King's AgriSeeds Inc.

COVER CROP PROGRAM

Designing Cover Crop programs for your farming system.
Proven Mixtures, Diverse Species, Experienced Support

Understanding Cover Crops, Benefits, Selection and Establishment

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Introduction

Your most valuable resource on your farm is your soil. Cover crops slow erosion of that resource, improve its tilth, feed its microbiological life and improve water infiltration rates and water holding capacity by creating root channels and increasing or sequestering carbon in the soil in the form of organic matter; they enhance nutrient cycling and help break pest cycles, they can smother weeds and also can be used to attract pollinators and other beneficial insects. Planting cover crops is a proactive and crucial step to take in managing your rotation for sound soil management and accumulate benefits for long-term soil stewardship.

Long term cover crop use can increase yields, save on nitrogen costs over time and lead to a more profitable system. Utilizing cover crops takes a new mind set and management to fit them into your rotation.

There are different cover crops for varying soil types, climate and terrain. There are covers to fit into the rotation, in the most demanding large scale corn-soybean rotations or smaller high maintenance diverse vegetable production systems. Many cover crops can also be utilized as forages and thereby extend grazing systems or can be utilized as green chop, hay or silage.

The genetic resources of cover crops have vast and often untapped potential. Adaptability and versatility of the cover crop is an important aspect to supplement your rotation improving the soil for profitable long-term production. Growing cover crops helps to set the stage by building up nutrients and improving soil structure and permeability. Cover crops do have the potential to enhance tillage, no-tillage and minimum-tillage systems.

The key to understanding cover crops is not necessarily understanding what is seen above ground, but rather understanding what is unseen below the soil surface. A robust and extensive root system is a major key to the benefits of growing cover crops. The plant's root-zone environment is the most active microbial site in the soil. Keeping the soil covered and active, with a living root zone more months out of the year, leads to long term soil improvements, productivity and profitability. Cover crops add the crucial element of biodiversity.

King's Agriseeds has cover crops to fit into your cropping system, legumes to fix nitrogen, small grains and brassicas to recycle nutrients, improve soil tilth; build soil organic matter and help break pest cycles. We have diverse cover crop mixes to fit into various growing zones. Check our cover cropping brochure and ask our reps to get the details of how to best fit cover crops into your particular cropping system and growing zone.

Planting note/Herbicides: The cover crop you select may not be compatible with your current herbicide program. Make sure you refer to information on susceptible plants and residual times for herbicides used in fields that will be planted with a cover crop.

Cover Crop Terminology

Cover Crops: Cover crops are those crops that are planted to provide a cover for the soil; they may be grown between orchard trees, or in fields between cropping seasons regardless of whether they are later incorporated. They are grown as a cover primarily as a biological soil conservation tool to prevent soil erosion by water and/or wind; they also foster multiple benefits in a farming system. They are typically planted before and after the main designated cash crop in a rotation. Cover crops may be used as a ground cover or mulch, green manure, nurse crop, or a smother crop. When crops are grown as forage or food for animal and human consumption, they are not necessarily termed a cover crop but they still provide the benefit of keeping the soil covered with a living crop. The cover crops can be annual, biennial, or perennial species, including legumes, grasses and the brassicas. They can benefit the crop that follows and improve and protect the soil.

Green Manure: Any crop that is grown and incorporated into the soil while it is green or soon after flowering which can improve the soil, especially with the addition of organic matter. Some of the most important green-manure crops are hairy vetch, rye, crimson clover, sweetclover and alfalfa. Buckwheat, lespedeza, cowpeas, soybeans, ladino clover, and field peas are also used in limited areas. On a dry-matter basis, Hairy vetch, Austrian winter peas, field peas, and alfalfa green manures typically contain 3 to 4 per cent nitrogen, other legumes typically contain 2 to 3.5 per cent, and the cereal plants and ryegrass 1.2 to 1.4 per cent. The average availability of nitrogen in green-manure material turned under is typically about 40 to 60 per cent of the initial amount. Green manure was once the conventional method of supplying nitrogen to crops and was practiced widely before commercial nitrogen fertilizer became available.

Catch Crop: When cover crops are planted to reduce nutrient leaching they are termed “catch crops”. These are cover crops planted after the cash crops are harvested or after legume plow downs. They are also planted in late summer or early fall to trap nutrients from freshly spread manures. They are grown to take up and hold the nutrients in their tissues or "catch" the nutrients from the soil, especially nitrogen that may otherwise be leached lower in the soil profile and lost below the active crop root zone. Growing a cover crop as a “catch crop” prevents the nutrients from leaching out of the upper soil during such times as between fall harvest and spring planting, when the soil is typically left bare without cover. Catch crops, capture, store and then slowly release nutrients after they are terminated the following spring. Soils are particularly vulnerable to nutrient leaching due to the heavy fall and spring rains and/or snow melt that occurs when soil is left uncovered after the cash crop harvest and before the next spring crop is growing. Catch crops may also be planted as a “substitute crop" to “catch” applied nutrients when it is too late in the season to plant a regular crop or after the regular crop planted has "failed" for one reason or another. Short season crops such as millet and buckwheat are often used for this purpose.

Scavenger Crops: Farm soils that have been heavily cropped with shallow-rooted plants such as corn may become deficient in certain micronutrients. Deep rooted "scavenger cover crops" such as annual ryegrass, alfalfa, red clover and sweet clover grow roots deep into the subsoil and have the ability to bring soil nutrients from the lower soil profile to the upper layers, the deep growing root structure additionally help to break up soil compaction and when these plants die their decaying roots leaves channels in the soil that provide pathways for the roots of the following crop to follow down the profile; these root channels also provide pathways for water to drain from the surface.

