SDSU Extension

Transitioning to Soil Health Systems in Eastern South Dakota

Intended for beginners: Where do I start?

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SOUTH DAKOTA STATE UNIVERSITY®
AGRONOMY, HORTICULTURE & PLANT SCIENCE DEPARTMENT

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Adopting Soil Health Principles on your farm with the emphasis on no-till as the base practice:

Tillage seems to be a rite of passage for most young people learning to farm. Cultivating the soil is an ancient practice that had many purposes that included loosening the soil for seed placement, weed control and nutrient incorporation. In modern agriculture, we have technology that enables us to place seeds without loosening the soil, herbicides that have high probabilities of success and chemical technologies and knowledge to protect surface applied nutrients and a realization of soil microbial and plant interactions that improve nutrient uptake. The need for tillage is gone, yet society keeps producing large, powerful tractors to pull very large cultivators. W.C. Lowdermilk, in Conquest of the Land Through 7000 Years said "any nation's most valuable resource is the soil. Food production and availability leads to stability and opposite to chaos and war". Protecting our soil resource has many sustainable benefits and is accomplished by adopting the soil health principles for farm management.

1. Soil Armor

Maintaining soil covering with plant residues known as soil armor stops wind and water erosion. Soil structure is the clumping of aggregates of sand, silt, clay and organic matter into larger conglomerates important for air, water and nutrient exchange. Unprotected soil is vulnerable to rain drop impacts that destroy soil structure and wind that dries the soil therefore making the soil structure vulnerable to saltation degradation and wind erosion (Renard, et al., 2011).

2. Reducing and stopping Soil Disturbance (tillage)

Stopping tillage reduces carbon losses from soil (Reicosky, etal., 1997). Soil carbon is the foundation for all soil processes whether it be physical, chemical or biological. Soils that are higher in carbon have improved structure created from microbial processes, provide a storage home for other nutrients and energy source for micro-organisms that cycle plant available nutrients. Stopping tillage will slow and in some cases mitigate greenhouse gases, therefore slowing global warming and climate change. One percent increase in soil carbon enables the soil to hold nearly one inch of additional water (Hudson, 1994).

3. Enable a living root throughout the growing season.

Soil aggregation, the clumping of sand, silt, clay and organic matter is greatly improved by leaving the aggregates in place and not destroying them with tillage. Soil aggregation occurs at the surface of a living root where the plant and soil microbes conduct the "great exchange" of carbon based exudates for nutrients supplied by specific soil microorganisms (Jacoby etal., 2017). Tillage destroys most all that is gained by the plant's living roots in one growing season. It is very important to have a living root in the soil as much as possible to promote soil aggregation, soil structure formation and enhanced nutrient cycling. Change sentence to: Nutrient cycling is important for sequestering and holding inorganic nutrients as well as solubilizing unavailable nutrients and transforming organic nutrients into plant available forms. The growing season should be mostly all green. The native prairie consisted of plant species that grew early and late as well as throughout the growing season.

4. Crop plant diversity.

Designing crop rotations that include all of the crop types at least once in the rotation is very important. These included cool and warm season grasses as well as broadleaf species. Corn is a warm season grass and soybeans is a warm season broadleaf. The cool season plants are missing in this "perceived rotation", which some say is not a rotation because of this issue and others refer to the corn/soybean rotation as conventional agriculture which is lacking diversity (Mitchell, et al. 2018). Cereal grains and cover crops give us the opportunity to grow more cool season plant species. The importance of crop diversity is to help use excess soil water, keep soil microbial activity heightened for increased nutrient cycling, soil aggregation and soil structure formation. All of these benefits result in increased soil temperature moderation and soil air exchanges. Increasing crop rotation diversity and cover crop inclusion enables more opportunities for livestock integration on croplands.

