

# **UNDER COVER**

**A GUIDE TO USING COVER CROPS IN THE MARITIMES**

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## INTRODUCTION

In 1994-1995, the Nova Scotia Organic Growers Association (NSOGA) completed a study of options for using cover crops in vegetable production. Twenty-five farmers and scientists cooperated to evaluate cover crops for weed suppression and biomass production in the Maritime climate. Over two years of study, we observed the soil benefits from, and nutrient-enhancing effects of, cover crops. We described the various the plants in terms of their usefulness as living mulches, smother crops and catch crops. We also experimented with methods of on-farm research to evaluate cover crops. The NSOGA Cover Crop Research Project is part of a larger effort to encourage farmers and gardeners to experiment with ecological agriculture techniques developed for and by farmers and gardeners in Nova Scotia.

*Under Cover* contains information on how to use cover crops to save time and energy, improve the soil, and add fertility. The handbook provides information needed by experienced organic growers, novice gardeners and conventional farmers.

There are many questions the handbook will not answer, but we provide ideas on how to set up trials and record data easily so every farmer and gardener can try to find their own answers. After all, ecological agriculture at its best requires people willing to experiment and observe.

## WHY USE COVER CROPS?

Cover crops are non-cash crops used to improve and protect the soil, provide and conserve nutrients and control weeds. ‘Cover crop’ is a general term encompassing a variety of other terms, each referring to a specific use. For example, green manures are cover crops that are grown and tilled under to add nutrients and improve the soil. Smother crops are used to control weeds. Living mulches are planted around or beside cash crops (ie. overseeded, underseeded or intercropped) for weed control. Catch crops are planted to ‘catch’ excess nutrients that might otherwise be leached from the soil. We discuss the benefits of using cover crops in terms of effects on soil, weeds and pests. We also examine the different uses and types of cover crops.

Throughout *Under Cover*, we refer to four groups of cover crops.

### 1. LEGUMES

Legumes are plants that can fix nitrogen. They decompose quickly after they are incorporated into the soil, and do not have much of an effect on levels of soil organic matter. They have taproots which can sometimes break up hardpans or bring up nutrients from deep in the soil. Examples include clover, alfalfa, vetch and lupins.

### 2. GRASSES & CEREALS

Grasses grow quickly and are good for weed control. They produce large quantities of plant material both above ground and in their fibrous root systems. The plant material is slow to decompose, and adds organic matter to the soil. Examples include fall rye, oats and ryegrass.

### 3. BRASSICAS

Brassicas are usually chosen as winter-killed catch crops. They have a very fast growth start, and are effective at taking up residual nitrogen. Examples include oilradish and wild mustard.

### 4. HERBS

Herbs include a variety of unrelated plants. These plants often grow quickly, accumulate nutrients and are used as bee plants. Examples include phacelia and buckwheat.

## COVER CROPS CAN IMPROVE THE SOIL

Cover crops have many beneficial effects on soil fertility and structure. They can add and conserve nutrients, increase soil organic matter, reduce the rate of erosion, improve soil structure, reduce compaction, affect soil temperature and increase soil biological activity. Cover crops vary in their effects on the soil. For example, a lush crop of clover can add plenty of nitrogen but not increase organic matter, and grass would do the opposite. Farmers can determine what their soil needs, and then choose the appropriate cover crop.

### **BUILD UP POOR SOILS**

A succession of cover crops can be used to build poor soil and control weeds. Buckwheat is often the first cover crop to plant; it grows quickly even in poor soils and is excellent at suppressing weeds. After, a cereal or grass cover crop (e.g. oats or ryegrass) can be used to add organic matter.

A legume, such as red clover, can be overseeded into the cereal cover crop or grain crop to add more nitrogen. After the crop is mowed, harvested or winterkilled, the legume can grow for another season. Cover crops can be used renovate hayfields, or replenish exhausted cropland.

### **IMPROVE SOIL STRUCTURE**

Decomposing plant material adds organic matter (humus) to the soil. Organic matter is essential for a healthy soil in that it improves the capacity of the soil to retain water and nutrients. Organic matter also improves drainage, aeration and general soil structure.

The roots of cover crops can also improve soil structure by breaking up compacted soil. Plants with deep taproots such as oilradish, sweetclover and red clover are great for breaking up hardpans. By reducing compaction, cover crops increase the infiltration rate of water. Consequently, rainfall is more likely to penetrate the soil rather than flow off the soil (taking topsoil and nutrients along with it).

Cover crops also improve soil structure by stimulating the activity of soil life, such as earthworms, bacteria and fungi. The soil organisms aerate the soil through tunnelling, help break down organic matter and secrete glue-like substances which are essential for soil aggregation. Earthworm populations are lower on tilled, compared to uncultivated land, primarily because of the lack of protective cover and organic debris from fall to spring.

### **ADD NUTRIENTS**

Cover crops provide nutrients for the crops that follow them in the crop rotation. Many deep-rooted cover crops such as sweetclover and buckwheat are particularly good at bringing up certain nutrients (such as P, K and micronutrients) from deep in the soil, and releasing these during decomposition.

Legumes can 'fix' nitrogen and transform nitrogen from the air into a form that plants can use. The nitrogen-fixing ability of legumes depends on a symbiotic (mutually beneficial) relationship between certain bacteria, called rhizobia, and the legume. The N-fixing process occurs in nodules -- small growths on the roots of legumes. For annual legumes, N-fixation usually peaks before flowering (6-10 weeks after planting), and ceases during flowering at which time the nitrogen is transferred into the seeds.

Legumes tend to be 'lazy' and won't fix nitrogen if there is already a high level of it in the soil. Adding straw, leaves, grain stubble or other carbon-rich material can tie up soil nitrogen. This stimulates the legumes to fix nitrogen from the air instead. Make sure the legumes are actually adding nitrogen to the system instead of just using what is already present.

Evans, Chalk and Connor (1995) found that incorporating straw increases the proportion of nitrogen fixed from the air from 67% (no straw) to 96% (10 tonnes straw/ha). They also found the amount of nitrogen fixed can be increased when both soil and seed are inoculated with rhizobia.

N-fixation is most successful in neutral or slightly alkaline soils with neutral optimal levels of phosphorus, potassium, calcium and molybdenum.

Crops growing next to legumes can use some of the nitrogen fixed by the growing legume if the legume roots are shedding nodules due to drought, shading or defoliation. However, most legume N is released after the legume is incorporated into the soil. Nitrogen is slowly released from the dead mulch at a rate that corresponds to the N needs of many crops. Consequently, legume-fixed N is more efficiently used than synthetic N from fertilizers, leaving less nitrate to leach out of the soil or be taken up by weeds.

Deep-rooted cover crops, such as sweetclover, can take up nutrients from deep in the soil. When these plants decompose, the nutrients are released near the soil surface and are available for following crops to use. Some cover crops can take up nutrients unavailable to other plants, and then release the nutrients during decomposition. For example, buckwheat and certain brassicas can take up phosphorus and calcium and release these to following crops.

#### **CONSERVE NUTRIENTS**

Cover crops can take up excess nutrients in the soil, and thus reduce the loss of nutrients (from leaching). For example, when a crop of clover is turned under, or manure is applied in the fall, some of the nutrients may leach out of the soil. However, if a cover crop is planted soon after, it can 'catch' excess nutrients and hold them in the plant material throughout the winter. The nutrients will then be released when the cover crop is turned under in the spring, in time for spring-planted crops to use.

A PEI study compared N uptake and release by several catch crops planted in potato fields after harvest (MacLeod & Sanderson, 1995). They found that catch crops took up nitrogen in the fall (thereby reducing soil nitrate levels and nitrate leaching), and

released N in the spring. Oilradish, fall rye and a combination of oats & ryegrass were most successful at N uptake (taking up more than 75 kg/ha) and reducing soil nitrate levels. In the following spring, soil nitrate levels were greater where catch crops had been grown; oilradish and fall rye plots had the highest nitrate levels.

#### **ADD ORGANIC MATTER**

When selecting a cover crop, the best choice depends on whether the farmer wants to improve soil organic matter or release available nutrients to the cash crop. Fast-growing cover crops, such as mustard and canola, conserve N that might leach in the fall, but will decompose quickly when incorporated into the soil. Such rapidly decomposing crops (including most legumes) will not greatly affect levels of soil organic matter. In fact, fresh material may even lead to a decrease in soil organic matter by stimulating soil biological activity and the rate of decomposition.

To increase levels of soil organic matter, incorporate plant materials that decompose slowly (ie. are low in nitrogen and/or high in carbon or lignin) such as straw, leaves, wood chips, grain stubble or dry grass. Fall rye, oats and annual ryegrass are ideal crops to use to increase organic matter.

Legumes and cereals are often grown together to improve the soil. The legumes provide readily available nitrogen, and the cereals (when dry) add organic matter that decomposes slowly. As well, legumes and grasses or cereals usually have complementary rooting patterns. Generally, legumes have deep taproots with lateral branches, whereas grasses have more fibrous roots close to the soil surface.



## **REDUCE EROSION**

The term 'cover crop' is based on the use of such plants to cover soil and protect it from erosion. Erosion can be reduced by simply covering bare soil and protecting it from wind and water runoff. Erosion control is particularly needed on sloping ground. For effective erosion control, the ground should be covered throughout the year.

Living mulches provide ground cover between crop rows throughout the growing season. Or cover crops can be overseeded into other crops so the ground won't be bare after the main crop is harvested. Fast-growing cover crops (e.g. buckwheat or oilradish) can be grown whenever the soil is left bare for part of a season. After harvest, more cover crops can be planted and provide cover throughout the winter. If the crops are winterkilled, the mulch can provide cover.

For erosion control, choose a cover crop that covers the ground completely, and forms a thick mulch. For example, common vetch,

once established, forms an excellent living ground cover and a thick mulch after it dies.

## **MODERATE SOIL TEMPERATURE**

Cover crops can moderate soil temperature, keeping the soil cooler in the summer and warmer in the winter than bare soil. This makes living mulches great for cool-temperature crops like brassicas, (but less than ideal for hot-weather crops in cool regions). Spring soil warming may be delayed slightly by a thick mulch.

## **STIMULATE BIOLOGICAL ACTIVITY**

Cover crops, particularly those that are lush and succulent, can stimulate the soil life. As biological activity increases, organic matter will be broken down by soil organisms more rapidly and made available to plants. Soil organisms are essential to maintaining a healthy soil. They cycle nutrients, and improve soil structure and aeration.

Although a healthy soil life is important, stimulating soil life can lead to nutrient loss.

## **COVER CROPS CAN CONTROL WEEDS**

Cover crops can smother weeds (through competition for light, water and nutrients) and can suppress weeds by allelopathy. As well, cover crops aid in weed control by improving soil structure, drainage and nutrient release. The ideal cover crops for weed suppression become established quickly, grow rapidly, cover the ground completely and are allelopathic.

Allelopathic suppression occurs when a plant produces compounds that inhibit germination of other plants. This can occur while the allelopathic crop is living, or by allelopathic compounds in the dead mulch.

Several cover crops are allelopathic including fall rye, ryegrass, buckwheat, oats and sweetclover. Small-seeded plants are

most vulnerable to allelopathic compounds. This includes certain annual weeds (e.g. lamb's quarters, ragweed, barnyard grass) and small-seeded crops (e.g. carrots and lettuce). Avoid intercropping small-seeded crops with allelopathic living mulches or planting them into the decomposing mulch of allelopathic crops.