Manure Management: Cover crops take up manure Nitrogen and other nutrients that are applied over the fall and winter. Not only do they "recycle' or "scavenge" unused soil Nitrogen left in the soil after crop harvest at the end of the growing season; but also cover crops recycle applied manure nutrients. Cover crops make better manure nutrient allocation, adding a cover crop increases the percentage of the fall and winter applied manure nitrogen that will be available to the following years' crop. Approximately, we can gain a 20% increase from dairy and beef manure applied, a 25% increase for swine manure and about a 35% increase for poultry manure. This is if the cover crop residue is not harvested and left in the field to decompose. If the crop is a cover that is harvested for forage, we gain those allocations of nutrients in the forage we harvest.

Smother Crops: Fast growing Buckwheat with its wide canopy leaves, Sorghum-Sudan grass, hairy vetch and sweetclover help control weeds by growing a thick canopy that reduces the amount of sunlight for weed seeds to germinate and grow. The grass crops and buckwheat also have fibrous root systems that grow quickly and out-compete weeds for water and nutrients. Smother crops grow tall at a fast rate or quickly produce broad leaves that shade out lower growing weeds. Including these covers in your rotation, growing different crops in a single season is an effective strategy for weed control. An effective sequence of smother crops is oats in spring, buckwheat or sorghum-Sudangrass in summer and rye, triticale or forage brassicas in the fall. Hairy vetch planted in the fall and overwintering will then act as a spring smother crop smothering early spring weeds.

Break Crop: Different plants attract and harbor different populations of insect pests. Different species of cover crops can be used in the rotation as a different crop that does not harbor those pests or actually diminishes their population by interrupting the insects' life cycle. Reducing pests and disease populations is another one of the best reasons for using cover crops in your rotation.

Nurse Crop: A nurse crop is one that germinates and emerges quickly, holds the soil with quick cover and root structure and assists the development of a slower maturing crop. Oats planted in the late summer or fall is a favorite nurse crop to be planted with fall seeded legumes. The oats germinate first, out-compete weeds for available resources and then can be mowed when the clover starts to emerge and grow. If left go Oats will winter kill and the residue can be left to protect legumes from winter wind and ice sheeting and they help somewhat to reduce frost heaving.

Allelopathy: The term allelopathy is often used when referring to the weed suppressing attributes of cover crops. Allelopathy is defined as "the inhibition of growth in one species of plants by chemicals produced by another species." It can be any direct or indirect harmful effect produced in one plant through toxic chemicals released in to the environment by another. The magnitude of the detrimental effects depends on the extent of any other stresses, such as environmental conditions or biological factors (e.g. insect or disease pressure) that occur at the same time. Different cover crops have different allelopathic effects, and the activity may be reduced or enhanced by microbial action, oxidation, and other transformations in the soil.

Some allelopathic compounds from crops include:

(Peas, lentils, vetches) Beta-(3-isoxazolinonyl) alanine: released as root exudates. Suppressing lambs quarter, yellow foxtail, Yellow nutsedge and pitted morning glory

(Buckwheat) a compound called diethyl phthalate is produced by buckwheat and is responsible for weed suppression. This weed-suppressing compound is mainly in the stem rather than the shoots, so it is likely to be most active by suppressing weeds after the buckwheat is harvested. It was especially active on pigweed, and not particularly effective on plants in the mustard family.

Cereal Rye produces several compounds that inhibit crops and weeds. The most active compounds are two hydroxamic acids and their breakdown products.

Crimson Clover has been shown to suppress pitted morning glory, wild mustard and Italian ryegrass.

Sorghum-Sudangrass: Sorgoleone – released as root exudates

Soil Improvement

Most cover crops serve multiple purposes to improve the soil.

As a soil quality improver, cover crops are a biological means used to:

- Conserve nutrients, reduce nutrient looses in the soil by inhibiting leaching losses with their living roots.
- Re-Cycle nutrient resources while growing after the cash crop.
- Carbon sequestration**,** by adding organic matter - to the soil (both by root growth and above ground growth if incorporated).
- Reduce compaction.
- Increase soil aggregation.
- Increase infiltration.
- Improve water holding capacity.

- Improve aeration.
- **Legume** cover crops increase nitrogen fixation.
- Enhance phosphorous availability (acid phosphatase as root exudates).
- pH buffering (adding organic matter, **non acidic Nitrogen from legumes**).
- Reduce erosion by keeping the soil covered, anchoring it with root structures.
- Reduce sediment from floodwaters and wind.
- Reduce soil crusting.
- Increase biological activity - promotes ecological balance, beneficial organisms and biodiversity – Cover and Green manure crops increase the available food supply for microorganisms (energy & nutrient source for soil biota).

Organic Matter/Soil Quality

Organic matter is one of the most important indicators of soil quality. Organic matter cycles in the soil and includes different forms: living organisms, fresh residue, decomposing organic matter and finally stabilized organic matter known as humus. Some of the beneficial effects of soil organic matter include better aggregation and aggregate stability, longer cycling of nutrients, higher microbial activity, more water holding capacity and lower bulk density. Cover crops, as part of a rotation provide protection of the soil surface; add residue and organic matter to the soil. By growing cover crops in the off season, keeping the soil covered, you increase the amount of organic matter added to the soil over time.

(Don't forget the roots) Surface residue is only part of what cover crop plants contribute to soil organic matter , roots can add half again as much material, in grass/legume mixes often half of the plant production is underground. In no-till situations where surface residue is not regularly tilled into soil, growing cover crops roots become especially critical as a source of soil organic matter.

Grass and legume cover crop roots support Mycorrhizal fungi. Mycorrhizal fungi are beneficial plant-root fungi. Cover crops growing in the off-season support the growth of this Mycorrhizal fungi because these fungi require "living" plant roots in order to survive, the practice of having a living cover crop over winter supports the mycorrhizal fungi population in the soil. These fungi grow into the plant root and extend beyond the root hairs accessing more soil area to feed the plant. The fungal extensions called 'hyphae" produce an organic compound called "glomalin". **Glomalin** is an extremely "tough" organic carbon compound, adding to soil carbon and nitrogen storage. It is resistant to microbial decay, lasting 10 to 50 years and does not dissolve easily in water. These properties make glomalin a good protector of the hyphae and of soil aggregates. Glomalin released into the soil from mycorrhizal fungi, in some respects acts as biological "glue" and holds soil particles together in aggregates, and is also an important component of long term soil organic matter.