5. Livestock Integration on croplands

Livestock integration on croplands is important for nutrient cycling of above ground crop residues. While some plant nutrients can leach from plants after desiccation such as potassium, nitrogen and phosphorus are trapped in plant cells and are somewhat locked in the cells as natural hardening of cell walls occur. Grazing fresh or recent living plant nutrients helps to convert otherwise unavailable plant nutrients into organic and eventually more available forms. Above ground plant residues have a poor conversion rate to stable soil organic carbon forms (Berhongaray, etal. 2019). Livestock conversion of above ground carbon to organic forms in manure is a strong improvement when compared to losing above ground carbon to the atmosphere. While livestock are not an absolute requirement for soil health as the other four principles, proper grazing management of crop residues can greatly improve soil health benefits.

Soil Health Principles Summary

Adopting the soil health principles helps maintain old root channels and promotes soil macro-pore formation. Water infiltration and air exchange improve therefore promoting soil temperature moderation and thus reducing soil erosion and unnecessary nutrient losses. No-till production practices allow the soil microbial food web made up of fungi, bacteria and earthworms to proliferate. Earthworms do the tillage and help make new soil. Earthworms are ecosystem engineers that do tillage the natural way. Ecosystem environments are improved when soil health practices are adopted. Less run-off and erosion lead to less nutrients in our streams, rivers and lakes. Air quality is greatly improved during dry climatic periods because less dust is in the air. Inorganic nutrients that are harmful to the environment are less predominant because organic forms are more prevalent in soil health systems. Lastly, soil health systems save time, fuel and money. Less field trips require much less fossil fuel and the need for tillage equipment investments and maintenance are greatly reduced.

These are the reasons to adopt soil health systems! While stopping tillage is not the only crop production practice to change, adapting the soil health principles leads to many more benefits that ensure no-till success. Stopping tillage is only one of the 5 soil health principles.

How to transition into soil health systems with no-till as the base practice:

Residue management (previous crop)

Evenly spread crop residues allow for more consistent soil moisture and temperatures across the field and vertically in the soil profile (Photo 1).

Photo 1 shows evenly spread soybean residues completely covering the soil surface demonstrating optimal soil surface covering (armor).

Properly managed previous crop residues promotes more even seed placement at planting resulting in more even plant emergence, growth and root exploration in the soil.

Residue managers operating too deep un-cover soils with higher moisture and lower soil temperatures that make optimal seed placement more difficult.

Residue managers are important when previous crop residues are not spread evenly. Set residue managers only to move residues which are unevenly spread.

Residue managers set too deep are actually doing tillage which cuts off pores connected to the soil surface. This is a form of vertical tillage and inhibits air movement around the seed zone. Soil crusting and erosion conditions are increased.

Maintaining the previous crop residues above the soil surface allows for more gradual and consistent decay of organic matter at the soil surface. Do not use chopping corn heads that lay a mat of corn residue on the soil surface and allows wind to blow off the field.

Well managed no-till systems do not need rolling as it flattens and breaks up previous crop residues creating mats on the soil surface and enables blowing off the field (Photo 2).

Photo 2 shows a road ditch filled with corn stalks blown off the adjacent field because of excessive loosening and flattening of soil surface from rolling.

Row unit coulters are only required when planting in heavy crop residues and only intended to cut a slot prior to seed disc openers and not to do tillage. Row unit coulters designed to do tillage incorporate crop residues, bring up wetter soils and interject air pockets into the seed zone that inhibit seed emergence and even plant stand establishment. Row unit coulters disc thickness should be as narrow as possible.

Soil Nutrient assessment

Immobile nutrients, such as phosphorus can be broadcast if soil tests are medium or higher. Research from many states has shown similar crop yield responses between banded and broadcast phosphorus and potassium (Figure 1).

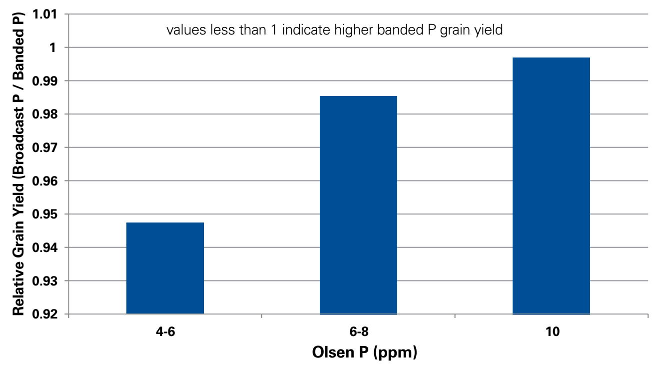

Figure 1. Relative no-till corn grain yield of broadcast and banded P comparisons at 9 locations in SD in 1998 and 1999. A. Bly, 2014.