Weed control is enhanced by growing combinations of plants (ie. intercropping). The two crops can use resources (light, water, nutrients) more effectively than one type of crop; consequently, fewer resources are available for weeds. Intercropping works best when the two crops have different needs. For example, one plant may have shallow, fibrous roots and the other has a deep taproot; one plant may be tall and the

other short or climbing, one may grow quickly and the other slowly. In one living mulch study, mowed vetch and rye suppressed weeds at least as effectively as herbicides (Mangana et al, 1995).

The use of legumes rather than liquid manure or synthetic fertilizer, may help to control weeds. The N is slowly released by legumes and more effectively used by the crops, leaving less N for the weeds to use.

Oats and vetch are an example of an excellent combination of cover crops. The oats are tall and provide support for vetch to climb on. Oats are quickly established, providing early weed control, whereas vetch is slower but covers the ground more completely after the oats have grown. However when grown with vetch, oats can't be easily harvested, and oats with vetch were more likely to lodge than oats alone.

Grains, particularly oats and fall rye, are sometimes used as 'nurse crops' for clover. The grains are planted first and provide weed control. The legume is then over-seeded into the crop. The clover becomes established under the grain canopy, and grows quickly once the grain is harvested.

One way to bring old weedy fields into production is to do the following steps:

- (1) mow the field,
- (2) add manure or compost (if available and necessary),
- (3) incorporate and harrow,
- (4) seed winter rye or buckwheat with vetch (either common or hairy),
- (5) mow throughout the season to prevent cover crops from going to seed,
- (6) plant catch crop in autumn (eg. oilradish) and let it winterkill,
- (7) plant crops in the following spring.

For severe weed problems, summer fallow (repeated tillage), combined with cover crops, may be necessary.

Neil van Nostrand used winter cereals as nurse crops for clover in his soil-building rotation (Table 1). In mid-September, Neil planted the cereal (e.g. fall rye). The next spring (mid-April), he overseeded white clover into it; the grain grew until fall and was then harvested. It was still low and hadn't yet flowered. Clover the following year, and the stand was lush, flowering and had few weeds. The following spring, the clover was incorporated into the soil and crops were planted. This routine adds both nitrogen and organic matter to the soil, improves soil structure and controls weeds.

**TABLE 1. Neil van Nostrand's soil improvement rotation.**

<b>Year</b>	<b>Season</b>	<b>Action</b>
1	Autumn	Winter grain is sown.
2	Spring	White clover is overseeded into grain.
2	Summer	Grain and clover grow.
2	Autumn	Grain is harvested.
3	Spring - Autumn	Clover grows.
4	Spring	Clover is turned under; crops are planted.

## **COVER CROPS CAN REDUCE PEST PROBLEMS**

Cover crops can be used to reduce pest problems. Living mulches can lead to lower pest damage on crops, and cover crops can be used as >break= crops and grown as part of a rotation to help break pest cycles.

Living mulches make it difficult for pests to find the crops, by increasing plant diversity and providing more complete ground cover. The mulch can also provide food and habitat for beneficial insects which may prey on the pests. As well, increased plant diversity often leads to fewer specialized pests.

Many studies have found that crops grown with a living mulch have fewer pest problems than crops grown in bare soil. The living mulches appeared to reduce the problems with flea beetles, aphids, leafhoppers, potato beetles, cabbage worms and smut.

Farmers in Nova Scotia found that cabbages grown in clover and vetch had significantly fewer flea beetles than cabbages grown in bare soil. However, the living mulches did not seem to affect the number of cabbage worms. However, at one farm (where slugs were a problem for many crops), the slugs seemed to prefer the mulched cabbages.

As well, optimal soil fertility improves crop resistance to insect damage. Inadequate or excessive fertility will leave plants more susceptible to pest damage or competition from weeds.

## **COVER CROPS CAN PROVIDE FORAGE, NECTAR AND HABITAT FOR BENEFICIAL ORGANISMS**

Many green manures can be used for animal feed, either as hay for pasture. Legumes provide protein for fodder, but may cause bloating. The risk of bloat is minimized by feeding livestock fed a mix of grasses and legumes. This has been described as the need to combine ‘muscle makers’ (ie. legumes) with ‘fat formers’ (ie. grasses or cereals). In the Cover Crop Profiles, we mention the suitability of different cover crops for feeding livestock and honeybees.

Buckwheat, phacelia and many legumes provide excellent nectar for bees. Phacelia in particular, is a favourite among beekeepers. Phacelia produces blossoms for a long period of time. It produces a great deal of nectar and the resulting honey is light-coloured and mild tasting.

# USES OF COVER CROPS

## LIVING MULCHES

Living mulches are plants that grow beside and/or around crop plants. They suppress weeds by blocking light, like straw or black plastic mulch. They also can protect the soil from erosion, help control insects and add both nutrients and organic matter to the soil. A living mulch is also a simple way to bring legumes into a crop rotation. Ideally, a living mulch should establish itself quickly, covering the ground rapidly so that it smothers weeds but it shouldn't compete with the main crop. Various techniques, such as mowing and leaving the living mulch residue, can be used to reduce competition between the crop and mulch.

### NSOGA RESULTS

The NSOGA research examined the use of different living mulches with cabbage. In 1994, a dry year, the cabbages grown in living mulches were the same size, or slightly larger than cabbages grown in bare soil. It appeared that the dry conditions inhibited the growth of the living mulch and consequently, the living mulch couldn't compete with the cabbage.

At some farms in 1995, the cabbages in living mulch were much smaller than those grown in bare soil. The living mulches (white clover, subclover, hairy vetch) were lush and appeared to be competing with the cabbages for water and/or nutrients. The clovers were planted at 2-4 times the recommended seeding rate; perhaps lower seeding rates would lead to less competition. At one farm, where the recommended seeding rates were used, the cabbages in clover seemed to be slightly larger than cabbages in bare soil.

At all farms, the cabbages in the living mulches had fewer flea beetles than those grown in bare soil. However, on one farm, there was more slug and sowbug damage on the cabbages in the living mulches.

Farmers tried various ways to reduce competition between the crop and the living mulches. Some hoed the clover that was surrounding the cabbages; this seemed to be successful. Many growers mowed or clipped the clovers, but this often stimulated (rather than suppresses) the clover growth. As well, some farmers felt that clipping the living mulches took more time than weeding the control (total weeding time was, on average, 2 hours for a bed with 15 cabbages).

Based on weights of plant material, white clover inhibited weeds by an average of 74% before mowing, subclover by 75% and both by 90-100% after mowing. White clover produced slightly more biomass (green growth) than subclover. Purple cabbage in white clover yielded slightly more than subclover. These two yielded more than weedy control plots that were also mowed.

Using living mulches under broccoli, corn and Savoy cabbage seemed to be quite successful, according to various farmers. Broccoli was transplanted one week before subclover was planted. The broccoli thrived, and formed a canopy over the clover. However, broccoli transplants which were stressed and planted at the same time as white clover living mulch were not able to form a canopy over the clover. There was more competition between the two in this case.

Both white and subterranean clover living mulches seemed to improve the growth of Savoy cabbage. The Savoy spread out over the clovers and was not inhibited by them. They produced an excellent crop. The purple cabbage, which has a more upright growth and is slower-growing, suffered from competition with clover and weeds.

Mowed clover or soybeans were effective living mulch for corn (better than unmowed clover or clover mixed with soybeans). A few farmers planted subclover and hairy vetch under tomatoes. This did not work; the tomatoes were smothered by rampant legume growth.

### GREEN MANURES & SMOTHER CROPS

Green manures (or smother crops) are cover crops grown mainly for soil conditioning and weed suppression. By rotating between cultivated row crops and green manures, a farmer can prevent certain weeds from becoming established. Green manures can have other uses as well; some can be used as forage, fodder or as bee (honey) plants.

The NSOGA researchers studied the benefits of combining cover crops, specifically oats with common vetch, and crimson clover with annual ryegrass. For both combinations, we planted the grass/cereal alone, the legume alone and the combination (seeded at 1/2 the normal seeding rate for the grass + 2/3 the seeding rate for the legume).

Common vetch mixed with oats proved to be excellent at weed suppression and producing a high yield. The success of common vetch varied, probably due to differences in soil moisture. At two farms, vetch plots contained only 2% weeds (of the total dry matter yield), whereas at another farm, the vetch plot contained 40% weeds. In the latter case, the vetch was not raked in after planted, and was planted during a long dry spell; consequently the vetch had poor germination and very slow establishment. At the other farms, the vetch was planted in moist soil and then raked or harrowed.

On weedy fields (with serious wild radish problems), oats produced more plant

material and had fewer weeds than oats & vetch. Where there was no wild radish problem, the combinations of oats & vetch did better than oats alone in terms of both plant growth and weed control. At all sites, the vetch plots had low dry matter with many weeds. At a few farms however, deer had grazed the vetch quite low (while ignoring the oats) and so biomass estimates for vetch are not very accurate.

Oats grow quickly and provide early weed control. The vetch takes a while to become established, but later climbs on the oats, preventing light from reaching the low weeds. The oats that were growing with the vetch were taller than oats grown alone, and (due to the oat's weed control), vetch grown with oats was more lush than vetch grown alone. Oats grown with vetch were more likely to lodge than oats grown alone.

In the NSOGA study, the farmers also planted pure and mixed stands of Berseem clover & phacelia, crimson clover & ryegrass, and vetch & barley. These stands were very weedy despite using twice the recommended seeding rates. Common vetch, in particular, failed to compete with weeds. Crimson clover outperformed all others by a wide margin.

The combination of Berseem clover and phacelia did much better than either alone. Initially, the other cover crops were not impressive at smothering weeds. However,

after the plots were clipped, ryegrass, crimson clover and Berseem clover regrowth was very rapid. Final estimates for regrowth showed Berseem, Berseem & phacelia, ryegrass, ryegrass & crimson clover, and particularly crimson clover to have 85% or better cover. Crimson clover had an average of 99% cover.

At one farm, all cover crops did well (with only 5% or fewer weeds). The soil at this farm is in good condition with few weeds, and the cover crops were planted mid-summer.

It was also observed that the soil was much more friable under the Berseem clover and under phacelia than under the other cover crops.

## **Nodulation**

Nodulation rates varied between cover crops and farms. Where soil was very dry and hard, legumes had very few nodules on their roots. Hairy vetch, even when not inoculated, seems to nodulate very well at various locations.

Where crimson clover had been inoculated with species-specific rhizobia and replanted in the same spot the following year, nodules increased from 10-15/plant to 50+ per plant; from 50% active to 90% active.

White and subterranean clover began nodulating a month and a half after planting. By ten weeks of growth, the white clover had many nodules (80-100% active) and was close to flowering. Subclover had 30-50% active nodules. Note: Active nodules are reddish inside whereas inactive nodules are brown or black.

## **CATCH CROPS**

Catch crops are plants sown after harvesting the main crop, and/or after nutrients are added to the soil (eg. manure is added or a leguminous cover crop is turned under).

### **Catch crops:**

- (1) conserve nutrients that might otherwise leach out of the root zone,**
- (2) cover the soil over-winter, and**
- (3) control weeds.**

Catch crops may overwinter (like fall rye) or may be winterkilled (like oilradish). Catch crops are chosen for their ability to establish very quickly and take up residual nitrogen.

Nitrogen is released from organic matter and other nitrogen sources even after crops have been harvested in late summer or fall. This can lead to a loss of nutrients, particularly soluble nitrogen. Cover crops take up N that might otherwise be leached and hold them in

their tissues either until they are turned under, or until they begin to decompose in the spring (if left on the surface). Several studies have shown that white mustard is one of the best crops for taking up residual N. Fall rye, phacelia, canola and oilradish are also excellent at taking up N.