Pest Management, cover crops attract beneficials:

- Cover crops create a habitat for beneficial arthropods (insects, crustaceans, arachnids, and myriapods).
- Beneficial insects, such as lady beetles or ground beetles, may be encouraged by planting cover crops. Lady bugs attack aphids, mites, insect eggs, and small insects, the lady bug predator can eat its own weight in aphids in a single day.
- Hubam clover, attracts beneficial big eye bugs, (also called seed bugs), which will attack spider mites, thrips, leafhoppers, aphids and other insect eggs.
- Flowering buckwheat attracts hoverfly, (also called Syrphid flies); the larvae are voracious eaters and will attack aphids.
- Buckwheat and annual white sweetclover (Hubam) attract many species of predatory wasps.
- Brassica cover corps (Mustard family, Oilseed/Forage Radish, Rapeseed, White, Yellow, and Black Mustard) when used in rotation with other crops they will disrupt pest and disease life cycles associated with typical grass/legume rotations. These covers contribute some control on soil borne pathogens and nematodes.
- Honeybees - All of the true clovers, including red clover, white clover, crimson clover and alsike clover will provide nectars and pollen for honeybees, in addition the sweet clovers are very good nectar providers. One of the best nectar sources is 'Hubam' sweet clover which is an annual sweet clover and flowers in the first year; it blossoms for about two months and produces nectar from morning to evening. Buckwheat, as well, is a good summer annual that can be planted several times throughout the summer as a cover crop and attracts many honey bees.
- A late planted crop of buckwheat planted as a nurse crop with hairy vetch or other legume in early September will still flower and provide foraging bees with food up until October in Pennsylvania, just before the first frost sets in.

Weed Suppression, cover crops also act as weed suppressors

- Small-grain crops (barley, oats, rye, and wheat) are strong competitors against weeds, and some cover crops (such as Rye, Buckwheat, Hairy Vetch, Sorghum-Sudangrass) can be allelopathic, emitting chemicals that inhibit weed seed-and other seed-germination.
- Many cover crops and their residues can suppress weed growth by altering light and temperature. Used as"living mulch" the cover crop can reduce the amount of sunlight from reaching the soil surface, preventing weed seeds to germinate and grow.

- Cover crops prevent weed establishment in fields during "non-crop periods." Perennial weeds will quickly invade a fallow field, starting weed problems that can take years to control. This is why cover crops grown in fallow fields are especially important.
- Cover crops suppress the growth of winter annual and biennial weeds for an early start in the spring. Cover crops are usually easily controlled and leave a clean seed bed for the next crop. They can be plowed under or terminated with herbicides, in the case of winter annuals; they can also be rolled and killed to create a soil covering mulch.
- In the case of summer annuals such as spring oats and sorghum-Sudangrass, and some of the brassicas; they can be grown in the late summer and will be left as winter-killed mulch.
- Cover crops also present a competitive barrier to emerging weed seedlings.
- Sod cover crops, when mowed or grazed regularly, also help manage perennial weeds.
- Brassica species have been cultivated in India since 4000 BC and utilized as fodder crops, greens, root crops, condiments, green manure crops, oil seed crops and smother crops. The smothering ability of these species may be harnessed for weed control through selecting smothering varieties. Daikon radish drilled at 14-15 lbs /acre in August/September will out-compete most winter annual weeds greatly reducing weed pressure in fall and early spring.

Diseases

- Rolled down cover crop mulches will reduce soil borne diseases which are spread by rainfall splashing the soil onto crop leaves.
- Some disease problems can be reduced with appropriate cover crop rotation. Incorporated alfalfa and white sweetclover residues can reduce fungus *Sclerotium rolfsii*, while cereal rye has the capacity to reduce the incidence of *Phythium*.

Nematodes

Nematodes are very small roundworms that interact both indirectly and directly with plants. Some pathogenic nematodes will feed on plant roots and weaken the plant; some will introduce diseases through their activity of feeding.

- Brassicas (mustard, rapeseed, radishes,) and sorghum-Sudangrass, have nematicidal properties.
- Brassicas used before soybean crops or grown between potato crops can improve potato production and lower pest control costs.
- Sorghum-Sudangrass hybrids have also been shown to help reduce population levels of root-knot nematodes.

Steps in Selecting and Using Cover Crops

Cover crops can be a key soil improvement resource for conventional and organic growers alike. Here is an introduction of the role and selection of cover crops for farming systems. There is a cover crop to fit almost every type of cropping system.

For Certified Organic Agriculture: According to the USDA National Organic Program Standards "the producer is required to implement a crop rotation, including but not limited to sod, cover crops, green manure crops, and catch crops."

Many types of plants can be grown as cover crops. There are two general types of cover crops – non-leguminous and leguminous. The leguminous cover crops fix and add nitrogen to the soil.

Non-leguminous cover crops are often preferred on erosive soils. Each plant type has advantages over others and differs in its area of adaptability.

Mixes of both are very beneficial.

Non-Legume Cover Crops

Some of the commonly used non-legume cover crops are listed below. Most of these are grasses, which are good for scavenging nitrogen (recovering residual soil N), preventing erosion, building up soil organic matter, and suppressing weeds. Some can be classified as winter annuals, perennials, biennials, and summer annuals. Grasses typically have dense masses of fibrous roots that improve the soil structure and that stimulate soil microorganisms which in turn aggregate soil particles; the fine roots of grasses also bind soil crumbs directly.