When soil test P is very low and low, band some P on or near the seed. Maintaining soil test P levels in the medium to high range (8-15 ppm Olsen, 10-20 ppm Bray) is a good practice for optimal crop productivity. Some soil health producers (>20 years of following soil health principles) are reporting that soil test P levels are not a concern as the soil microbial influence helps to maintain optimum P availability to the crop plant from mineral forms of P.

Nitrogen stabilizers containing NBPT active ingredient might be needed for surface broadcast nitrogen if precipitation is infrequent.

Adding extra nitrogen (30 lbs N/a) for developing no-till fields up to 8-10 years is a good practice since rapid building of carbon will require additional nitrogen to satisfy the soil carbon/nitrogen ratio (Figure 2). Cover crop sequences with legumes or livestock grazing can also provide the extra nitrogen if managed well.

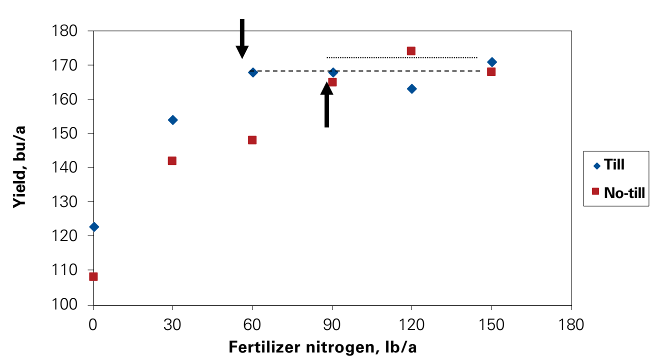

Figure 2. Influence of nitrogen and tillage on corn grain yield, Beresford, SD, 1998.

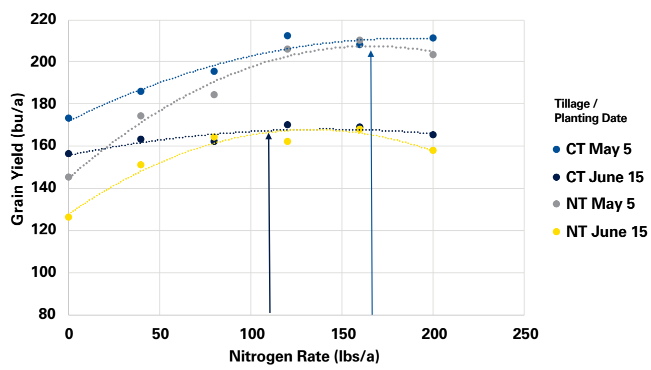

Figure 3. Corn nitrogen response from conventional and 24 year no-till at Southeast Research Farm near Beresford, SD.

The need for extra fertilizer N in long-term no-till fields or diverse rotations with cover crops does not occur (Berg, 2016, Figure 3). Therefore, adopting soil health principles will hasten the need for extra N after converting to no-till management.

Nitrogen application on soils over vulnerable water aquifers should be delayed as much as possible and applied as closely to plant uptake.

Apply sulfur when soil tests (SO_4-S, 0-2ft) are below 40 lbs/a especially on deep well drained and sandy soils. Sulfur is not as critical on glacial till soils when naturally occurring gypsum layers occur within 2 feet of the soil surface. Sulfur application rates for corn are 15-20 lbs/a and soybeans and wheat are 10-15 lbs/a.

Seed selection

Choose corn hybrids with good emergence and root system ratings. These characteristics will help when fields conditions are suboptimal and planting dates are impending.

Crop variety selection should not be overlooked and should consider top producing varieties with good agronomic traits.