Brassicas (including canola, oilradish and mustard) are good at taking up nutrients and producing large amounts of dry matter. As well, many brassicas, such as white mustard, thrive in cool weather and can be planted after harvesting other crops. Oilradish works well when in late August or early September (for most of Nova Scotia). This gives the oilradish sufficient time to grow before it winter kills, but not enough time to go to seed. Fall rye and mustard can be planted even later in the autumn.

For the spring or summer, buckwheat is an excellent catch crop. It grows quickly in

warm weather, and effectively takes up extra N in the soil.

The NSOGA study found that phacelia, oilradish and buckwheat were fast-growing spring and summer catch crops. Oilradish and fall rye both appeared to be fast-growing fall catch crops. Oilradish responded dramatically to the high levels of nitrogen. The oilradish roots were huge (a foot long with a 3-inch diameter) where manure had been applied. At other farms, the roots were the size of thin carrots.

In a Quebec study, Lemieux (1995) compared various white mustards, oilradish and Budwig Cream (a hybrid of white mustard and oilradish). White mustard and oilradish have very poor growth on poor soils whereas Budwig Cream grew well on all types of soil conditions. Budwig Cream has two types of roots that work the soil and improve drainage; this may make it more adaptable to poor soils.

According to this study, the three top choices for catch crops are Ultra white mustard, oilradish and Budwig Cream, based on the criteria of late seed set, high yields (in high and low fertility conditions), and quantity of nutrients in the plant tissues.

Donald, Lewis, Caldwell and Goodyear (1995) compared oilradish, ryegrass, alsike clover, oats and phacelia at Truro and Canning, Nova Scotia. They high seeding rates should be used found that for late planting to compensate for the fact that the plants won't reach full size by winter. They recommended planting oilradish before mid-August if farmers wanted to have it take up extra nitrogen. Note that oilradish planted before September 1<sup>st</sup> may go to seed before being winterkilled.

Oilradish and ryegrass produced the most biomass, and the best ground covers over

winter were from oilradish, oats, ryegrass and phacelia. Oilradish and phacelia were most efficient at carrying over N to subsequent crops, with 76-155 kg N/ha accumulated in the fall. The earlier the crops were planted, the more N was carried over with only negligible N contributions from September and October plantings. Barley was planted in the spring following cover crop growth. The highest barley yields were in the oilradish fields (yields were correlated with cover crop biomass and N-content).

Ryegrass and oats were slow to break down. They inhibited the following yields of spring-planted barley. This points to the advantage of combining catch crops—perhaps a mix crimson clover, oats and a brassica would be ideal. The clover and brassica would break down more quickly and have less of an allelopathic effect than the ryegrass or oats.

The study concluded that fall-planted cover crops do not appear to influence the levels of residual (leftover) soil nitrate and consequently will do little to reduce leaching of nitrate from intensively cultivated soil in the fall. The exception is oilradish, which significantly reduced soil nitrate levels.

## CHOOSING THE RIGHT COVER CROP

To choose the most suitable cover crop for a specific use, consider the following factors:

**Rotational fit.** Consider the type of cover crop in terms of the crop rotation. For example, oilradish is a brassica, so it should not be grown where broccoli will be grown in the following year. Buckwheat and phacelia have the advantage of being unrelated to crops.

**Soil and seedbed preferences.** Some cover crops are rather finicky in terms of soil and seedbed preferences. Farmers should choose cover crops that are adapted to their specific soil conditions, and available equipment. For example, farmers who don't have the equipment to make a firm smooth fine-textured seedbed might consider frost-seeding small-seeded crops, or simply using larger-seeded crops.

**Seeding time.** Some cover crops grow well in the summer (eg. buckwheat) and others (eg. oilradish) are great for autumn growth. Small-seeded cover crops, such as most clovers, can be frost-seeded in late winter.

**Cold-hardiness.** Fall-planted cover crops that winterkill often save time in the spring. However, any crop planted in the early spring or fall should be somewhat frost-hardy.

**Height and ground cover.** Living mulches should be low-growing whereas a green manure or catch crop can be quite tall. For erosion and weed control, the cover crop should provide a thorough ground cover.

**Rooting system.** Cover crops with strong and deep taproots are good for breaking up hardpans and bringing up nutrients from deep in the soil. Extensive root systems (either fibrous or taproots) are good for catch crops. The fibrous root systems of grasses and cereals add organic matter, as well as help control erosion and compaction.

**Growth.** Fast-growing crops are suitable for weed control, erosion control and catch crops. Slow-growing crops should be weeded either until they become established, or planted with another crop (either seeded with a fast-growing crop or overseeded into an existing crop). However, some fast-growing cover crops (eg. buckwheat, oilradish) also go to seed within a couple of months after planting.

**Competitiveness.** Cover crops should provide weed control, either through smothering the weeds or by allelopathic suppression. Living mulches however, should not compete with crops.

**Seeding cost.** The seeding cost of a cover crop reflects both the cost of seed and seeding rate. The cost of the seed often reflects the seeding rate (and size of seed). Many expensive crops (like white clover) are small-seeded have low seeding rates. Farmers also might consider saving seed.

**Maintenance.** Some cover crops may need weed control at first, or may need to be mowed to prevent them from going to seed. As well, some cover crops are difficult to till in without mowing first (eg. ryegrass, vetch, two-year old sweetclover).



**N-fixation.** Some legumes are more efficient at N-fixation than others. (See Table 2.)

**Other uses.** Ideally, cover crops are multi-purpose crops. Some provide habitat for bees and other beneficial organisms. Others provide forage for animals or human food.

**Compatibility with another cover crop.** Often a combination of cover crops is better than planting one alone.

**TABLE 2. Matching cover crops with uses.** Examples of suitable cover crops.

<b>Use</b>	<b>Suitable cover crops</b>
N-fixation	<i>Heavy N-fixers:</i> alfalfa, vetch, lupins, fava beans, crimson clover <i>Moderate N-fixers:</i> field peas, birdsfoot trefoil, field peas, soybeans, sweetclover and alsike, Berseem, white and red clover <i>Light N-fixers:</i> common bean, subclover
Weed control	Ryegrass, buckwheat, fall rye, winter wheat, oilradish, mustard, crimson clover. Many legumes (eg. alfalfa, subclover, white clover, vetch) provide good weed control once they are established.
Adding organic matter	Ryegrass, fall rye, oats, fava beans
Breaking up hardpans	Oilradish, sweetclover, red clover, alfalfa, lupins
Ground cover	Ryegrass, subclover, white clover
Catch crops	<i>For summer catch crops:</i> buckwheat, ryegrass, phacelia <i>For fall catch crops:</i> oilradish and other brassicas, fall rye
Living mulches	White clover, subclover, ryegrass
Forage and fodder	Alfalfa, birdsfoot trefoil, Berseem clover, red clover, oats
Bee plants	Phacelia, buckwheat, alsike clover, fava beans, sweetclover
Human food	Fava beans, field peas, soybeans, cereals

## INOCULATING LEGUMES

Nitrogen fixation occurs when certain soil bacteria (rhizobia) infect the roots of legumes. The bacteria enter the roots and form growths called nodules. Nodules are formed when the plant is 2-3 weeks old, and disappear when the legume sets seed or undergoes harsh conditions (eg. drought). Inside these, the bacteria convert nitrogen in the air to a form of N that plants can use.

The process of N-fixation uses energy from the plant. Consequently, N-fixing plants usually grow more slowly and take longer to become established than other plants.

To check for nodules, dig up a legume that is at least a month old but not yet flowering. Shake or wash the soil from the roots. The nodules look like round or rod-shaped tubers on the root. Break a few nodules open. If the inside is pink or red, the nodules are actively fixing N; inactive nodules are green, brown or black inside.

Most species of N-fixing bacteria are generalists and will form nodules in several different cover crops (Table 3).

**TABLE 3. Suitable inoculants for various groups of legumes.** For optimal N-fixation, farmers should use the inoculants specific to a particular type of legume.

Type of inoculant	Legumes
Alfalfa / medic	Alfalfa & medic ( <i>Medicago</i> ), sweetclovers ( <i>Melilotus</i> ), Berseem clover ( <i>Trifolium alexandrinum</i> )
Bean	Beans ( <i>Phaseolus</i> ) not including soybeans
Clover	True clovers ( <i>Trifolium</i> ) not including sweetclover; crimson clover has a specific inoculant
Cowpea	Cowpeas ( <i>Vigna</i> ), peanuts ( <i>Arachis</i> )
Crownvetch	Crownvetch ( <i>Coronilla</i> )
Lotus	Lupins ( <i>Lupinus</i> ), trefoils ( <i>Lotus</i> ), chickpea ( <i>Cicer</i> )
Pea	True peas ( <i>Pisum</i> ), vetches ( <i>Vicia</i> ), lentil ( <i>Lens</i> ), chickling vetch ( <i>Lathyrus sativus</i> )
Soybean	Soybeans ( <i>Glycine</i> )

(From Sarrantonio, 1994)

Rhizobia can survive in the soil for a couple of years. However, adding a commercial source of rhizobia (called inoculant) is an inexpensive way to maximize rates of nitrogen fixation.

The inoculant contains live bacteria and must be stored in a cool place (eg. fridge or coldroom) until use. Be sure to use fresh inoculant (check the 'best before' date)

To inoculate legume seed, add just enough water to moisten the seeds and then mix in the inoculant. The seed must be planted immediately; rhizobia will die if the inoculant dries out.

Certain inoculants are made from genetically modified organisms (GMOs). Certified organic growers *must* ensure that the inoculants they use are GMO-free.

Sarrantonio (1994) recommends wetting the seed with a sugar-water solution (1 table-spoon sugar/pint) and adding 1/2 teaspoon of this to every pound of seed. This helps the inoculant stick to the seed. Other farmers have used milk instead of sugar water. Once mixed with the sticking solution, the seed should be planted immediately. Note that certified growers must ensure that the sticking agent is not genetically modified.

## SEEDING

### Preparing the seedbed

Ideally, the seedbed should be weed-free, firm and level. Legumes, in particular, require a well-prepared seedbed. If preparing a firm seedbed is not possible, farmers should either increase the seeding rate or choose a cover crop that is tolerant of rough seedbeds (generally the larger-seeded varieties). Some small-seeded clovers are particularly demanding, such as Berseem clover. In the NSOGA study, Berseem clover grew well at one farm where the seedbed was smooth and the seed was tamped in, but was hardly established wherever farmers lacked the time and equipment to create a smooth and firm seedbed. At these farms, a more tolerant clover, such as red clover, would have been more successful.

N-fixation rates are highest in soils with fairly low levels of nitrogen and adequate levels of phosphorus and calcium. If there is a lot of nitrogen in the soil, the legumes use the available nitrogen rather than fixing more.

### Seeding

A range of seeding rates for cover crops is provided in *Cover Crop Profiles*. The lower seeding rates should be used when drilling seed under optimal conditions. The high rates should be used if the seed is broadcast,

or growing conditions are less than ideal.

For example, increase rates when:

- the seedbed is rough,
- you are planting late in the fall when growth will be slow,
- the seed that has questionable germination rates, or
- for any other reason you don't expect to have optimal rates of germination, establishment and/or growth.