- **Annual ryegrass.** A reliable performer, it can be grown all over the US where there is moisture, grows quickly, holds soils well, good scavenger of nitrogen. Cutting the ryegrass will increase dry matter through re-growth. Six to eight inches of top growth correlate to three to five feet of root growth, deep growing fine fibrous roots help open up soil for water infiltration and for the following crops root to follow and grow down the root channel in the soil. Kill with herbicide in conventional systems before plants go to seed, in organic systems plowing or disking to incorporate and kill will accomplish this. (**Don't let this crop go to seed.)**

- **Winter Cereal Rye**. A winter annual, Rye is the hardiest of the cereals and may be seeded later in the fall than the others and still gives good soil protection, dry matter, and N scavenging. It grows all over the US. It is a good weed suppressor, by both shading and alleopathy. A favorite for rolling down or mowing in late spring and no-till seeding soybeans or pumpkins into the mulch, or using a modified no-till transplanter to transplant tomatoes, peppers, pumpkin plants into the mulch. Drip tape irrigation can be run along top of the mulch for controlled irrigation in vegetable systems. Cereal rye also does well in a mix with legumes such as vetch. The advantage of using grasses such as cereal rye as a cover crop include low seed costs and quick establishment of ground cover in the fall, vigorous growth, and good winter survivability.

- **Triticale.** A winter annual, Triticale is a cross between wheat and rye, planted and established similarly as wheat or rye. This crop is often grown as a forage, it provides fall and winter cover similarly to rye. Triticale will typically grow ground cover canopy quicker than rye in the fall, which makes it advantageous for weed control of winter annual weeds. Forage varieties of triticale will produce more biomass and do better as cover crops to build organic matter and recycle nutrients compared to the grain varieties. Triticale can be mixed with legumes and/or annual ryegrass.

- **Oats,** a summer annual, oats are low-cost, and perform reliably. Oats can be planted as a **nurse crop** as a bi-culture (mix) in combination with hairy vetch or other winter annual legumes or perennial legumes. The oats will establish quickly in the fall and then winter kills in Zone 6-7 and colder. They like cool, wet weather and produce prodigious biomass and are competitive with weeds. If planted as a companion crop with legumes it may out-compete the legumes if planted too early (August). Wait until September to use it as a companion crop with legumes such as Austrian winter peas and hairy vetch or other legumes. Oats may be prone to lodging in Nitrogen rich soil.

- **Buckwheat.** A favorite warm-season cover crop amongst both produce growers and organic farmers, in rotation also used for a quick cover after small grains are harvested. Buckwheat is fast growing, loosens tight soils with its abundant roots. It is known as a summer smother crop and suppresses weeds well by shading and some allelopathy. Buckwheat flowers are a nectar source for beneficial insects. Buckwheat grows well in poor soils, disks down easily, breaks down very quickly and is known to scavenge and improve the availability of phosphorus with its root exudates of acid phosphatase.

- **Sorghum-Sudangrass**. This crop results from a cross between forage or grain sorghum and Sudangrass. A warm season crop, no other cover crop produces the sheer biomass for building up soil organic matter. Will grow more efficiently in dry summer soils, in severe droughts they go dormant and then commence growth when there is sufficient rainfall. Sorghum-Sudangrass as a single cut produces 5 tons or more of dry matter per acre. If cut several times during the season 13,000 to 18,000 lb/A of dry matter is often grown. Sorghum has weed-fighting allelopathic exudates. Sudangrass is particularly good for building up beneficial, root-colonizing mycorrhizae in the soil. This crop has more secondary roots compared to corn and Mid-season mowing at two to four feet tall will stimulate root growth to build soil organic matter. Sorghum-Sudangrass can be cut and used as forage. After being cut as forage at the end of summer the stubble can be no-till drilled into with a winter annual legume or perennial legume. The remaining stubble and roots of the Sorghum-Sudangrass will hold the soil in place preventing erosion until the slower germinating legumes have time to get established.

- **Mustards.** There has been rapid growth in the use of mustards as a bio-fumigant cover crop for controlling nematodes, soil-borne diseases and the weed seed bank. Sown in the fall and tilled in the spring.

- **Brassica cover crops** – A diverse group of crops also in the mustard family Oilseed/Forage Radish and Rapeseed. Oilseed radish is more winter-hardy than forage radish. Brassicas prefer cool moist climates, doing best in early spring and fall. They grow very rapidly and are highly competitive in the fall. Their deep taproots provide them with some drought tolerance. Forage radishes can penetrate and break up plow pans. Brassicas are efficient Nitrogen, Phosphorous and Calcium feeders and can capture excess nutrients as a **catch crop** after main crop has been harvested. Their value as cover crops lies in their ability to establish quickly in cool weather. They establish a thick taproot which helps improve soil physical characteristics. Many of these double as a highly digestible forage for grazing which makes them a dual-purpose crop in grazing livestock systems. When used in rotation, brassicas will "break" or disrupt pest and disease life cycles associated with typical grass-legume rotations. When Brassicas decompose their sulfur containing compounds in their tissue break down into compounds that inhibit soil-borne pathogens as well as insects, weeds and nematodes.

Legume cover crops

Legumes are nitrogen fixers, different legumes are classified as winter annuals, perennials, biennials, and summer annuals. Legumes often have relatively simple root systems, dominated by a central taproot and are often heavily nodulated. Few other plant families fix significant amounts of nitrogen, so legumes are a key component in long-term sustainable productive farming systems. Different legumes require different inoculants; refer to the chart on page 13. Some common legume cover crops are:

- **Crimson clover.** If planted in spring, it will establish as an annual and bloom that year. If planted in the fall (mid-August to September) it can over winter and establish as a biennial, growing vegetatively in the fall and blooming the next year. It is a popular spring and summer green manure crop because of its nitrogen fixing capability and also due to its beauty during flowering, also attracting beneficial insects. It reseeds well after winter. It is not as winter hardy in northern locations, so we do not recommend for northern locations (Central to northern Indiana and the upper mid-west and central PA and north) unless local climate conditions are buffered by lakes for example. It can be planted with oats in the fall, the oats acting as a nurse crop and it can also be mixed with hairy vetch.