Producers following a diverse crop rotation enables them to choose corn hybrids and soybean varieties with less traits, because the pest cycles are disrupted. Conventional corn and soybeans are good examples for reducing seed costs because the crop rotation has reduced the intensity of the pest cycles. However, rotating conventional seed sources with genetic traits is recommended to create diversity for optimum pest control.

Planter Adjustments

Sharp disc openers on the planter or drill are very important for optimal residue cutting and reduced hair pinning of residues. Some producers that are just beginning soil health systems replace their openers very often, while producers that have been following soil health practices for many years (>20) have noticed their disc openers get sharper with age in the finer textured soils.

Proper down pressure (350-400 lbs/row) is an important requirement for no-till planting into diverse residue covers. Tool bar weight should be heavy enough to hold planting units down and exert down pressure to the ground for residue cutting and correct seed placement. Too much down pressure on furrow closing wheels will cause row units to rise out of the soil decreasing the residue and soil penetrating capability by offsetting the weight placed on the row unit.

Automatic row unit down pressure is a very nice equipment option. However, stopping the tractor and getting out to do a field check is vitally important. Check for consistent seed depth, seed furrow sidewall compaction (Photo 3), seed furrow covering and too much down pressure. The row unit depth gauge wheels should be firmly on the soil and somewhat difficult to turn by hand.

Photo 3 shows a single corn plant with half of the soil removed to show the roots and side wall compaction revealing pancake roots fanning out along the length of the seed trench.

Seed firmers are required for consistent seed depth that ensures even plant emergence.

Furrow closers are very important for placing crumbled soil in the seed trench and removing side-wall compaction. Minimal down pressure is required to accomplish this task.

Drag chains can improve the activity of the furrow closers by moving a small amount of soil into the seed trench to ensure the seed is covered and will not dry out.

Planter hitch height should be adjusted to enable tool bar tilt slightly to the rear. Parallel row unit linkages tend to pull the back of the row unit up when level or tilted forward.

Crop rotations

The main feature of crop rotations for successful soil health systems should include all of the crop types as a cash crop or a cover crop. The crop types are: warm season grasses and broadleaves and cool season grasses and broadleaves. The corn and soybean rotation does not include a cool season grass or broadleaf. This is why we are experiencing increasing problems with higher water tables. The water use cycle of the corn and soybean rotation only uses considerable water from June to September.

Examples of Crop rotations that lead to rapid soil health improvement:

1. Corn (cereal rye CC) – Soybean - Small grain (CC)
2. Corn (cereal rye CC) - Soybean
3. Corn- corn (cereal rye CC) – Soybean - Small grain (CC) - Soybean
4. Corn after alfalfa, followed with crop diversification and cover crops.

Notes: (CC = cover crop, cereal rye CC = flown into corn at maturity)

Cereal grains must be followed with cover crop.

Winter annual grass cover crops (cereal rye, winter wheat or triticale) are great choices for water management tools. These plant species start growing very early in the spring and can be terminated if precipitation is infrequent or allowed to grow if abundant.

Enhancing crop rotations for quicker soil health improvement and carbon sequestration:

Photo 4 shows crop residues of a previously cropped corn field in March, after cereal rye was flown in the previous Fall at corn physiologic maturity.

1. **Corn** (Cereal rye CC) (Photo 4)
   - **Soybeans** planted green into cereal rye
     - **Small grain** (CC including winter annual grass)

   Corn (kill winter annual grass 2 weeks prior to planting corn into brown residue)

2. **Corn** (cereal rye CC)
   - **Soybean** planted green into cereal rye (cereal rye seeded after soybeans)

   Corn (kill cereal rye 2 weeks prior to planting corn)

3. **Corn** (cereal rye CC)
   - **Corn** (kill cereal rye 2 weeks prior to planting corn) (cereal rye CC)
     - **Soybean** planted green into cereal rye (experiment with clovers after soybeans)
       - **Small grain** (CC including winter annual grass)
         - **Soybean** planted green into winter annual grass (cereal rye seeded after soybeans)

   Corn (kill cereal rye 2 weeks prior to planting corn)

Soil Compaction: the hidden yield robber

Equipment efficiency has led to implement weights greatly exceeding hard surface road restrictions. The ideal soil is 50% solids (minerals and organic matter) and 50% voids (25% water and 25% air). Healthy plants need aerated soil for root respiration and nutrient uptake to occur. The load bearing strength of the soil is greatly increased as soil aggregation and structure develop. However, there is a limit beyond which the soil cannot resist downward pressure from exceedingly heavy implements.