The ideal seeding rates can also vary with the variety of a crop used, and even the lot number, particularly for large-seeded crops. For example, one type of fava bean may have almost twice as many beans per pound than another type. The seeding rate should be adjusted accordingly.

When combining grasses and legumes, you can use the following seeding formula:

$$\frac{1}{2} \text{ grass seeding rate} + \frac{2}{3} \text{ legume seeding rate}$$

When planting (either broadcasting or drilling) a cover crop for weed control, seed 1/2 the seed in one direction, then the other half at right angles to the first pass. In biodynamic farming, the large seeds are drilled in one direction, and the small seeds drilled at a 30-degree angle to the first drilling.

The seeds should be watered after planting, particularly in mid-summer. If irrigation is not possible, try to time planting to coincide with a rain shower.

### **Firming the seedbed**

You need to have a firm seedbed with a fine texture before you plant to ensure even seeding. Firming it after planting ensures contact between the seed and the soil, and this leads to higher rates of germination.

To create a firm seedbed, you can rake or lightly harrow the soil before planting. Afterwards, create a firm bed by rolling, tamping or packing the soil (without compacting it). The seed can be covered by raking or harrowing it lightly. These steps are crucial, particularly for small-seeded crops, such as clover.

In the NSOGA study, most, if not all, of the cover crops that had poor establishment and growth, were either not raked in or were harrowed too deeply.

The seeds that were broadcast and not covered often failed because they either didn't germinate, they sprouted then dried up, or were eaten by birds. If rates of germination and establishment are poor, the

cover crop stands become weedy and have poor growth.

At a couple of farms, small-seeded cover crops were covered too deeply and had poor germination. The cover crops were chain-harrowed at one site and another farmer slightly disked over the seeds (with the disc at an angle). These techniques worked well for the large-seeded crops (eg. vetch, oats and buckwheat) but were less successful for the small-seeded crops. Small-seeded crops (eg. white clover) should be covered with no more ¼-inch of soil and should be either raked by hand or lightly harrowed with a spring-tooth harrow.

### **Frost-seeding**

Clovers can be frost-seeded into stands of winter grain. To frost seed, simply broadcast seed onto snow or frozen ground. The seed will be drawn into the soil by freeze-thaw cycles. The clover can get an early start and can provide better weed control than clover planted after the land can be worked in the spring. Clover is also frost-seeded into pastures. Frost-seeding is most effective if pastures were heavily grazed in the fall. The pasture should be grazed for a short time once the grass begins to shade the clover.

## **MOWING AND MANAGING COVER CROPS**

### **Weed control**

Ideally, weeds should be controlled until cover crops become established. Blind harrowing is sometimes used to control early weeds. The field is lightly harrowed after the crop is planted but before it emerges. On a small-scale, farmers can try 'blind raking.' NSOGA farmers controlled weeds in clover living mulches by hand-pulling or mowing the weeds until the clover was established.

### **Mowing**

A cover crop can be killed, suppressed or stimulated by being mowed; the effect depends on how high the crop is mowed, the time of the year, the age of the cover crop, and the type of cover crop.

Most cover crops can be killed by mowing them close to the ground, particularly when they are in flower or if they are hit by a heavy frost after the mowing. In this way, the cover crop can be killed without tilling

and the ground will remain covered. However, mowing the more tenacious cover crops to prevent them from going to seed doesn't always work. When we mowed oilradish (before flowering), it quickly grew back. When we scythed flowering oilradish, it simply flowered (and went to seed) at a height too low to be scythed. Viney plants are more easily mowed if they are grown with a supporting companion plant (eg. oats).

Mowing can help give cover crops a competitive edge over weeds. Cover crops, such as ryegrass and most clovers, grow more vigorously after being mowed. To stimulate growth by mowing, mow quite high before the plants have gone to flower. If the plants are stressed by drought or frost, mowing may kill, rather than stimulate, them.

### **TO REDUCE COMPETITION BETWEEN THE LIVING MULCH AND CROP:**

Three common organic ways to reduce competition include:

(1) schedule planting so that the mulch is not growing vigorously during the crop's critical growth period,

(2) mow the living mulch, or

(3) till strips in an established living mulch, and plant the crop in the tilled strips.

The living mulches don't have to be suppressed all season-long, just during the cash crop's critical growth period. At other times, the mulch should be allowed to grow (and fix N and/or add organic matter).

#### **Schedule planting times**

A simple way to reduce competition is to plant the mulch late enough in the season, so the mulch and crop won't be growing vigorously at the same time.

In one study, living mulches were seeded

(1) five weeks before,

(2) at the same time as, and

(3) five weeks after sweet corn was planted.

The results showed that planting the crop and mulch at the same time worked best—planting early led to competition, and planting late led to weed problems.

Most organic growers in the Nova Scotia study preferred to plant the living mulch at

the same time they were transplanting the crops. This way, the mulch was planted when the seedbed was already prepared and weeded. Another successful method is to plant living mulches right after the first weeding.

#### **Mow the mulch**

Mowing can reduce competition between living mulches and crops while maintaining ground cover and weed control. Both small-scale hand mowers and field-scale cutters can be used. Mowing can stimulate the growth of some cover crops and improve their ability to compete with weeds.

In one study, hairy vetch was planted in fall, and mowed in the following spring. Tomato seedlings were then transplanted into the mulch. Although the mulch delayed fruit maturity by ten days, plants in the mowed vetch treatment had higher yields than those grown under black plastic, paper or no mulch. Another study found that mowed living mulches of vetch and vetch/rye consistently produced better broccoli and cabbage yields than a rye living mulch, or no mulch.

In the NSOGA study, we found that vetch can overwhelm tomatoes. However, perhaps

living mulches can be managed to produce the right amount of stress for extra fruiting. Fruit-bearing plants (eg. tomatoes, peppers, grapes) should be a little stressed during fruiting so that they put more energy into producing fruit than into leaves.

### **Till the living mulch**

One way to use living mulches is to till strips in an established living mulch and plant (or transplant) the crop into the strips. Planting squash in tilled clover has worked well. The clover suppressed weed growth but did not inhibit squash growth. With this method, the ground is completely covered year-round, and the crops can benefit from additional nitrogen. In Maritime Canada, this method would likely work best with a low white clover. As well, living mulches can be partially rototilled shortly after the emergence of the main crop. By rototilling

in a way that a strip of roots passes intact between the tines, some mulch will be turned under and add organic matter to the soil while the mulch itself can survive. One study found that partially rototilled white clover plots produced as much corn as plots that used herbicides.

There are several other ways to reduce competition between a crop and living mulch, without using herbicides. One study found that corn yields increased by planting white clover between narrow corn rows (38 cm/15 in.). When corn rows were far apart, the clover competed with the corn but when the rows were narrow, the corn over-shadowed the clover. The clover was suppressed enough that it didn't compete, but grew well enough to fix N.

## **INCORPORATING COVER CROPS**

Green manures are usually tilled under before they set seed. Viney plants (such as vetch) and tough fibrous plants (such as sweetclover) can be difficult to incorporate. These can be mowed before tilling, or better yet, mowed throughout the summer.

### **No-till techniques**

Rather than tilling cover crop residue, the mulch can be left on the surface and crops planted into it. To do this, the cover crops can be killed by mowing very low to the ground, smothered with an opaque mulch or be winterkilled. These no-till approaches avoid many negative consequences of tilling, and keep the soil covered and protected from erosion. However, by simply leaving the mulch on the soil, a small amount of nitrogen may be lost to the air and decomposition may be slower (due to less contact between mulch and soil organisms and often poor temperature and

moisture conditions).

At Windhorse Farm, no-till techniques are used that are fast, simple and effective at conserving soil nitrogen. Before cover crops go to seed, hay bales are placed over the cover crops to smother them. The hay is removed 4-6 weeks later, exposing beautiful rich soil below. The hay (which was cut before going to seed) is then used as a mulch to protect the soil.

At a grassy area of the farm, sod was mowed low and buckwheat was broadcast. The grass and weed clippings were then put over the buckwheat. The buckwheat emerged through the mulch within a week, even though there had been no rain or irrigation. Another no-till technique to bring hayfields into vegetable production is to burn sod with manure slurry, and then plant a catch crop.

### **Timing of incorporation**

When succulent crops, particularly nitrogen-rich ones, are incorporated in warm soil, they will decompose rapidly. The nitrogen is transformed into a soluble form that will leach out of the soil if it isn't taken up by crops.

There are a few ways to avoid this type of nutrient loss.

- Plant a fast-growing catch crop right after tillage (e.g. buckwheat or oats).
- Incorporate some carbon-rich material (straw or leaves) into the soil immediately after tillage.
- Leave incorporation until the fall when the temperatures are cooler; in this case, just partially incorporate the residues so that there is ground cover.
- Plant fibrous cover crops with the succulent ones when possible. A green manure of mature oats and red clover will add both nitrogen and stable organic matter (humus).

### **Waiting before planting the next crop**

After tilling in cover crops, wait before planting a new crop (at least 1-2 weeks after turning under a legume, and 2-3 weeks after a grass or grain). After tilling a crop under, the decomposing material releases ethylene gas that inhibits germination, and the microorganisms breaking down the crop tie up nitrogen. The temporary N deficiency may hinder the growth of seedlings. As well, some cover crops have allelopathic effects that inhibit germination of other crops (particularly small-seeded crops).

Two NSOGA farmers planted onion sets into two parts of a field where clover had grown. For most of the field, the clover had been turned under two weeks before planting onions. In the rest of the field, the clover had been tilled the same day as the onions were planted. Two months later, there was still a dramatic difference between the areas. Where the land had rested, the

onions looked fine. However, many of the onions that were planted right after tilling had died and the surviving ones were stunted.

Students at Windhorse Farm experimented with the lag between tilling and planting. After turning sod under, buckwheat was immediately planted. For a few weeks the buckwheat was stunted and spindly, (compared to where they waited before planting) but then recovered and grew very well.

## **ON-FARM RESEARCH**

There is a lot of potential for on-farm research to answer pressing questions for organic growers. There are, however, key ingredients to the success of on-farm research.

First is the will to know more than what the extension and other literature can offer and more about what your particular farm or garden can achieve. For example, we found that if we tried to investigate two questions, four new questions emerged.

Second, a strong link to government researchers and libraries is crucial to ensure that we have access to the tools, methods and literature to keep our research current, and to prevent us from wasting time on questions that had already been answered. With the NSOGA study, government researchers helped to review proposals, provide information about seeds and cultivars and give us insights into data that is best collected on research stations.

Third, it was important to have links with other farm research groups. Some of the most valuable ideas and methods came from on-farm research groups from around the world.

Fourth, the local network of farmers connected with the Nova Scotia Organic Growers Association provided a crucial forum for answering questions and generating ideas. The popular farm tours solidified the experience and multiplied the learning beyond just cover crops!

The fifth crucial ingredient is funding. We are grateful for the support received, but it was never enough to do the job properly. Fall-to-spring experiments were never possible because of funding restrictions. We were not able to do as many analyses as needed. Given that NSOGA had different results from different farms, and that increased learning from each experiment or trial is multiplied by the variety of sites, it is important to recognize the cost-effectiveness and increased potential for important discoveries presented by on-farm research.

### **METHODS FOR ON FARM RESEARCH**

Farmers and gardeners are always experimenting. During the course of this cover crop project, we learned a few things that might help along the way.