- **Field peas, Austrian Winter peas.** A high N-fixer, field peas are easily broken down and a quick source of N. They grow well in cool, moist conditions. Spring type field peas grow well when spring drilled as early as you can get them in the ground. Austrian Winter peas and winter hardy type peas are planted as winter annuals in fall. They over-winter and can be used as green manures in spring. Use oats at 40 lbs/acre as a nurse crop planted with the peas when planted in the fall. Peas can be mixed with Hairy vetch and oats as well for a diverse mix. Peas are very susceptible to residual herbicide carry over in the soil, check the herbicide labeling of susceptible plants and residual times for herbicides used in fields before planting.

- **Hairy vetch**. This can be established as a winter annual if planted in fall or an annual if spring seeded. This is an organic farming favorite and is rapidly being adapted by conventional growers for its N-fixing properties and high N biomass production in spring commonly used as a nitrogen rich green manure or a rolled down mulch mat. Its prolific spring growth smothers spring weeds well. The easily decomposed leaflet residue provides N during the growing season. It is good in a cover mix with rye or triticale.

- **Red clover**. (Medium-red clover or common red clover) Red clover is a perennial. It is dependable, easily established, widely adapted, low cost and winter hardy. Good for frost-seeding into standing small grain crops or broadcasting into standing corn at lay by or last cultivation. Red clover is an excellent forage crop.

- **Sweetclover**. A tall-growing biennial with a deep taproot, which can produce lots of biomass. Sweetclover will typically fix the greatest amount of nitrogen in the shortest period of time compared to alfalfa or red clover. There are two types of sweet clover, Yellow blossom sweetclover and white sweetclover. The yellow sweetclover is earlier maturing than the white. Yellow blossom sweet clover puts a higher proportion of the total first year's growth into the roots than does the white. Yellow sweet clover does better in a dry season and on dry seedbeds compared to white sweetclover.

- **White clover**. A perennial and a favorite for living mulch, white clover is a short plant that stands up well when mowed and in high traffic. Three types include: Dutch white, New Zealand, and Ladino. The Dutch being small (low growing) the Ladino being a "jumbo" large leafed and taller type. The Dutch white is preferred by produce growers to grow in between raised beds and can be mixed with grasses to develop a walkway between permanent beds that is maintained with periodic mowing.

Legumes used for Green Manure in Rotations – Legume crops, grown in rotation with other crops can be used to add nitrogen to the soil. The amount of nitrogen fixed annually by rhizobia varies with legume species.

Legume crop	**lbs/acre of Nitrogen fixed**
Alfalfa	160 to 300
Hairy Vetch	150 to 250
Field Peas/Austrian Winter Peas	90 to 150
Ladino Clover	85 to 180
Red Clover	85 to 135
Crimson Clover	60 to 150

Higher Nitrogen values in these ranges are realized by letting the legume grow full term, a legume terminated earlier in spring will not provide as much nitrogen compared to if its let to grow later in the spring. Over-wintering legumes will provide more Nitrogen than spring seeded legumes. Frost seeded clovers in small grains left to grow the remainder of the season and into the next year will provide more nitrogen than late summer planted legumes or legumes seeded the following spring.

Note- Rule of thumb about 40% to 60% of the nitrogen from legume plow down is available in the first year if the cover crop is incorporated as a green manure. Hairy vetch will typically provide more nitrogen compared to other legumes when rolled or killed as no-till mulch.

The final amount of nitrogen that is fixed by the legume is primarily dependent on the species grown and the growth of the legume in the spring, which in turn is dependent upon the temperatures and the physiological stage of the cover crop. Maximum accumulation of nitrogen from legumes usually occurs within two months after the legume begins to bloom. 50% bloom to full-bloom stage is a good time to plow under the legume cover crop as a green manure to obtain a substantial amount of nitrogen to enrich the soil for the next crop in the rotation.

Nitrogen Availability - A high percentage of the biologically fixed nitrogen is in the top growth of legumes, approximately 80 percent is in the top growth and 20 percent is in the roots with the top growth nitrogen becoming available much quicker than that in the roots. Legumes break down quickly after being incorporated into the soil. The nitrogen in the top growth, roots and nodules becomes available for use by other plants grown in the soil later, the nitrogen being released into the soil as nitrates. Nitrates are readily available for plants. Approximately 40% to 60% of the nitrogen in the legume green manure will be available in the first year after plow down for the following crops; the rest of the nitrogen will be released over a period of a few years.

Inoculation of Legumes - Legume cover crop seed should be inoculated to insure that nodules will be formed on their roots. Nodules are formed on the roots of the legumes when the bacteria (Rhizobia) infect the root hairs of the plant. Many of these nodule producing bacteria are found in soil, but they are not all equally effective in fixing nitrogen. To ensure that nodules will form from the best bacteria strain of Rizobium bacteria, you should properly inoculate the legume seeds before planting. (This is important, especially in fields where a particular legume cover crop has not been grown before.)

Most of the commercially available inoculants are a mix of a strain or strains of Rhizobia bacteria along with a finely ground peat, which helps keep the bacteria alive for several months when stored in a cool dry location. For adequate optimum inoculation and nodulation to take place the inoculants bacteria must be the correct strain for the species of legume and be placed on the seed so it will be in contact with roots of the legume as the seeds germinate and grow.

The association between legume species and rhizobial strain is often highly specific. One bacterial strain is able to infect the root system and produce effective nodules on one group of legumes but not on legumes of another species. Legume inoculants are divided into groups based upon their ability of infection of a particular legume species. The different groups are Alfalfa, Clover, Cowpea, Lupine, Pea & Vetch and other groups listed in the table below. Some commercially available inoculants mix strains from the groups so that one inoculant may be used on most of the legume species.