The combine, grain carts and trucks pose the greatest

Photo 5 shows a very large grain cart with a single axle and large tires.

threats to compacting the soil. An empty weight of a 1300 bu grain cart (picture) is 25,400 pounds (Photo 5). The corn (1300 bu) weighs 72,800 pounds, therefore, the total weight of the grain cart is 98,200 pounds. Since the grain cart has a hitch weight of 6,600 pounds, the total weight on the single axle is 45.8 tons (91,600 lbs). This weight greatly exceeds what any soil can support. Scientific research has shown that axle loads exceeding 10 tons reduce yields by 15% the following year and can decrease yields 3-5% up to the tenth year. https://extension.psu.edu/avoiding-soil-compaction

Avoiding soil compaction is difficult since most all field equipment exceeds the 10 ton/axle recommendation. Limiting trips across the field is very important as well as knowing when to stay off the soil. The great size and power of current tractors and combines has enabled field traffic far beyond the point when soils are vulnerable to compaction. Knowing the soil moisture limit for increased compaction is very difficult. Not

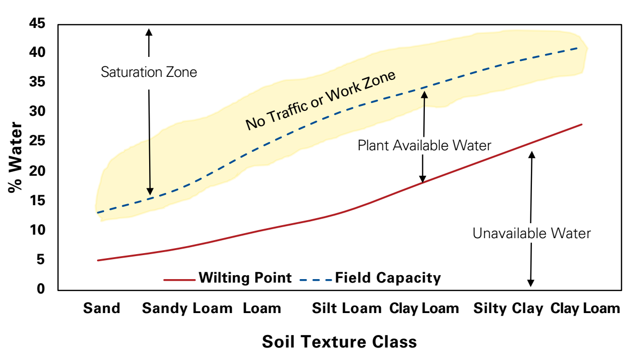

Figure 4. Influence of soil texture class on moisture content when detrimental soil compaction will occur.

many quick tests are available to help make this determination and are confounded by differing soil textures. Figure 4 shows how soil texture influences the levels of soil moisture when soil compaction is the greatest threat, as shown in the yellow area.

Measuring soil compaction is difficult due to complications caused by variable soil moisture, soil texture variability within the field, naturally occurring soil horizons higher in clay content and person to person variability. Soil bulk density measurement is the surest method to determine soil compaction, however are very time consuming and requires some specialized equipment. Other methods for assessing compaction are to dig a hole with a shovel and visually assess soil by pinching soil clods to see hardness, use a steel tiling rod to push down through the soil to find resistance or purchase a penetrometer specifically made for measuring soil resistance. The penetrometer measures soil pressure by pushing a rod into the soil. Similar variability issues influence the penetrometer as previously discussed. However, if multiple measurements are obtained, the penetrometer measurement variability can be reduced. Most all root growth is restricted at 300 psi (Figure 5).

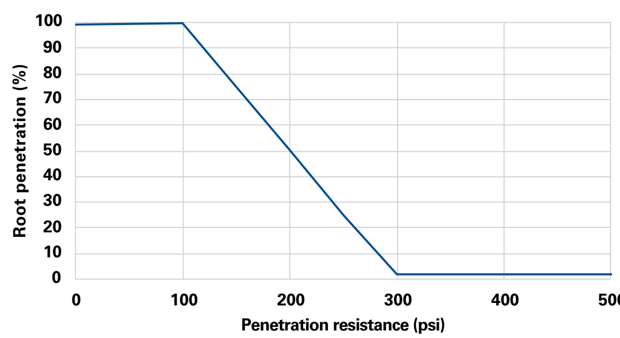

Figure 5. Penetration resistance and root penetration resistance. Adapted from Taylor et al., Soil Science 102:18-12.

Solutions to reducing Soil Compaction.