- (1) Use a control. If a new plant or technique is being tried out, test it alongside the normal practice. Better yet, divide an area so there can be two or more control plots (normal practice) beside the same number of test plots (new practice). It is better than comparing from one year to the next, or from one farm to the next.
- (2) Replicate studies. Developing an understanding is easier when similar tests occur in the same year on several different farms, or several different locations within a farm. This way you can learn if a new plant grows well in sandy or clay soil, short-season or long season locations, under intense management or little management. This requires co-operation from neighbours!
- (3) Keep experiments or trials simple. Try one or two things at a time, and set up only as much as you can meaningfully make observations from (keeping in mind hectic production schedules).



(4) Decide well in advance what information you really need, and draw up a data collection schedule for the various parameters (groundcover, pest-damage rating, yield, height, soil tests etc). Try to get someone else who is unbiased to collect the data for you. Of course, sometimes the difference between treatments is so obvious that eyeballing it is enough.

(5) Learn from accidents. Spilled seed, interrupted field operations and casual comments from visitors are all potential information sources. Having good field records of what was growing where and when will help to answer questions when the next year's crop flourishes or fails. It also helps to get out often to look at what is going on, and to ask field workers to report anything unusual also. Bring your shovel, magnifying glass and journal into the field.

Useful resources on on-farm research include *Northeast Cover Crop Handbook* (Sarrantonio, 1994), *Methods for Screening Soil-Improving Legumes* (Sarrantonio, 1991), back issues of *Sustainable Farming* (a magazine produced by REAP-Canada no longer printed), and the *American Journal of Alternative Agriculture*.

# COVER CROP PROFILES

**There are four types of cover crops to choose from:**

## **LEGUMES**

Legumes fix nitrogen and are usually grown as a green manure. Some legumes are used as living mulches, and this way they can add nitrogen to the soil without disrupting rotations of cash crops. Succulent young legumes decompose quickly after they die, and consequently do not significantly increase the levels of soil organic matter.

Legumes have taproots, which can sometimes break up hardpans or bring up nutrients from deep in the soil. Legumes are often grown with grasses; this increases weed control, prevents bloat if used for forage, and adds organic matter. For optimal levels of N-fixation, seeds should be inoculated before planting. Well-prepared seedbeds are needed by most clovers.

## **GRASSES & CEREALS**

Grasses and cereals grow quickly and provide effective weed control. They produce large quantities of plant material both above ground and in their fibrous root systems. The plant material is slow to decompose, and adds large amounts of organic matter to the soil. Grass and cereal seed is normally inexpensive.

## **BRASSICAS**

Brassicas are usually chosen as winter-killed catch crops. They have a very fast growth start, and are generally effective at taking up residual nitrogen in the field after the crop is harvested. They break down quickly once killed, and have a negligible effect on levels of soil organic matter.

## **HERBS**

Herbs include a variety of plants such as phacelia and buckwheat. These plants often grow quickly, accumulate nutrients and are used as bee plants.

As with brassicas, herbs decompose quickly and do not contribute much soil organic matter. Some herbs have the additional advantage of stimulating soil life, and others provide habitat for beneficial organisms such as parasitic wasps and pollinating insects.

# LEGUMES

## **Alfalfa (*Medicago sativa*)**

- also known as lucerne; a long-lived, perennial legume
- grows 1-2 feet high (up to 4 feet if uncut) and has a strong, deep taproot (with records of up to 30 feet long)
- Trefoil, also called black medic, is a relative of alfalfa that becomes established more quickly and grows quickly in the fall. Trefoil is less winter-hardy than alfalfa.

### **Applications:**

#### **Green manure**

- alfalfa is a high N producer and can help make P and micronutrients more available to subsequent crops
- a plowdown of alfalfa can supply 80-100% of N needed for winter wheat
- unlike most legumes, a mature stand of alfalfa can increase levels of soil organic matter significantly

#### **Fodder**

- alfalfa is high protein feed with twice the protein yield of red clover and 4-5 times the protein of oats
- can cause bloat

#### **Weed control**

- seedlings can't tolerate competition, but is highly competitive once established

## **Birdsfoot trefoil (*Lotus corniculatus*)**

- perennial with prostrate growth; grows slowly at first and often has poor seedling vigour.

### **Applications:**

#### **Erosion control**

#### **Green manure**

- moderate yields with moderate N

#### **Forage and fodder**

- does not cause bloat
- livestock can more efficiently use the protein than in alfalfa or red clover

### **Growing conditions:**

- prefers rich, well-drained soil, with a pH of 6.0-7.5
- can't tolerate wet, extremely sandy or heavy clay soil
- requires high levels of potassium for long-term viability
- drought-resistant

### **Seeding and management**

- sow at 18-25 lbs/A (20-28 kg/ha) at 3 to 2 inch deep
- can be cut a few times in a season and use the mulch elsewhere
- due to the extensive root system, alfalfa can be difficult to kill

### **Growing conditions:**

- adapted to moderately acid to neutral soils including poorly drained soils
- shade-sensitive
- less winter-hardy than alfalfa

### **Seeding and management:**

- seed at 10-15 lb/ac. (11-17 kg/ha)
- usually planted with grasses

# CLOVER

Clovers are usually less than two feet tall, and have taproots that extend a foot or two into the soil (ie. more shallow than roots of alfalfa or sweetclover). Clovers need a firm, weed-free seedbed. They usually emerge within a week after seeding, but have slow establishment and slow growth. Successful clover establishment and nodulation depends on adequate moisture. This points to the importance of building up good soil organic matter for successful use of legumes in vegetable systems. Organic matter helps to retain moisture during dry spells and helps with drainage during wet periods.

Clovers are grown primarily to add nitrogen to the soil. They usually don't add much biomass, and clover tissue readily degrades, so clover doesn't contribute organic matter to the soil. For weed control, clover should be planted with grasses, or planted with a nurse crop (eg. grain). Once established, clover can be fairly competitive with weeds.

Clover produce high-protein forage and fodder—this will often cause bloat unless the clover is mixed with a grass.

## **Alsike clover (*Trifolium hybridum*)**

- slow-growing, perennial with fine leaves and stems, survives 2-3 years
- 6-inches to 2-feet tall, with roots in the top foot of the soil

### **Applications**

#### **Green manure**

- can be oversown into grain, or frost-seeded, or sown at a late snowfall
- yields 1/3 less biomass than red clover
- is a moderate N-fixer
- great in wet meadows
- very slow establishment

#### **Excellent honey plant**

### **Growing conditions**

- prefers heavy, fertile loams
- thrives in wet conditions, including flooding
- tolerates acidic and alkaline soils better than other clover
- shade-tolerant

### **Seeding and management**

- seed at 4-10 lb/ac. (5-11 kg/ha) at 2 in.
- seedbed should be firm and weed-free

## **NSOGA Results**

- At Coldspring Farm, alsike clover was planted between rows of squash. Alsike plots contained more weeds than crimson clover, subterranean clover and ryegrass plots (but fewer weeds than in the vetch plots). As well, alsike produced more biomass and nitrogen than subclover, but much less than crimson clover.

## **Berseem Clover (*Trifolium alexandrinum*)**

- also called Egyptian clover
- winterkills in Nova Scotia
- grows upright more than 2 feet tall and has oblong leaflets
- reported to have good seedling vigour, rapid growth and rapid regrowth after mowing

### **Applications**

#### **Green manure**

- produces a large biomass for plowdown
- has a taproot with many branches
- moderate nitrogen-fixer

#### **Smother crop**

- good due to its fairly quick establishment

#### **Forage and fodder**

- high quality feed
- no reported cases of bloat
- very palatable to livestock (when fed to dairy cows, it increases the fat content of milk)

### **Growing conditions**

- grows in variety of soil types.
- tolerates alkaline and wet soils, and should be planted where the soil pH is 6 or higher.
- similar to alfalfa in drought-tolerance; moderate tolerance to waterlogged and saline soils
- survives light frost, but winterkills in the Maritimes (at -8C)
- not very shade tolerant

### **Seeding and management**

- should be seeded at 9-20 lbs/A (15-20 kg/ha)
- needs a well-worked seed bed and must be lightly harrowed or tamped in.
- mowing or grazing the clover closer than 3-4 inches from the ground could kill it, but it regrows quickly if mowed high before flowering

## **NSOGA Results**

- Berseem clover grew well at one farm where the seedbed was very well-prepared and at another farm with a weedy and rough seedbed. At other farms, where Berseem was either not raked in, not tamped or harrowed too deeply, Berseem had poor establishment.
- Berseem grew at about the same rate as crimson clover; however, Berseem was not as effective at weed control due to smaller leaves and a more upright growth.
- Berseem clover grows 80 cm tall before flowering. Clover planted June 25 didn't begin to flower until November (18 weeks later), and shortly thereafter was killed by frost.
- Berseem seems to have secondary growth occurring all over the plant after it is cut. It is opportunistic wherever there is light.

## **Crimson clover (*Trifolium incarnatum*)**

- usually 1-2 feet high with long, crimson flowers
- germinates well even in droughty conditions; grows faster than most other legumes.
- flowers in 70-90 days and goes to seed very soon after
- may survive (in patches) after mild Maritime winters

### **Applications**

#### **Green manure**

- produces more growth and grows faster than many other legumes
- moderate N-fixer
- crimson clover can be mowed several times in a season; repeated mowing will stimulate growth and delay flowering as long as it is mowed no lower than 3-5 in. from the ground

#### **Weed control**

- it grows quickly and is good for intercropping
- crimson clover is tall and doesn't cover the ground as completely as the low-growing white and subclover

#### **Erosion control**

- good on hillsides

#### **Fodder**

- palatable and seldom causes bloat

### **Growing conditions**

- prefers loam soils that are high in humus but is adapted to sandy well-drained soils with ordinary acidity
- will grow in soils with low fertility
- prefers cool, humid conditions but hairy leaves hold moisture in dry conditions
- shade-tolerant

### **Seeding and management**

- seed at 30-40lb/ac. (34-45 kg/ha) of unhulled seed, 15-20 lb/ac. (17-22 kg/ha) of hulled seed.
- seed at least 60 days before killing frost.
- must have adequate moisture for good germination and growth, so sow between rains or irrigate after planting
- should be killed soon after it flowers by mowing low when flowering
- inoculated with specific crimson clover inoculant for best results

## **NSOGA Results**

- At one farm, crimson clover was planted in late summer one year, overwintered and following year it had gone to seed by the end of June. Volunteers were easy to kill.
- Crimson clover was a great green manure. It grew more quickly, provided better weed control and added more plant biomass than any other clover studied.
- If mixed with a grass, the combination provided better weed control and covered the ground more completely than crimson clover alone. Crimson clover combined with oats produced more biomass and contained fewer weeds than crimson clover & ryegrass.
- Crimson clover was successfully used to control weeds between squash rows.
- A stand that was mowed once provided 99% weed control—better than any other plant studied.

## **Red clover (*Trifolium pratense*)**

- short-lived perennial that overwinters in the Maritimes
- grows 6 inches to 2 feet tall and has strong taproot with many branches
- grows slowly at first but becomes more quickly established than alfalfa and many other small-seeded clover.
- the most aggressive perennial legume used in the Maritimes

### **Applications**

#### **Soil conditioning**

- good for loosening up soils and bringing up nutrients including phosphorus and micronutrients

#### **Green manure**

- produces heavy crops in the Maritimes
- fixes moderate amount of N

#### **Living mulch**

- provides good ground cover in orchards and can be frost-seeded into winter grains.

#### **Weed control**

- good because red clover can cover the ground completely.

#### **Forage and fodder**

- in the Maritimes, red clover is often grown with grasses for hay and silage, and plowed under after 1-3 years
- produces excellent forage, but should be planted with grasses to prevent bloat.

