prussic acid.
- Send livestock into cover crop fields full, not with empty stomachs.
- After frost, wait 7 to 10 days before grazing. Beware of new shoots, high in prussic acid, developing after frost.
- Monitor livestock closely for signs of prussic acid poisoning, including:
    - rapid breathing, gasping and increased pulse rate
    - muscular twitching or nervousness, trembling
    - foam from the mouth
    - blue coloration of the lining of the mouth

Other Potential Toxicity Issues

Buckwheat is a primary photosensitizer to livestock. Ingesting a portion or entire plants, dried or fresh, has caused photosensitization in animals with exposed or light-colored skin.

Hairy vetch also causes poisoning and death in cattle, horses, and poultry after ingesting raw seeds. The poisoning is most prevalent in mid- to late-spring as hairy vetch reaches maturity. However, hairy vetch has been used extensively in Montana cover crop mixes and there have not been reports of toxicity problems.

Choking can be a hazard when grazing turnips Consider using forage collards or kale instead.

This technical note is not an exhaustive resource for cover crop toxicity issues. Producers are advised to consult USDA-NRCS MT Plant Materials Technical Note 124, "Plants Poisonous to Livestock in Montana and Wyoming" (USDA-NRCS MT, 2020), as well as other guides and local veterinarians for more information.

Summary

Designing, installing, and managing a cover crop can be an intimidating prospect for the new conservationist or producer as there are many factors to consider. However, with careful planning and management, cover crops can successfully address multiple resource concerns and objectives in a variety of soil and climate conditions across the state. Those new to the practice should be encouraged by the many successful examples of cover crops currently in use across Montana.

Producers are encouraged to try new techniques and ideas and talk with neighbors who have successfully installed the practice. Attendance at field tours and soil health conferences can also be a great place to start. Planting a small trial field is also a great way to become more confident with the practice. For more information on cover crops, contact your local MT NRCS office.

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Appendix

Table 5. Cover crop species for use in Montana with dryland seeding rates and depths.

Common Name	Latin Name	Cultivars[1]	Seeds/lb	Full Stand, Dryland Drilled Seed Rate (PLS[2] lb/ac)	Seeding Depth (inches)	Season	Lifecycle[3]
LEGUMES							
Chickpea	*Cicer arietinum*	Desi and Kabuli types	1,750	124.0	1.50	Cool	A
Clover, Balansa	*Trifolium michelianum*		500,000	5.0	0.25	Cool	A
Clover, Berseem (Egyptian)	*Trifolium alexandrinum*	Bigbee, Mulicut, Balady	206,900	8.0	0.50	Cool	A
Clover, Crimson	*Trifolium incarnatum*	Dixie, KY Pride	150,000	10.0	0.25	Cool	A
Clover, Persian (reversed)	*Trifolium resupinatum*		140,000	6.0	0.25	Cool	A
Clover, Red	*Trifolium pratense*	Cinnamon Plus, Cyclone II, Dynamite, Freedom, Kenland, Wildcat	272,000	5.0	0.25	Cool	B, P
Clover, Sweet	*Melilotus spp.*		225,000	4.0	0.75	Cool	B
Cowpea	*Vigna unguiculata*	Iron & Clay, Red Rippers, Black Stallion, Chinese Red	4,700	30.0	1.25	Warm	A
Fava (faba) Bean	*Vicia faba*	small-seeded types	2,066	105.0	1.25	Cool	A
Guar	*Cyamopsis tetragonolobus*	Kinman	13,000	8.0	1.00	Warm	A
Fenugreek	*Trigonella foenum-graecum*		19,000	13.0	0.50	Cool	A
Lentil	*Lens culinaris*	Richlea, Avondale, Viceroy, Imigreen	9,139	55.0	1.50	Cool	A
Mung Bean	*Vigna radiata*	Berken, OK2000	7,300	15.0	1.00	Warm	A
Pea, spring	*Pisum sativum ssp. sativum var. arvense*	Includes both grain and forage pea varieties, including Arvika 4010, Dunn, Maxum, Frost Master, Whistler	2,600	150.0	2.00	Cool	A
Pea, winter	*Pisum sativum subsp. arvense*	Austrian winter pea	4,000	55.0	2.00	Cool	A
Soybean	*Glycine max*		3,000	35.0	1.25	Warm	A
Sunn hemp	*Crotalaria juncea*	Tropic Sun	15,000	15.0	0.75	Warm	A
Vetch, chickling	*Lathyrus sativus*		2,500	55.0	1.00	Cool	A
Vetch, common	*Vicia sativa subsp. sativa*		8,000	25.0	1.00	Cool	A
Vetch, hairy or woolypod	*Vicia villosa subsp. villosa*	Groff, Lana, Purple Bounty, Purple Prosperity, TNT, Villana	12,000	20.0	1.00	Cool	A, B