- Investigate soil moisture and determine if field operations are appropriate.
- Determine if delaying field operations are possible given future chances of soil drying or freezing.
- Limit loads in combine grain tank and grain cart. Unload often.
- Evaluate field size and layout and develop a plan that allows for where heavy loads are often occurring and install field roads or access driveways to accommodate this commonly reoccurring operation.

- Convert heavy traffic lanes or field roads to grass for wildlife and/or pollinators.
- Strive for increased cover crop frequency to help stabilize and improve soil structure.
- Remember that large equipment can extensively damage soil properties that could take years to overcome.

Cover Crops

Reasons for:

- Improve soil aggregation, structure and macro-pores enabling stronger air and water exchange.
- Recycle inorganic nutrients to organic forms thus preventing losses out of the root zone and field.
- Alleviate soil compaction and increase weight bearing strength of the soil.
- Capture sunlight and use excess water to increase soil carbon.
- Livestock forage.
- Protect soil surface – amour preventing water and wind erosion.
- Provide living root for improved soil microbe activity resulting in soil aggregate and structure formation.
- Moderates soil temperatures.
- Excellent soil water management tool.

Cover Crop Management suggestions:

There is no standard cover crop mix that can be recommended to all producers, as each grower has unique circumstances with different production environments, soil types, management techniques and goals. Consider the following management suggestions.

Goal: Always begin with the end in mind. Soil health, weed suppression, nutrient capture, soil moisture management and grazing may all be common reasons to plant a cover crop. Focus on your own objectives when creating a cover crop plan. The SD Cover Crop Poster shows each species purpose, seeding rates and planting depths (Table 1).

Crop rotation: Consider the previous and future crops; it is generally recommended to plant cover crops of diverse growth habits in regards to the following cash crop, i.e., primarily broadleaves prior to grass cash crops, and vice versa.

Herbicide history: Consider your crop rotation and livestock forage restrictions of herbicides previously applied; this includes herbicides applied before and after the cover crops this season as well as the previous season.

Insurance and Farm Service Agency (FSA) Guidelines: Be sure to check with your insurance agent and FSA representative on all details regarding the seeding of your cover crop. Frequently asked questions and answers regarding insurance can be found on the Risk Management Agency (RMA) website.

Seed availability and price: Planning ahead and locating your cover crop seed ahead of time is a good idea. While selecting your cover crop species, consider getting the price sheets so you can know how much your blend will cost. Making your own blend and experimenting from year to year is a good approach to designing the blend that is best for you. Although most producers want to keep costs low, do remember that forage crops and/or improved soil health does come at a price, and some investment will be necessary.

Termination: Many annual cover crops will winter kill, however winter annuals such as cereal rye, winter wheat, and triticale do not. Other species have hard seed that can stay dormant for a prolonged period such as ryegrass, vetch, clovers and brassicas. This does not eliminate these crops as an option; it simply requires prompt spring attention and management as these crops may be of great value to utilize excess moisture in a potentially wet spring, provide soil surface cover for weed control or build soil nitrogen for successive crops.

Weed Control: Diverse specie cover crop mixes make it nearly impossible to chemically control weeds during the growth of the cover crop. If a mix is well-planned and grown under ideal growing conditions, weed competition is not typically an issue. However, if a particular weed is of concern, this should be considered before selecting cover crops. Cereal rye (a winter annual) is known for its inherent allelopathic characteristics, which is the ability to suppress weeds by the production of a biological chemical substrates that are harmful to other surrounding plant species. Other grasses as well as sprawling or ground covering broadleaf crops (such as vetches, or radish and turnip) can aid in weed suppression by keeping soils covered.

Summary

Converting farming operations to soil health systems is critically important to ensure economic and environmental sustainability as well as food security in our world with rapidly increasing populations. Scientific and on-farm testimonial evidence presenting multiple benefits of soil health systems are widely available. The common statement from many producers "this won't work on my farm" is not a valid response. Soil health producers can be found in all states, geographic regions, soil resource areas, food productions systems and economic demographics, demonstrating that soil health management is a very real farm management system. For more information, contact SDSU Extension, SD Soil Health Coalition, SD No-Till Association, SD Grasslands Association and USDA-SD NRCS.