Cross-Inoculation Groups and Rhizobium-Legume Association

Group	Common Legume names	Inoculant Bacteria name	Inoculant Code
Alfalfa Group	Alfalfa Black medic Bur clover (medic) Button clover (medic) White sweet clover Yellow sweet clover	*Rhizobium meliloti*	A (Lucerne-Medics)
Bean	Beans	*Rhizobium phaseoli*	D
Clover I	Berseem clover Crimson clover Lappa clover Persian clover Rose clover	*Rhizobium trifolii* strain	B [Note: Crimson clover and Berseem clover require rhizobial inoculant type **"R"** (Nitragin Co.)]
Clover II	Rose clover Subterranean clover	*Rhizobium trifolii* strain	B
Clover III	Alsike clover Ball clover Hop clover Ladino clover Red clover White clover	*Rhizobium trifolii* strain	B
Clover IV	Arrowleaf clover, Persian Clover	*Rhizobium trifolii* strain	B or O
Lupine	Lupines	*Rhizobium lupini*	H, G (Lupin-Serradella)

Cross-Inoculation Groups and Rhizobium-Legume Association

Pea	Caleypea Garden peas Lentils Vetches Winter peas	*Rhizobium leguminosarum* - Biovar viceae	C or E (Pea)
Soybean	Soybeans	*Bradyrhizobium japonicum* strain	S
Cowpea	Alyce clover Cowpeas Lespedeza Lima Bean Peanut Kudzu	*Bradyrhizobium japonicum* strain	S
Trefoil	Birdsfoot trefoil Narrowleaf trefoil	*Rhizobium loti*	K
Other	Cicer milk vetch		
	Crownvetch	*Rhizobium spp.*	M
	Sainfoin	*Rhizobium*	
	Kura clover		
	Leucaena		
	Chickpea		N (Chickpea)
	Faba bean	Special Inoculant faba bean	
	Fenugreek	Special Inoculant fenugreek	
	Pigeon pea		I
	Lablab		J
	Mungbean		M (Mungbean)
	Sun Hemp (*Crotalaria juncea)*		Inoculant type "EL"

Cover Crop Selection Criteria

1) Reasons for Planting Cover Crop.

2) Field History (What is the Long-Term Rotation, what was the previous Crop, what will be the next crop in rotation) **Check previous herbicide application and refer to information on susceptible plants and residual times for herbicides used in fields that will be planted with a cover crop.**

3) Neighboring Crops.

4) Irrigation Methods (if needed, if used).

5) Soil (type, pH).

6) Weeds.

7) Pest Problems.

8) Cover Crop Window in the rotation (planting, establishment – removal, or time of destruction).

For proper selection, ideal cover crops should be

- Easily established.
- Highly productive.
- Easily killed mechanically (organic or sustainable application).
- Not allelopathic to the main cash crop.
- Fits into your site specific growing condition.
- Fits into your rotation.

1) In choosing a cover crop for soil improvement, first identify the purpose or the primary function of the cover crop based on the needs of your system. Use the list below to identify the primary function(s) of the cover crop.

a) **Provide nitrogen** – Growing legume cover crops is one of the most important tools to increase soil fertility. The main benefit of using a legume as a green manure is that the legumes fix nitrogen from the atmosphere and convert it into a form that is available to other plants. Pick legumes that are adapted to your area. Legumes (peas, vetches, clovers, beans) grow in a symbiotic relationship with soil dwelling bacteria (rhizobia). The bacteria take gaseous nitrogen from the soil air and convert or ”fix” this nitrogen into a form that the plant can use, in exchange the plant provides carbohydrates to the bacteria. Legumes vary from one another in the percent of nitrogen they contain on a dry matter basis. Legumes contain nitrogen in both their top growth and in their roots. A high percentage of the biologically fixed nitrogen is in the top growth, so it is important to manage them to let them grow long enough to produce their full high potential amount of biomass (herbage). The residues of these crops can contribute substantial nitrogen to following crops.

b) **Increase soil organic matter -** By improving the soil biological activity cover crops can conserve or increase soil organic matter if they are managed to grow long enough to produce a high amount of biomass. A major benefit from green manures is the addition of carbon compounds in the form of organic matter to the soil. Over time soil organic matter is decreased through tillage and biological activity. Adding crop residues back to the soil helps maintain soil organic matter. Complex soil structure is built by the addition of organic matter. In no-till systems where we limit incorporation of plant residues, cover crops are important key crops to build soil organic matter; their roots will physically penetrate the soil and release carbon compound root exudates in the soil at varying depths as the roots grow deeper. When these cover crops are terminated their dying root biomass becomes incorporated organic matter at various depths.

c) **Improve the nutrient availability in the soil -** Nutrient availability is improved because the cover crop plant roots release 80% of the sugars that the plant produces into the soil to feed the soil microorganisms that build soil and in turn mineralize, recycle and release nutrients to the next crop. When incorporated into the soil, cover crop biomass is decomposed by soil bacteria and fungi. Through this process of biological decomposition the soil nutrients are recycled. Look for high biomass – producing cover crops. As a summer cover crop consider sorghum-Sudan grass hybrids. As winter annuals, cereal rye and triticale work well. Annual ryegrass planted in the fall works well. The legumes which produce much biomass include hairy vetch, alfalfa, medium red clover, ladino white clover, field peas and crimson clover. Mixes of legumes and cereal crops can be used as well.

In addition, increased plant residues associated with cover crops in a system improve the soil environment for certain beneficial organisms. Organisms such as earthworms, insects and microorganisms can improve soil quality and increase nutrient availability by quickly decomposing organic matter and plant residues.

d) **Scavenge nutrients** – Soluble plant-available nutrients, especially nitrogen, are left in the soil after the cash crop has been harvested. Over the winter, bare soil is prone to loses of nutrients both into the air by volatilization and to water by leaching or by erosion. Growing a cover crop will reduce those loses by taking up the nutrients into their own tissue. The nutrients in cover crops are not always directly available to plants. The soil microbes decompose the cover crop residues, taking up some of the nutrients and releasing the rest to the soil environment. When the plants and the soil microbes decompose, the nutrients contained in them become available for the next growing crop in the rotation like a slow release fertilizer. For nutrient scavenging use cover crops with extensive root systems and which will develop quickly after planting. The non-legumes such as the winter annual grasses (triticale, and rye) do well, as well as annual ryegrass is a magnificent scavenger of nutrients. Grasses can make efficient use of nitrogen already in the soil, because their roots are adept at scavenging nitrogen that might otherwise leach from the soil. Also the brassicas (rapeseed, oilseed radish and mustard blends) do well for this purpose.