#### **Seed crop**

The seed can be harvested under Maritime conditions.

### **Growing conditions**

- adapted to slightly acid to neutral soils.
- grows best on loam rich in organic matter, not as well on stiff clays and loose sandy soils
- can tolerate moderate drainage, clayey and acidic soils better than alfalfa and many other green manures.
- shade-tolerant

### **Seeding and management**

- seed at 12-18 lb/ac. (13-20 kg/ha) at 3-1/2 inch deep.
- great establishment if planted with a nurse crop (eg. oats)
- can be frost-seeded into winter grains.
- can be mowed many times, as long it isn't cut below 2 in. high
- can survive being mowed when it is flowering (since it isn't an annual)
- seeds are viable for a long time, so if it goes to seed, there will be clover coming up for years.

## **Subterranean clover (*Trifolium subterraneum*)**

- also called subclover
- low-growing annual
- called subterranean because the mature seed heads become buried in soil
- produces tight, thick sward that's very effective at suppressing weeds.
- has rapid germination and early growth.

### **Applications**

#### **Weed control**

- excellent at smothering weeds (including under heavy grazing pressure)
- produces very thorough ground cover

#### **Green manure**

- not as effective green manure as some other clovers because of its low height and poor to average ability to fix N.

#### **Living mulch**

- excellent living mulch due to subclover's ability to suppress weeds and low growth.
- attracts beneficial insects

### **Growing conditions**

- prefers sandy soils with a pH between 6.0-7.5.
- can survive mild Maritime winters

### **Seeding and management**

- seed at 10-20 lbs/A (11-22 kg/ha) at 3 to 2 inch deep.
- can be mowed or grazed several times.

## **NSOGA Results**

- Subclover was used as a living mulch under several types of vegetables. Generally, it produced excellent ground cover and controlled weeds well. However, subclover often competed with the crops, more so than white clover.
- When used as a living mulch with root crops, subclover completely smothered the root crops. When intercropped white cabbage, it led to reduced yields in white cabbage.
- Subclover appeared to be an effective living mulch for Chinese cabbage, tomatoes and squash.
- At a few farms, some patches of subclover survived the mild winter of 1994-95.



## **White clover (*Trifolium repens*)**

- perennial clover that overwinters in most of the Maritimes.
  - low-growing clover (usually 4-6 in. tall).
  - has a dense root system in the top 8 inches of soil with a taproot that can extend a few feet deep.
  - develops slowly in first year then spreads (by stolons) in following years. Established stands will last for years and require little maintenance.
  - has excellent regrowth after cutting.
- Varieties: the common (or Dutch) clover grows up to 8-in. high; Kent clover is a dwarf cultivar, Sonja is taller than the common white and often used for grazing; and Ladino is the tallest type.

### **Applications**

#### **Intercropping/pathways**

- often used in pathways between rows of crops because it can handle traffic well.

#### **Erosion control**

- forms a thick and complete ground cover.

#### **Living mulch**

- effective living mulch around vegetables (is low-growing and shade-tolerant).
- excellent perennial mulch in orchards or between raspberry rows.

#### **Green manure**

- fixes moderately high levels of N
- produces less biomass than many other clovers because of its low height

#### **Weed control**

- poor to fair weed control; more competitive if mowed.

### **Growing conditions**

- prefers humus-rich, well-drained clay loam and loam soils, with a pH of 6-7.
- needs high P and K levels.
- fairly tolerant of wet soils (compared to more other legumes).
- low drought-tolerance.
- shade-tolerant.
- cold hardy to zone 4.

### **Seeding and management**

- seed at 7-12 lb/ac. (8-13 kg/ha) at 2 inch deep and then roll or tamp.
- can be frost-seeded.
- mowing (to 2-3 in. high) or grazing stimulates the growth, health and competitiveness of stand.
- will winterkill if mowed low in late fall.
- should be grown with grasses only if the stand is mowed frequently; otherwise the grasses will outcompete the clover.

## **NSOGA Results**

- White clover is used for pathways at many NSOGA farms. Most farmers are quite satisfied with this use, however a few found that white clover became invasive after a few years.
- NSOGA farmers evaluated the use of white clover as a living mulch under various crops. It was successful under tomatoes, corn, Savoy cabbage and sometimes under white cabbage.
- In the dry summer of 1994, clover grew little and didn't compete with the cabbages. Cabbages grown with white clover were slightly larger than those grown in bare soil, indicating that the cabbages may have benefited from the clover.
- In 1995, white clover thrived and competed with the white and red cabbage (but not the Savoy cabbage). Mowing white clover between rows of corn and cabbages was successful at reaping the benefits of a living mulch without having it compete with the crop.

## **Lupin (*Lupinus spp.*)**

- there are two main strains, blue lupins (*L. angustifolia*) and white lupins (*L. albus*).
- have strong taproots.
- 'Wild' lupins contain alkaloids which make them unsuitable for feed, but also unpalatable to insects and other pests. New alkaloid-free (sweet) strains can be used as fodder, but are not as hardy as the old strains.

### **Applications**

#### **Green manure**

- can fix nitrogen under poor conditions, but are poor at controlling weeds

#### **Building poor soils**

- lupins can build up sandy and worn-out soil by improving soil structure and bringing up nutrients from deep in the soil

#### **Breaking up hardpans**

- lupins have strong taproots that can break up hardpans and loosen heavy clay soils.

#### **Mulch**

- when the dead residue is used as a mulch, either turned under or left on the soil surface, it can suppress weed growth (due to alkaloids)

### **Growing conditions**

- prefer coarse, well-drained soils with pH of 5.0 to 6.5.
- blue lupins need moderate fertility; they mature faster than other lupins.
- white (the most winter-hardy of the lupins) need neutral, fairly fertile soil. Spring-planted white lupins will go to seed in autumn, or not at all.
- yellow lupins (the least cold-hardy) do well on moderately acidic infertile soil, and are great for sandy soils.
- need moist conditions until established but they are drought-tolerant once established.
- can tolerate frosts and temperatures down to -4 C.

### **Seeding and management**

- seed blue lupines at 100 lb/ac. (112 kg/ha), white lupins at 150 lb/ac. (168 kg/ha) and yellow at 80 lb/ac. (90 kg/ha), all at 1-inch deep.
- can tolerate rough seedbeds, and can be used in no-till systems.
- must be inoculated.
- no additional phosphorus or potassium needed; they scavenge these from the soil.

# PULSES

Pulses (peas and beans) can be used for green manures. Pulses fix large amounts of nitrogen. After flowering, much of the N is transferred to the bean or pea and is used to produce protein. If the beans or peas are harvested, only a small amount of N will be added to the soil.

Most pulses are not effective at weed control unless they are planted with grains.

Pulses can provide fodder for animals, and many pulses also produce food for humans.

## **Fava bean (*Vicia faba*)**

- varieties of this bean include faba, horse, tick, broad and field beans.
- upright plants usually 2-3 feet in height with strong taproots.
- small-seeded varieties (tick and field beans) are hardier, and produce more biomass and better weed control than the larger-seeded varieties. The fava beans, however, are edible, fresh or dried.
- slow to become established because the plant uses early energy to develop nodules for N-fixation.

### **Applications**

#### **Green manure**

- excellent N-fixers; they add a considerable amount of plant material and N to the soil.
- not great at controlling weeds unless sown densely or overseeded into grain.

#### **Soil conditioner**

- fava beans have strong taproots that can improve soil structure.
- fava beans add organic matter to the soil.

#### **Forage and silage**

- can be fed to livestock or grazed (however it won't regrow after grazing).

#### **Food**

- the beans are edible either fresh or dry; the larger ones are often preferred.

#### **Honey plant**

- provides nectar to pollinators.

### **Growing conditions**

- prefer well-drained, heavy loam high in organic matter and lime.
- must have cool weather and ample water; can tolerate light frosts (overwinters in zone 8+).

### **Seeding and management**

- seed small-seeded varieties at 80-125 lb/ac. (90-140 kg/ha) and large-seeded types at 70-175 lb/ac. (78-196 kg/ha). Seeding rates vary according to type of bean and whether the beans are grown for food (low rates) or green manures (high rates).
- sow 8 inches apart, 1/8 to 3 in. deep
- seed should be inoculated with vetch inoculant.
- turn under at flowering, or mow the stand, wait a few days and then turn under.
- won't survive being grazed or mowed.

## Field Peas (*Pisum arvense*)

- also called Austrian winter pea
- viney and succulent plants with shallow roots
- peas flower at 25-50 days and mature at 52-75 days after planting
- brassicas or densely-planted cereals are good companions and provide support for the peas

### Applications

#### Green manure

- fix large amounts of nitrogen
- the crop residue breaks down quickly (and does not add much organic matter)

#### Weed control

- provides effective weed control when grown with grains

#### Fodder and human food

- field peas are an excellent choice for a Maritime-grown source of protein for livestock feed

#### Erosion control

### NSOGA Results

- Field peas did well in dry conditions (when planted with barley on acidic clay soil).
- When grown with grains, the grain is more likely to lodge.

## Soybeans (*Glycine max*)

- upright growing annual that grows well in warm weather
- if grown with or before potatoes, soybeans can reduce the amount of potato scab

### Applications

#### Green manure

- excellent N-fixer, but much N is removed if the soybeans are harvested
- not suitable for increasing organic matter or for controlling erosion

#### Living mulch

- can be overseeded into grains or corn
- Fodder and human food

### Growing conditions

- requires cool, moist conditions and grows best in loam soils high in lime.
- likes moderate fertility (high fertility will lead to lots of vine and few peas)
- moderate drought-tolerance

### Seeding and management

- sow at 70-220 lb/ac. (78-245 kg/ha) at 12 in. deep as early as possible in spring
- needs a weed-free seedbed
- can be frost-seeded into grains
- don't respond well to mowing

### Growing conditions

- prefer loam with average fertility, but can grow in nearly all types of soil
- need high levels of phosphorus
- acid-tolerant and drought-tolerant
- need firm, moist seedbed

### Seeding and management

- seed 60-100 lb/ac. (90-190 kg/ha) 1-1.5 in. deep, and 2-3 in. apart in rows 7 in. apart.
- plant when the soil warms up
- can overseed a grain catch crop into soybeans when half of the soybean leaves are yellow (3-6 weeks before harvest).

# SWEETCLOVER

Sweetclovers are tall, branching legumes with long taproots. They are used to break up plowpans and draw up nutrients from deep in the soil. The sweetclover are great catch crops and green manures—they grow quickly and produce a large amount of biomass with moderate-high amounts of nitrogen. Unlike many other legumes, sweetclovers can be used to increase levels of soil organic matter, as well as provide nitrogen. The second-year growth is fibrous and, once it decomposes, will add humus to soils.

Bees are attracted to sweetclover, and the plants produce lots of nectar, which results in a mild-flavoured, light honey. Sweetclover should not be used as fodder; spoiled hay may contain a potentially lethal compound called coumarin which inhibits blood clotting in livestock.

Older plants can become woody and difficult to mow or incorporate into the soil; frequent mowing can prevent this problem. If not mowed, sweetclover can be ‘rolled’ down before being disked under. Sweetclover should be inoculated with alfalfa inoculant.