Common Name	Latin Name	Cultivars[1]	Seeds/lb	Full Stand, Dryland Drilled Seed Rate (PLS[2] lb/ac)	Seeding Depth (inches)	Season	Lifecycle[3]
GRASSES							
Barley, spring	*Hordeum vulgare*		11,400	50.0	1.38	Cool	A
Corn	*Zea mays*	BMR varieties if grazing green	2,500	15.0	1.25	Warm	A
Millet, Foxtail (German)	*Setaria italica*		200,000	8.0	0.50	Warm	A
Millet, Japanese	*Echinochloa esculenta*		140,000	15.0	0.50	Warm	A
Millet, Pearl	*Pennisetum americanum*		80,000	15.0	0.50	Warm	A, P
Millet, Proso	*Panicum miliaceum*		80,000	20.0	0.50	Warm	A
Oat, spring	*Avena sativa*		17,500	50.0	1.38	Cool	A
Oat, black	*Avena strigosa*	Cosague black seeded oat	18,000	60.0	1.38	Cool	A
Rye, Cereal*	*Secale cereale*	Aroostook, Bates, Brasetto, Elbon, FL401, Guardian, Hazlet, Maton, Okon, Rymin, Wheeler, Wintergrazer 70, Wrens Abruzzi	22,000	55.0	1.38	Cool	A
Ryegrass, Annual*	*Lolium multiflorum*	Gulf, KB Supreme, KB Royal	190,000	15.0	0.25	Cool	A
Sorghum	*Sorghum bicolor*		18,000	5.0	1.00	Warm	A
Sorghum / Sudangrass	*Sorghum x drummondii*	GW Cover, Maxi-Sweet, Sweet Six, Yield Max	18,000	15.0	1.00	Warm	A
Sudangrass	*Sorghum bicolor var. sudanense*		25,000	15.0	1.00	Warm	A
Teff	*Eragrostis tef*		1,300,000	5.0	0.38	Warm	A
Triticale, spring	*x Triticosecale*	Trical 141	16,000	60.0	1.40	Cool	A
Triticale, winter	*x Triticosecale*		16,000	60.0	1.38	Cool	A
Wheat, spring	*Triticum aestivum*		17,500	60.0	1.38	Cool	A
Wheat, winter	*Triticum aestivum*		17,500	60.0	1.38	Cool	A
BRASSICAS							
Camelina	*Camelina sativa*		400,000	4.0	0.25	Cool	A
Canola (rapeseed)	*Brassica napus*	Dwarf Essex	140,000	7.0	0.50	Cool	A
Forage Collards or Kale	*Brassica oleracea*	Impact collards, Dwarf Siberian kale	175,000	6.0	0.50	Cool	A
Mustard	*Brassica juncea, Sinapsis alba*		140,000	7.0	0.50	Cool	A
Other brassica hybrids	*Brassica oleracea, B. napus, B. juncea, B. rapa*	Pasja turnip	175,000	6.0	0.50	Cool	A
Radish (deep rooted)	*Raphanus sativus*	Big Dog, Concorde, Control, Control, Defender, Driller, Eco-till, Groundhog, Lunch, Nitro, Sodbuster Blend, Tillage	25,000	10.0	0.50	Cool	A
Turnip	*Brassica rapa var rapa*	Purple top	175,000	6.0	0.50	Cool	B