Legumes and grasses have symbiotic relationships with fungi that produce mycorrhizal hyphae (fungus roots) which ramify through the soil and can help the plant obtain scarce nutrients (e.g. phosphorous). These fungi must be in association with a living root to survive. By having Legumes and/or grass cover crops growing after the cash crop, these microbial –plant root relationships can be maintained throughout the rotation to help foster nutrient scavenging and cycling.

d) **Prevent soil erosion and runoff -** Protect soil from raindrop impact. Choose species that grow rapidly and cover the soil surface. Most of the same species that are used as good nutrient scavengers also provide good soil cover. The cover protects the soil from direct raindrop impact and also impeding the velocity of rainwater flowing across the soil surface and thus reducing erosion potential.

e) **Improve soil structure** – Increasing the soil organic matter with cover crops as previously mentioned and listed in item **b** improves the soil structure. As plant residues degrade, the soil microbes feeding on them y release compounds into the soil; these compounds are (gums, waxes and other substances and exudates) which have glue-like" properties which cement soil particles together to form stable soil aggregates. Soil components aggregated together results in improved soil structure and tilth. Grasses have mycorrhizae associations as do legumes. However, grasses are characterized by dense masses of fibrous roots that improve the soil structure by exuding polysaccharides. The polysaccharides stimulate soil microorganisms which in turn exude gums that aggregate soil particles. Aggregates contribute to greater soil permeability, soil porosity, aeration, water infiltration and holding capacity, cat-ion exchange capacity and ease of crop emergence and root growth. The added organic matter also alleviates compaction by reducing the bulk density of the soil.

f) **Improve drainage, alleviate compaction** – Deep rooted species can help break through compacted layers in the soil such as a hard pan or plow pan. This can improve drainage. The penetrating roots of the cover crops make channels through which soil water can move after the root system decomposes. Species to consider are annual ryegrass and the sweet clovers. Winter cover crops with large tap roots such as the brassicas can help to alleviate some of the effects of soil compaction by penetrating the compacted layer when the soil is wet and relatively soft during the winter.

The brassicas (mustards) roots are known to penetrate about one foot deeper than cereals and nearly two feet deeper than grain legumes. The large taproot creates more space for beneficial soil organisms such as earthworms, which in particular help improve water infiltration and soil structure. Also the large taproot can help to penetrate plow pans by "biologically drilling" down into them as they grow, to loosen some of the compacted soil.

g) **Provide mulch to conserve soil moisture** – Choose cover crops with a combination of high above-ground biomass and moderate or high Carbon to Nitrogen ratios. The microbes that decompose crop residues use carbon as an energy source and nitrogen to build tissue. If residues have a C:N ratio higher than 25:1, the microbes will need to gather N from the surrounding environment to do their work. Generally speaking, the higher the C:N ratio of the cover crop residue, the more slowly decomposition will occur and the longer the residue will serve as both a moisture conserving and weed-suppressing mat. The small grain cover crops are well suited for this; most legume residues with higher nitrogen content will decompose more rapidly and be less effective as mulch. Mature rye and Triticale can be effectively used as weed suppressing mulches when rolled down which also conserves soil moisture evaporation by keeping the soil covered.

2) After identifying the cover crop for the major function desired, step 2 is to identify the planting niche and how the cover crop can be worked into your rotation. Cover crops can fit into many different cropping systems during portions of the year when no cash crop is being grown. Both agronomic and vegetable rotations can accommodate cover crops.

a.) Consider where the cover crop will fit into your crop rotation. Consider the timing of your field operations to plan both the planting and later incorporation of cover crops to avoid interfering with the cash crop production. The optimum planting date of the cover crop and the type of crop must be considered when looking at potential cover crops to fit the niche in your rotation. Many legume cover crops have hard seed coats and typically take two weeks to germinate and emerge with adequate soil moisture present but will take longer to germinate if planted during a dry spell, or when the soil temperatures are cooler.

b.) Examine cool weather and warm weather cover crops (winter annuals, summer annuals, biennials). Look at the typical planting dates for these crops and match that to fit in the timing of your current cash crop rotation and the required field operations.

Winter annual cover crops: Most of the winter cover crops are planted in the fall after the cash crop is harvested and provide cover over the winter months. Examples of these winter cover crops include the annual, biennial and perennial clovers, vetches, winter peas, cereal grains such as triticale and rye and the grasses such as annual and perennial rye grass. Spring oats planted in the fall will grow quickly and then winter kill to provide a soil covering dead mulch. Fall also can be the time for seeding the brassica (mustard family) cover crops including forage radish, oilseed radish, rapeseed or canola.

There may be some variance in this fall seeding depending on the crop. Sometimes winter cover crops can be over seeded into the living cash crop earlier in the season to act as a relay crop system, either after the last cultivation in corn (lay by) or before leaf drop in soybeans to get the cover crop established earlier in the growing season. In smaller vegetable production systems cover crops can be hand broadcast or spun on. Cover crops such as annual ryegrass, cereal rye or crimson clover can be broadcast underneath fall growing cauliflower, cabbage and broccoli to get a jump on germination and establishment before these vegetables are harvested.

Summer annual cover crops: These are typically planted when the soil temperatures are warmer during the summer and if there is adequate water available. Many of these species are fast-growing and will produce much biomass in a short period of time with optimum temperature and moisture conditions. Examples include Sorghum-Sudan grass hybrids; others are Sudangrass, buckwheat and the millets: German (foxtail) millet, Pearl millet and Japanese millet. In vegetable rotations fast-growing buckwheat can follow lettuce and still be plowed down in time for fall broccoli.