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USDA/NRCS, Resources for Cover Crops in South Dakota. Table 1. Cover crop – Common Species and Properties.

Table 1: Cover Crop - Common Species and Properties

Cover Crop	Erosion Reduction	Increase soil organic matter	Capture, recycle, redistribute nutrients in the soil profile	Promote biological nitrogen fixation	Weed suppression	Provide supplemental hay	Provide supplemental grazing	Rooting Depth/Plant Water Use /1	Minimize / reduce soil compaction	Seed size (Large or Fine)	Crop Type and Seeding Dates /2 /3	Full Seeding rate, lbs/acre /4	Seeding depth, inches	Salinity tolerance	C:N Ratio	Attract Beneficial Insects	Mycorrhizal fungi association
Alfalfa	G	G	G	Y	G	F	F	DH	G	F	CB	6.5	.25 - .75	P	L	Y	M
Alsike clover	G	F	G	Y	G	F	F	SL	P	F	CB	3	.25 - .75	P	L	Y	M
Annual Oregon ryegrass	F	G	G	N	F	G	G	MM	P	F	CG	15	.5-1.5	F	M	Y	L
Barley	G	G	F	N	G	F	F	MM	F	L	CG	50	.75 - 2	G	M	Y	M
Brassica hybrids	F	F	G	N	G	F	F	MM	G	F	CB	7	.25 - .5	G	L	Y	N
Buckwheat /5	G	F	G	N	G	P	P	SL	P	F	WB	50	.5 - 1.5	P	L	Y	N
Canola	F	F	G	N	P-G**	F	F	MM	G	F	CB	5	.25 - .75	G	L	Y	N
Chickling vetch	G	F	G	Y	F	F	F	SL	F	L	CB	50	.5 - 1.5	P	L	Y	M
Common vetch	G	F	F	Y	P	F	F	SM	F	L	CB	25	.5 - 1.5	P	L	Y	M
Corn	G	G	G	N	P-G**	F	F	DH	G	L	WG	12	1-1.5	P	H	N	H
Cowpeas	P	P	F	Y	G	F	F	SL	F	L	WB	30	1 - 1.5	P	L	Y	M
Crimson clover	G	F	G	Y	G	G	G	SM	F	F	CB	15	.25-.75	P	L	Y	M
Dry beans	P	P	F	Y	G	F	F	SL	F	L	WB	30	1 - 1.5	P	L	Y	M
Ethiopian cabbage	F	F	G	N	F	F	F	MM	G	F	CB	5	.25 - .75	G	L	Y	N
Flax	F	F	F	N	P	P	P	SM	P	F	CB	30	.25-.75	F	H	Y	H
Forage sorghum (includes sudan hybrids)	G	G	G	N	G	G	F	MM	G	L	WG	15	.5 - 1.5	F	M	Y	H
Grain sorghum	G	G	G	N	G	G	F	MM	G	L	WG	5	.5 - 1.5	F	M	Y	H
Hairy vetch	G	F	F	Y	P	F	F	SM	F	L	CB	15	.5 - 1.5	P	L	Y	M
Kale	F	F	G	N	G	F	F	MM	G	F	CB	4	.25 - .5	G	L	Y	N
Lacy Phacelia	G	G	G	N	G	P	P	DH	G	F	CB	4	.25 - .5	P	L	Y	M
Lentils	P	P	F	Y	P	F	F	SL	P	F	CB	30	1-1.5	P	L	Y	M
Millet	G	G	F	N	G	G	F	SL	F	F	WG	25	.25-.75	P	M	N	H
Mustard, oriental or brown	F	F	F	N	G	F	F	MH	F	F	CB	6	.25 - .75	P	M	Y	N
Mustard, tame yellow	F	F	F	N	G	F	F	MH	F	F	CB	12	.25 - .75	P	L	Y	N
Oats	G	G	F	N	F	G	F	MM	F	L	CG	70	.5 - 1.5	F	M	N	M
Peas	P	P	P	Y	F	G	F	SL	P	L	CB	70	1.5 - 3	P	L	Y	M
Radishes	P	P	G	N	G	P	G	DH	G	F	CB	8	.25 - .5	P	L	Y	N
Rapeseed	F	F	G	N	F	F	G	MM	G	F	CB	5	.25 - .75	G	L	Y	N
Red clover	G	F	G	Y	G	F	F	SL	P	F	CB	5	.25 - .75	P	L	Y	M
Safflowers	F	F	G	N	F	P	P	DM	F	L	WB	30	.5-1	F	M	Y	M
Soybeans	P	P	F	Y	P-G**	F	F	SM	P	L	WB	35	1-1.5	P	L	Y	M
Spring wheat	G	G	G	N	G	F	F	MH	F	L	CG	60	.5 - 1.5	F	M	Y	M
Sudangrass	G	G	G	N	G	G	G	MM	G	L	WG	20	.5 - 1.5	F	M	Y	H
Sugar beets	P	P	G	N	F	P	G	DH	G	F	CB	4	.25 - .5	G	L	N	N
Sunflowers	F	F	G	N	F	P	G	DM	F	L	WB	7	.5-1	F	M	Y	M
Sunn hemp	F	F	F	Y	G	P	P	DM	F	L	WB	15	1.5-2	P	L	Y	Y
Sweet clover	G	F	F	Y	F	P	F	MM	F	F	CB	4	.25 - 1	F	L	Y	M