Common Name	Latin Name	Cultivars[1]	Seeds/lb	Full Stand, Dryland Drilled Seed Rate (PLS[2] lb/ac)	Seeding Depth (inches)	Season	Lifecycle[3]
BROADLEAVES							
Beets, sugar	*Beta vulgaris*		10,000	5.0	0.50	Cool	A
Buckwheat	*Fagopyrum esculentum*	Horizon, Mancan, Springfield	20,000	45.0	1.00	Warm	A
Flax	*Linum usitatissimum*		81,000	20.0	0.75	Cool	A
Phacelia, Lacy	*Phacelia tanacetifolia*		240,000	5.5	0.25	Cool	A
Ramtilla	*Guizotia abyssinica*		150,000	5.0	0.50	Cool	A
Safflower	*Carthamus tinctorius*	Finch, MonDak	15,000	30.0	1.25	Warm	A
Sunflower	*Helianthus annus*	black oilseed	8,000	7.0	0.75	Warm	A

[1]Cultivars are only suggestions, not requirements, and are based on Montana field trials and observations.
[2]PLS = Pure Live Seed = Bulk Seeding Rate x (Purity x Germination)
[3]Lifecycle: A = annual, B = biennial, P = perennial

Table 6. Cover crop species and resource concerns addressed.

Common Name	Reduce Erosion[1]	Increase Organic Matter[1]	Nutrient Cycling[1]	Promote Nitrogen Fixation	Suppress Weeds[1]	Provide Hay[1]	Provide Grazing[1]	Root Depth[2] and Water Use[3]	Reduce Soil Compaction[1]	Seed Size[4]	Salinity Tolerance[1]	C:N Ratio[1]	Attract Beneficial Insects	Mycorrhizal Fungi Association
LEGUMES														
Chickpea	P	F	F	Y	F	G	F	DM	F	L	P	L	Y	Y
Clover, Balansa	F	F	F	Y	F	P	G	SM	F	S	P	L	Y	Y
Clover, Berseem (Egyptian)	P	P	F	Y	F	F	G	MH	F	S	F	L	Y	Y
Clover, Crimson	F	F	F	Y	F	G	F	SM	P	S	P	L	Y	Y
Clover, Persian (reversed)	F	F	G	Y	F	F	G	L	F	S	F	L	Y	Y
Clover, Red	F	F	G	Y	F	G	G	SM	F	S	P	L	Y	Y
Clover, Sweet	G	F	F	Y	G	P	F	MM	G	S	F	L	Y	Y
Cowpea	P	P	F	Y	G	F	F	SL	F	L	P	L	Y	Y
Fava (faba) Bean	P	F	G	Y	P	P	G	SM	F	L	P	L	Y	Y
Guar	P	P	G	Y	P	P	F	SL	F	M	G	L	N	Y
Fenugreek	P	P	F	Y	F	P	P	MM	F	M	P	L	Y	Y
Lentil	P	P	F	Y	P	F	F	SL	P	L	P	L	N	Y
Mung Bean	P	F	G	Y	P	P	G	ML	F	L	P	L	Y	Y
Pea, spring	P	P	F	Y	P	F	F	MM	P	L	P	L	N	Y
Pea, winter	F	F	G	Y	F	G	G	MM	P	L	P	L	Y	Y
Soybean	P	P	F	Y	P-G	F	F	SM	P	L	P	L	N	Y
Sunn hemp	F	F	G	Y	F	P	G	ML	P	M	L	L	Y	Y
Vetch, chickling	G	F	G	Y	G	G	G	SL	F	L	L	L	Y	Y
Vetch, common	F	F	G	Y	F	F	G	MM	G	L	P	L	Y	Y
Vetch, hairy or woolypod	G	F	F	Y	P	F	F	SM	F	M	P	L	Y	Y