## **White sweetclover (*Melilotus alba*)**

- an annual sweetclover but can emerge the second year after planting, probably because there is a proportion of ‘hard’ seed – seed that doesn’t germinate the year it is planted.
- smaller than yellow sweetclover
- slow to become established

### **Applications**

- *as described in detail above*

### **Soil conditioner**

### **Green manure**

- moderate N-fixer

### **Catch crop**

### **Smother crop**

### **Honey plant**

### **Growing conditions**

- adapted to variety of soil types, clay to sand but prefer clay loams with neutral to alkaline pH
- won’t nodulate if the pH is lower than 6.0
- not cold-tolerant; has slow fall growth in the Maritimes and is killed by frost
- shade-tolerant

### **Seeding and management**

- seed at 15-30 lb/ac. (17-34 kg/ha) at 3 to 2 inch deep.
- see general information on sweetclover

## **Yellow sweetclover (*Melilotus officinalis*)**

- a biennial sweetclover
- grows 4-5 feet high in its second year (with records of up to 8 feet high) and has a long taproot (up to 8 feet long)
- very slow to become established
- the contributions to nitrogen and levels of soil organic matter are made during yellow sweetclover's second year of growth

### **Applications**

- *see sweetclover description on previous page*

#### **Soil conditioner**

#### **Green manure**

- high N-fixer, with large biomass in second year.

#### **Catch crop**

#### **Smother crop**

- provides good weed control in second year, also has allelopathic effects

#### **Honey plant**

#### **Living mulch**

### **Growing conditions**

- will overwinter in much of the Maritimes—is hardy to zone 4
- not very shade-tolerant

### **Seeding and management**

- seed at 10-15 lb/ac. (11-17 kg/ha).
- see general information on sweetclover
- Eliot Coleman overseeds yellow sweetclover into squash, onions, carrots and cabbages

## **NSOGA Results**

- Sweetclover was used as a living mulch for lettuce. The lettuce grew very well even though at maturity the two plants were about the same height—sweetclover isn't shade-tolerant and was suppressed by the lettuce. The lettuce did not appear to be suffering from competition (even though it wasn't watered); rather, it seemed to benefit from the sweetclover. After each crop of lettuce was harvested, the sweetclover was turned under and more lettuce and sweetclover were planted.

- For many years, Neil van Nostrand used yellow sweetclover as a green manure on poor land (the topsoil had been removed by a previous landowner). He didn't mow the sweetclover but instead rolled it before discing it under.

# VETCH

Vetch are viney, bushy legumes. They have taproots (1-3 feet deep) with a dense root system in top 8 inches of soil. Vetch are relatively slow to become established.

When used as green manures, vetch produce large amounts of nitrogen-rich plant material. This breaks down rapidly and quickly provides N (which can leach into groundwater if not taken up by a catch crop). Mowing before trying to disc the vetch in will make harrowing easier.

Vetch can help make phosphorus and micronutrients more available to subsequent crops. Half of the vetch N is available after plowdown; the other half becomes available in the following two years.

Vetch can be broadcast into late vegetables in late summer, or can be grown with grains, but don't expect a grain crop. The vetch will climb on the grain making harvesting difficult, if not impossible. Vetch can be overseeded but the seed must be covered and/or irrigated.

To kill vetch, mow it close to the ground or when it vetch is flowering (note that this is not always successful). Farmers can transplant into the residue. The freshly killed mulch may have allelopathic effects, so consider waiting a week or so before planting into it, and use transplants rather than small seeds. For hay, mow vetch at 3/4 bloom (this will kill stand). Caution: vetch can bind and catch in equipment.

## Common vetch (*Vicia sativa*)

- also called tares or spring vetch; has larger and rounder leaves than other vetches.

### Applications

- see *Vetch intro above*

#### Green Manure

#### Living mulch

#### Dead mulch

#### Erosion control

### Growing conditions

- adapted to slightly acid soils, but does very well in fertile soils
- less suitable for sandy soil than hairy vetch
- poor shade tolerance
- winter hardy to zone 8

### Seeding and management

- seed at 28-45 lb/ac. (32-50 kg/ha) 3/4 in. deep

## NSOGA Results

- Vetch worked well as a living mulch for cucumber, zucchini and winter squash.
- At a couple of farms, deer grazed the vetch and ignored neighbouring plots of oats and clover. This reduces the biomass that is added to the soil but may also reduce deer damage to crops.
- Vetch is slow to germinate; at many farms, the weeds became established before vetch. Where vetch was established, it provided great weed control. As it grew, the lower leaves died and formed a thick mulch, which smothered weeds and protected the soil from erosion.

## **Hairy vetch (*Vicia villosa*)**

- also called winter, sand or Russian vetch, similar to the wild tufted or purple vetch
- a biennial that overwinters in parts of the Maritimes.

### **Applications**

- see Vetch section

### **Green Manure**

### **Living mulch**

### **Dead mulch**

### **Erosion control**

### **Growing conditions**

- is best suited to well-drained soils and produces well on moist soils.
- has relatively high P and K requirements and can tolerate pH of 4.9 to 8.2, but prefers a pH of 6-7
- winter hardy to zone 4

### **Seeding and management**

- seed at 25-40 lb/ac. (28-45 kg/ha)

## **NSOGA Results**

- We compared common and hairy vetch and found that common vetch was more effective at controlling weeds and produced more biomass (foliage). It appeared that hairy vetch did less well in dry weather than common vetch.
- Hairy vetch took longer to germinate than white and subterranean clover; seedlings didn't appear for a week and a half after seeding.
- When hairy vetch was planted under cabbages, the cabbages were much smaller than those grown in either bare soil or straw mulch. Some farmers found it was time-consuming to clip the vetch to keep it controlled.
- Maggie Hope-Simpson and Derek Lynch grew hairy vetch. The following spring they turned the vetch under and planted lettuce. The lettuce was huge, deep green and very healthy. The vetch apparently provided ample, if not excessive, levels of N.
- At Red Fox Co-op, hairy vetch has been growing in a field for three years. It was established under a nurse crop of buckwheat (planted simultaneously). The vetch rejuvenated the soil of an old cornfield and choked out a bad case of couchgrass and ragweed. Also, the sheep ranged on the vetch well into January and hoofed through the snow to reach it.



## **Chickling vetch (*Lathyrus sativus*)**

- the most common commercial variety is called AC Greenfix.
- only used recently in the Maritimes so information on its growth habits, tolerance, etc. are limited. Farmers Supply (contact below) has done field research on AC Greenfix.
- used as an annual in Atlantic Canada.
- the seed should not be fed to livestock as it contains a neurotoxin that can be lethal.

### **Applications**

- see Vetch section

### **Green Manure**

- can fix 80-100 lb/ac. (90-115 kg/ha) of nitrogen within 8-10 weeks of growth
- appears to fix more N early in the season than other types of vetch

### **Weed control**

- appears to be the fastest growing and most competitive of all the vetches, although some farmers have complained that it has slow establishment
- can be intercropped with oats to provide better weed control (and add more organic matter)

### **Erosion control**

### **Growing conditions**

- tolerant of a range of soil and moisture conditions, including drought
- prefers light, rather than clay, soils
- winter hardy to zone 4

### **Seeding and management**

- seed at 70 lb/ac. (80 kg/ha)
- plant as early as possible (it is frost-tolerant)

# GRASSES

## Ryegrass (*Lolium spp.*)

- grows rapidly and holds soil well with heavy, fibrous roots.
- annual ryegrass (*L. multiflorum*) may set seed during the same year as seeding, and might survive mild Maritime winters or winters with extensive snow cover. Ironically, in the Annapolis Valley, annual ryegrass (Italian) is more likely to overwinter than perennial ryegrass.
- there are two types of annual ryegrass. The Westerwolds ryegrass is an annual that can set seed in its first year. The Italian ryegrasses (including Maris Ledger) may overwinter in the Maritimes but they rarely go to seed.
- Perennial ryegrass (*L. perenne*) will overwinter in some areas of the Maritimes. It grows 1-3 feet high and may survive for 3-4 years.

## Applications

### Green manure

- produces more organic matter than most other cover crops
- loosens compacted soil
- improves soil structure

### Weed control

- great weed control due to rapid establishment, thorough ground cover and allelopathic suppression

### Erosion control

- provides thorough ground cover when alive and when winterkilled, the thick mulch protects and insulates soil

### Catch crop

### Living mulch

- provides good weed control
- may control pests including carrot root maggots and flea beetles
- may compete with crop for N

## Growing conditions

- prefers loam or sandy loam soils, but will grow on any soil including acidic soil.
- tolerates wet periods but not drought
- need plenty of moisture and N
- annual ryegrasses are more shade-tolerant than perennial ryegrasses.

## Seeding and management

- seed at 20-35 lb/ac. (22-39 kg/ha) at 3-2 in. deep; the seeding rate depends on the cultivar
- plant at least 40 days before a killing frost is expected.
- for a living mulch, seed after the main crop has become established.
- mowing stimulates growth
- to kill ryegrass, mow it very low, ideally before a killing frost
- after turning ryegrass under, wait at least a few weeks before planting new crops.

## NSOGA Results

- Ryegrass can be very tenacious. Not only can ryegrass survive mild winters, but it can also survive being mowed, rototilled and disked under.
- At virtually all farms, ryegrass provided excellent ground cover and weed control. The only weedy and sparse stands were found in infertile or droughty conditions.
- At one farm, ryegrass was planted in an area that was filled with couchgrass. Alex deNicola mowed the area five times during the summer. With each mowing, the ryegrass grew quickly and the couchgrass was suppressed. By the end of the summer, the field had little couchgrass.

# WINTER CEREALS

Winter cereals are grains planted in the autumn, usually September, in time to become established before winter. They are harvested the following summer (July-early August). Winter grains produce more grain and straw than spring cereals. As well, they provide cover over the winter, better spring weed control and they can better use snow-melt water.

## Fall rye (*Secale cereale*)

- also called winter or cereal rye; is winter hardy
- grows to 4-5 feet tall and has very extensive, fibrous root system.
- flowers when daylight is longer than 14 hours, and temperatures are between 5-10EC
- grain and straw are poor quality feed (note: a poisonous black growth on grain called ergot, may occur in poor conditions)

## Applications

### Fall catch crop

- grows late into the fall and takes up large amounts of nitrogen

### Increasing organic matter

- produces large amounts of organic matter (125-150 bales of straw per acre)

### Soil conditioning

- loosens compacted soils
- brings nutrients from deep in the soil
- great for improving sandy soils

### Green manure

- excellent in that provides much green material but may be difficult to eradicate

### Erosion control

- provides a fast-growing crop that quickly covers the soil

### Companion or nurse crop

- by trapping snow, rye increases winter survival of overseeded legumes

### Weed control

- good weed control due to rapid growth and allelopathic effects

## Growing conditions

- adapted to a wide range of soils including infertile and acidic soils
- prefers fertile, well-drained soils with ample moisture
- high drought-tolerance
- fall rye can tolerate cool temperatures (and can be planted later than brassicas)
- hardy to zone 3

## Seeding and management

- seed at 90-135 lb/ac. (100-150 kg/ha) at 3/4 in. deep (use lower rate for a grain crop, higher rates for a green manure)
- seed in September and harvest the following late-July to early August
- can often kill rye by mowing it during flowering
- excellent companion to hairy vetch and most other legumes
- may regrow if tilled when less than 8 in. high
- the crop residue contains allelopathic compounds that can suppress the growth of subsequent crops; so wait 3-4 weeks between turning rye under and seeding a new crop

## NSOGA Results

- Neil van Nostrand used fall rye throughout his farm. He used it to control couchgrass, to cover bare soil (eg. at top and bottom of fields) and to add organic matter to the soil (Table 1).