Cover Crop	Erosion Reduction	Increase soil organic matter	Capture, recycle, redistribute nutrients in the soil profile	Promote biological nitrogen fixation	Weed suppression	Provide supplemental hay	Provide supplemental grazing	Rooting Depth/Plant Water Use /1	Minimize / reduce soil compaction	Seed size (Large or Fine)	Crop Type and Seeding Dates /2 /3	Full Seeding rate, lbs/acre /4	Seeding depth, inches	Salinity tolerance	C:N Ratio	Attract Beneficial Insects	Mycorrhizal fungi association
Tall wheatgrass	G	G	G	N	G	G	G	DH	F	L	CG	13	.25 - 1	G	H	N	M
Teff grass	F	G	F	N	F	G	F	SM	P	F	WG	5	.13 - .25	P	M	N	N/A
Triticale	G	G	G	N	G	F	F	MH	F	L	CG	60	.5-1.5	G	M	Y	M
Turnips	P	P	G	N	G	P	G	DH	G	F	CB	4	.25-.5	P	L	Y	N
White clover	G	F	G	Y	G	F	F	SL	P	F	CB	1.5	.25 - .75	P	L	Y	M
Winter camelina	F	F	G	N	F	P	P	ML	G	F	CB	3	.25-.5	P	L	Y	N
Winter wheat or rye	G	G	G	N	G	F	F	MH	F	L	CG	60	.75 - 2	G	M	Y	M

/1 Rooting Depth/Water Use

SL = Shallow rooted/Low water use
SM = Shallow rooted/Medium water use
SH = Shallow rooted/High water use
ML = Medium rooted/Low water use
MM = Medium rooted/Medium water use
MH = Medium rooted/High water use
DL = Deep rooted/Low water use
DM = Deep rooted/Medium water use
DH = Deep rooted/High water use

/2 Crop types

CG = cool season grass
CB = cool season broadleaf
WB = warm season broadleaf
WG = warm season grass

Shallow = 6-18 inches
Medium = 18-24 inches
Deep = 24+ inches

Ratings

L= Low
M = Medium
H = High
Y = Yes
N = No or None
N/A = Not Available
G = Good
F = Fair
P = Poor

* Variable depending on seed size and row spacing
**Poor weed competitor, but herbicide-tolerant varieties are available.

/3 Seeding Dates

November 1 through May 15 – predominantly cool-season species
May 15 through August 1 – predominately warm-season species
Seeding dates fluctuate annually. The dates listed about are averages that maybe changed 10 days in either direction depending on current climatic conditions.

/5 Buckwheat contamination

To reduce chances of buckwheat contamination in wheat do not rotate to wheat for grain for 2 years.

/4 Full Seeding rates

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