Common Name	Reduce Erosion[1]	Increase Organic Matter[1]	Nutrient Cycling[1]	Promote Nitrogen Fixation	Suppress Weeds[1]	Provide Hay[1]	Provide Grazing[1]	Root Depth[2] and Water Use[3]	Reduce Soil Compaction[1]	Seed Size[4]	Salinity Tolerance[1]	C:N Ratio[1]	Attract Beneficial Insects	Mycorrhizal Fungi Association
GRASSES														
Barley, spring	G	G	F	N	G	F	F	MM	F	M	G	H	N	Y
Corn	G	G	G	N	P-G	F	G	DH	G	L	P	H	N	Y
Millet, Foxtail (German)	G	G	F	N	G	G	F	SL	F	S	F	M	N	Y
Millet, Japanese	G	H	F	N	H	G	F	MM	F	S	M	M	N	Y
Millet, Pearl	G	G	F	N	G	G	F	SL	F	S	F	M	N	Y
Millet, Proso	G	G	F	N	G	G	F	SL	F	S	F	M	N	Y
Oat, spring	G	G	F	N	F	G	F	MM	F	M	P	M	N	Y
Oat, black	G	G	F	N	G	G	G	MM	F	M	P	M	N	Y
Rye, Cereal*	G	G	G	N	G	G	G	MM	F	M	F	H	N	Y
Ryegrass, Annual*	G	G	G	N	G	F	G	SM	G	S	F	H	N	Y
Sorghum	G	G	G	N	G	G	G	MM	G	M	F-G	H	Y	Y
Sorghum / Sudangrass	G	G	G	N	G	G	G	MM	G	M	F-G	H	Y	Y
Sudangrass	G	G	G	N	G	G	G	MM	G	M	F-G	H	Y	Y
Teff	G	G	F	N	F	F	F	SM	F	S	F	H	N	Y
Triticale, spring	G	G	G	N	G	F	F	SM	G	M	G	H	N	Y
Triticale, winter	G	G	G	N	G	F	F	SM	G	M	G	H	N	Y
Wheat, spring	G	G	G	N	G	F	F	MH	F	M	P	M	N	Y
Wheat, winter	G	G	G	N	G	G	F	MH	F	M	P	M	N	Y

Common Name	Reduce Erosion[1]	Increase Organic Matter[1]	Nutrient Cycling[1]	Promote Nitrogen Fixation	Suppress Weeds[1]	Provide Hay[1]	Provide Grazing[1]	Root Depth[2] and Water Use[3]	Reduce Soil Compaction[1]	Seed Size[4]	Salinity Tolerance[1]	C:N Ratio[1]	Attract Beneficial Insects	Mycorrhizal Fungi Association
BRASSICAS														
Camelina	F	F	F	N	F	P	F	ML	F	S	F	M	Y	N
Canola (rapeseed)	F	F	G	N	P-G	P	F	MM	G	S	G	L	Y	N
Forage Collards or Kale	P	P	G	N	F	P	G	DH	G	S	F	L	N	N
Mustard	P	P	G	N	G	P	G	DM	G	S	F	L	Y	N
Other brassica hybrids	P	P	G	N	F	P	F	MM	F	S	G	L	Y	N
Radish (deep rooted)	P	P	G	N	F	P	G	DH	G	M	P	L	Y	N
Turnip	P	P	G	N	F	P	G	MH	G	S	P-F	L	N	N
BROADLEAVES														
Beets, sugar	P	P	G	N	F	P	G	DH	G	L	G	L	N	Y
Buckwheat	G	F	G	N	G	P	P	SL	P	M	P	L	Y	Y
Flax	F	F	F	N	P	P	P	SM	P	S	P	H	Y	Y
Phacelia, Lacy	F	F	F	N	F	P	P	SL	P	S	P	M	Y	Y
Ramtilla	F	F	F	N	F	P	P	MM	F	S	Unknown	M	Y	Y
Safflower	F	F	G	N	F	F	G	DH	F	M	F	M	Y	Y
Sunflower	F	F	G	N	F	P	G	DM	F	M	F	M	Y	Y

[1] Ratings: L = Low, M = Medium, H = High, P = Poor, F = Fair, G = Good

[2] Rooting Depth: S = Shallow rooted (6 - 18 inches), M = Medium rooted (18 - 24 inches), D = Deep rooted (24+ inches)

[3] Water Use: L = Low water use, M = Medium water use, H = High water use

[4] Seed Size: L = Large (0 - 10,000 seeds/lb), M = Medium (10,000 - 25,000 seeds/lb), S = Small (> 25,000 seeds/lb)