Cover Crop mixes: Cover crops can be planted as mixtures which combine some of the advantages of each of the component species. Cover crop mixtures sometimes function synergistically, providing more benefits than the individual species grown alone. Mixtures typically involve using two species, but can include five or more species. The most common mixtures include a legume and a cereal grain, for example, cereal rye and hairy vetch. The cereals such as rye and triticale germinate and grow readily through the fall, protecting the soil.

The roots of the grasses are more physiologically active in the autumn compared to legumes. If planted early, they provide good soil cover and capture some soil nitrogen that might otherwise be lost due to soil leaching during the winter and early spring rains or snow thaws. The competition for soil N in mixed stands can also result in increased biological nitrogen fixation by the legume. The legumes, such as hairy vetch, crimson clover and Austrian winter peas, typically become established more slowly and do not provide good soil cover or soil nitrogen-capturing ability in the fall. The legumes put on most of their growth in the spring and then can fix substantial amounts of nitrogen. The C:N ratio of a bi-culture or poly-culture may be greater than a single-species cover.

3) If unfamiliar with a cover crop before planting it on a large scale obtain a small amount of seed from our dealers and plant it into a small section of a field for observation. Establishment considerations include can it be broadcast, or must it be drilled, how fine must the soil be prepared or in some cases the cover crop seed can it be no-tilled or seeded after minimum tillage such as a disking. Consider how much time before the first killing frost is required for establishment. We plan to have cover crop demonstration plots at various locations as well to show you the seed, talk about methods of establishment and other considerations such as their use in rotation and winter hardiness

Look at the size of the seed, small seeded legumes, most of the true clovers i.e. (medium red clover, white clover, alsike clover) and also alfalfa and sweet clover seeds for instance have very small seeds and should not be planted too deep, ¼" to ½" deep is adequate. These small seeds can be broadcast in late winter in a frost seeding manner and let the freezing and thawing of the ground incorporate them into the soil, or for spring or fall planting they can be broadcast and just covered lightly. Larger legume seeds such as crimson clover can be planted ½" deep, hairy vetch can be planted ½" to 1" deep and field peas can be planted 2 to 2 ½" deep.

4) By growing a small section with a cover crop you can get familiar with how long it takes to germinate and establish; small seeded legumes need good seed to soil contact and do not establish well if planted too deep, they take time to imbibe water in order to germinate compared to the small grains or larger seeded cover crops, also if planted in the fall they need adequate time to establish before the first killing frost.

5) Get familiar with the growth habit of the cover crop and the amount of biomass it produces as well as its time of bloom and maturation. If it is a winter annual assess its ability to over-winter in your climatic zone. Some legumes are not very winter hardy and will not over winter in the northern colder zones. Understanding these observable traits of the cover crop will help you to identify both the planting niche and how the cover crop can be worked into your rotation. Cover crops will react differently just as main crops do from year to year in biological response to environmental factors such as soil temperature, soil fertility, soil drainage, soil moisture, soil pH, amount of rainfall throughout the growing season, the occurrence of first killing frost and last spring frost.

Organic No-Till and **killed mulch No-Till systems** utilizing cover crops: Recent progress has been made in organic no-till and killed mulch no-till systems using a crimper/roller that is mounted to the front of a tractor to roll down and mechanically kill fall-planted small grains or hairy vetch cover crops in the spring. With the front-mounted roller this is a time and energy saver being a one-pass system of roll and plant. A no-till planter or no-till transplanter can be used to cut through the mat of rolled-down cover crop and then seed or transplant into it. Winter annual cover crops species are used to cover the soil and recycle nutrients from fall through early spring and then rolled and into a weed-suppressing killed cover crop mat to no-till plant into. The rolled down cover crop influences weed emergence by the formation of the physical barrier of the cover crop residue, in addition light transmittance to the soil surface declines with increasing residue biomass. Many weeds require light to activate a germination process prior to emergence. Reducing the amount of light reaching the soil surface by the residue is an important factor inhibiting weed germination. Early weed suppression provided by the cover crop residue will permit crops to become established before weeds.

Cover crops recommended for building soil organic matter

- Annual rye grass
- Winter cereal rye
- Sweet Clover
- Sorghum-Sudan grass hybrids
- Triticale Plus cover crop mix

Cover crops recommended for improving soil nitrogen

- Hairy Vetch
- Crimson clover
- Three way clover mix; Red clover, Yellow blossom sweet clover, Ladino white clover
- Pea, Hairy Vetch and Oats (mix)
- Oats, Annual Rye Grass and Crimson clover, (mix)
- Alfalfa
- Sweet Clover
- Red Clover

- Field peas or Austrian Winter Peas

Cover crops recommended for Fighting Soil Erosion

- Winter cereal rye
- Annual Ryegrass
- White clover
- Sorghum Sudan grass
- Oats, Annual Rye Grass and Crimson clover, (mix)
- Triticale Plus cover crop mix

Cover crops recommended to Loosen Compacted Subsoil

- Sorghum-Sudangrass Hybrids
- Sweet Clover
- Forage Radish, Oilseed Radish, and Daikon Radish (bio-drilling)
- Alfalfa, medium red clover if grown for at least 3 years
- Triticale Plus cover crop mix

Cover crops recommended for Combating Weeds

- Annual Ryegrass
- Winter cereal rye
- Oats
- Sorghum-Sudangrass Hybrids
- Buckwheat
- Hairy Vetch
- White Sweet Clover
- Field Peas
- Daikon Forage radish, brassicas (spring/fall)
- Triticale Plus cover crop mix

Cover Crops recommended for Soil disease suppression

- Winter cereal rye
- Sorghum-Sudangrass Hybrids
- Daikon Forage radish and other Brassicas
- Rotate monocots (grasses) in Vegetable rotations to break typical Dicot vegetable diseases
- Rotate Legumes and Grasses

Cover Crops recommended for attracting beneficial insects and pollinators

- Buckwheat
- White Sweet Clover
- Red clover
- White clover
- Crimson clover
- Three way clover mix; Red clover, Yellow blossom sweet clover, Ladino white clover