## **Winter wheat (*Triticum aestivum*)**

-Both hard red and soft white varieties are available. Hard wheat is gluten-rich and is used for breads; soft wheat is used for pastry and all-purpose flour.

### **Applications**

#### **Erosion control**

#### **Weed control**

- grows rapidly in the spring, providing good weed control

#### **Catch crop**

- can be overseeded into soybeans

#### **Fodder**

#### **Grain**

- produces more grain (and better weed control) than spring wheat

### **Growing conditions**

- prefers loam soil with pH of 7.0-8.5
- grows best in fertile soil but will tolerate moderately fertile soil
- drought-tolerant
- heavy feeder

### **Seeding and management**

- sow at 90-140 lb/ac. (100-157 kg/ha) at 3/4 in. deep at the last fall frost (September-October)
- harvest mid-July to early August.
- can have clover overseeded into it for N-fixation, or wheat can be overseeded into soybeans to act as a catch crop after soybean harvest

# SPRING CEREALS

Spring cereals are planted in the spring and harvested later than winter cereals. They often have lower yields than winter grains, and can't control early weeds as well. Spring cereals can however grow on less fertile soil than winter grains. Spring cereals often produce higher quality grain than winter cereals.

## **Barley (*Hordeum vulgare*)**

- an annual that is well adapted to semiarid regions
- a light-feeder with shallow roots

### **Applications**

**Nurse crop for legumes**

#### **Green manure**

- doesn't produce as much organic matter as either wheat or rye
- for effective weed control, overseed with a legume or blind-harrow

**Fodder and human food**

### **Growing conditions**

- prefers well-drained loam soils with pH 7-8 and moderate fertility.
- tolerates saline and alkaline soils; doesn't like sandy or acidic soils

### **Seeding and management**

- sow at 60-125 lb/ac. (67-140 kg/ha) at 3/4 in.
- plant in the spring as soon as possible.

## **Japanese millet (*Echinochloa crusgalli*)**

- fast-growing annual with extensive root system
- better than oats for accumulation of phosphorus

### **Applications**

#### **Green manure**

- produces lush growth if enough N available
- accumulates phosphorus

**Weed control**

### **Growing conditions**

- needs moderately high levels of N and K

### **Seeding and management**

- seed at 18-27 lb/ac. (20-30 kg/ha)

## **Oats (*Avena sativa*)**

- annual grain that prefers cool, moist climates
- fast-growing, especially in spring and fall
- older varieties are more competitive (and produce more straw) than new varieties.

### **Applications**

#### **Green manure**

- produces more dry matter than buckwheat and has a deeper, more extensive roots
- if planted in late summer (eg. broadcast into strawberries), oats will winterkill and leave a straw mulch.
- great for adding organic matter

#### **Weed control**

- great, especially if overseeded, due to rapid growth and possible allelopathy

#### **Catch crop**

- great when planted with brassicas

#### **Nurse crop for legumes**

#### **Fodder and human food**

- good quality fodder (better than rye)

### **Growing conditions**

- will grow on many types of soil but doesn't do well on heavy clay
- tolerates wide range of pH.

### **Seeding and management**

- seed at 75 lb/ac. (84 kg/ha) at  $\frac{3}{4}$ -1 in. deep on firm seedbed
- requires phosphorus (unlike buckwheat)
- low N requirements
- lodging may occur, particularly in high N or high moisture conditions or if oats are grown with viney legumes
- harvest 12 weeks after sowing
- can be overseeded with peas to produce a high protein livestock feed (as hay, silage or harvested grain crops)

## **NSOGA Results**

- Oats establish quickly and provide early weed control.
- On weedy fields, oats produced more plant material and had fewer weeds than a combination of oats and vetch. Where there was no wild radish problem, the combination of oats and vetch produced more organic matter than oats alone, and managed to control weeds well.
- Oats are a dependable and economical catch crop to plant after harvesting summer vegetables. They can become established quickly and form a dense cover if planted from July to early September. Caution: oats that grow tall enough to become fibrous take time to breakdown, immobilizing (taking up) nitrogen in the process. As a result, the soil needs to rest before planting another crop. The trade-off is the older more fibrous oats contribute more to building organic matter than lush crops, but you need to wait longer before planting a following crop.
- Oats grown with vetch were more likely to lodge than oats grown alone.

# BRASSICAS

Brassicas are excellent fall catch crops. They grow quickly in cool weather, take up excess nitrogen and then winterkill. The mulch will then protect the soil over the winter. Brassicas have strong taproots that are great for soil conditioning and breaking up hardpans. As well, many brassicas can be used for fodder but should be mixed with grasses to avoid bloat.

Brassicas provide excellent weed control, due to their rapid growth and possible allelopathic effects. Also, as they decompose, they release chemicals that inhibit soil-borne pathogens, insects, weeds and nematodes. To take full advantage of this, after incorporating the residues, farmers can cover the soil with plastic.

Many vegetable crops are also brassicas (broccoli, cabbage etc.), and so crop rotations should be considered when choosing a cover crop. Like vegetable brassicas, the cover crops are vulnerable to flea beetles, brassica root maggot, clubroot and many of the other pests and diseases that affect cole crops. As well, brassicas are heavy feeders and this should be considered when placing them in a rotation.

## **White mustard (*Sinapsis alba*)**

- grows slowly in cold conditions, but rapidly in warm weather
- flowers 6-8 weeks after seeding.

### **Applications**

**Fall catch crop**

**Loosening up soil**

**Forage and fodder**

- can be used as feed when young, but becomes bitter after it goes to flower

### **Growing conditions**

- needs fertile soil (is a good indicator of soil fertility).
- killed by frost

### **Seeding and management**

- sow at 25 kg/ha.

## **NSOGA Results**

- Mustard grew well into November in Dartmouth. It survived frost and outlasted oilradish.

## **Oilradish (*Brassica campestris* var *oleifera*)**

- also called oilseed radish
- has a central taproot with an enormous number of roots sprouting from it. These extend well into the subsoil, and can loosen and aerate the soil
- has heavy plant growth (2-3 ft of top growth); flowers 6-8 weeks after seeding.
- grows well into the fall (is frost-tolerant) but winterkills

### **Applications**

#### **Fall catch crop**

- excellent at taking up extra N and releasing it the following spring

#### **Soil conditioner.**

- increases solubility and availability of phosphorus
- large taproot loosens compacted soil

#### **Weed control**

- very competitive against weeds due to its rapid growth

### **Growing conditions**

- needs fertile soil for rapid growth;

### **Seeding and management**

- broadcast at 10-20 lb/ac. (11-22 kg/ha)
- plant in the Maritimes in mid-late August for maximum growth with minimal risk of the plant going to seed.
- heavy N user; responds dramatically to applications of compost or manure.

## **NSOGA Results**

- If planted in early summer, oilradish can be difficult to control. When mowed before flowering, it quickly grew back and was too fibrous to mow again. When scythed while flowering, it didn't grow back but rather flowered at a height that was too low to scythe.
- Oilradish provided excellent early weed control. It grew rapidly and produced large leaves that smothered weeds. It controlled wild radish better than oats, vetch and ryegrass.
- Oilradish and ryegrass grow well together, and provide great weed control.



# HERBS

## **Buckwheat (*Fagopyrum esculentum*)**

- fast-growing summer annual that grows 2-5 feet high
- has rapid establishment, germinates in 3-5 days and then forms a dense canopy which suppresses weeds.
- has taproot with branches, producing a dense root system in the top 10 inches of soil
- flowers in 4-6 weeks and sets seed soon after. It sets seed while flowering (don't be fooled by the flowers--check for seeds at the bottom of the flower to decide if it's time to mow or till)
- not suitable for animal feed; buckwheat contains a compound called fagopyrin which makes animals light-sensitive
- the large-seeded Japanese variety is most often used in the Maritimes
- when mowed with a bush hog, the machine may just push over some of the plants, and these can then set seed

### **Applications**

#### **Soil conditioning**

- roots produce acidic compounds that increase the solubility of rock phosphate and other minerals. Buckwheat accumulates phosphorus, potassium and calcium and makes these available to following crops
- breaks down very quickly and doesn't increase soil organic matter.
- great at building poor or worn-out soils

#### **Weed control**

- provides excellent weed control due to its rapid growth, large leaves and release of allelopathic compounds. After it is killed, the residue inhibits germinating weeds.

#### **Catch crop**

- great spring and summer catch crop.
- fits into short gaps in the growing season.

#### **Honey plant**

#### **Grain**

### **Growing conditions**

- can grow on poor infertile and acidic soils.
- doesn't tolerate heavy, wet or alkaline soils
- somewhat shade-tolerant
- very sensitive to frost, grows best in warm weather

### **Seeding and management**

- sow at 45-60 lb/ac. (50-65 kg/ha) at 3/4 in. deep; plant after the last spring frost.
- for weed control, incorporate when 4-7 weeks old, cultivate, and plant again (or plant next crop)
- mature seed is produced while flowering, so till under one week after buckwheat begins to flower.
- buckwheat goes to seed quickly and will readily self-seed creating a weed problem. Fortunately, buckwheat volunteers are easy to weed.
- to use buckwheat as a nurse crop for legumes, mow the buckwheat before planting the legume.

## **NSOGA Results**

- Buckwheat provided fast and effective weed control, better than ryegrass, crimson clover or the two combined. Buckwheat is only suitable for short periods in crop rotations; the buckwheat was going to seed before the crimson clover began to flower.
- Dry matter yields were low, compared to other cover crops, and residue quickly decomposed.
- On new land, buckwheat grew better than legumes; buckwheat even grew out of an old stump.

## **Phacelia (*Phacelia tanacetifolia*)**

- also called California Bluebell and Bee's Friend
- annual crop
- can be slow to become established but grows quickly afterwards
- belongs to Nemophila family (which does not include any other crops), so phacelia can be inserted anywhere in a crop rotation
- flowers after 6 weeks of growth, seeds begin forming 8-9 weeks after planting

### **Applications**

#### **Summer catch crop**

- grows rapidly and breaks down rapidly

#### **Weed control**

#### **Bee plant**

- phacelia has a very high nectar content, and flowers for several weeks

#### **Erosion control**

#### **Inhibits nematodes**

### **Growing conditions**

- tolerant of many soil types except for clay or crusty soils
- doesn't tolerate waterlogged soils
- sensitive to low temperatures, hence its restricted use for spring-planted cover crops or late-season catch crops.
- needs moderate to high levels of P and K
- Tolerates temperatures as cool as -8EC

### **Seeding and management**

- drill at 9-13 lb/ac. (10-14 kg/ha) at 2 cm deep
- plant from spring to mid-August, or before mid July to have flowers

## **NSOGA Results**

- Most farmers who tried phacelia were quite impressed; however, there was poor growth at a couple of farms where the seed was covered with too deeply.
- When phacelia was planted midsummer, it was a bit slow to get established but after a bit of rain it grew rapidly.
- Patches of flowering phacelia were literally buzzing with bees, and there were virtually no weeds in some of the phacelia plots.
- The phacelia produced large amounts of plant material, which decomposes quickly and leaves friable rich soil, which is easy to till.
- Plant tissues (not including roots) contained more N, P and K than tissues of other cover crops, confirming that phacelia is both a good at taking up N and mining other nutrients.

# WEEDS

Weeds can be used as cover crops. Several of the cover crops described here (or closely related species) can be found growing wild (eg. clover, vetch, medic).

Using weeds rather than planting cover crops will obviously save time and money. Many weeds produce excellent low ground cover and can be used as living mulches; other weeds are legumes and fix nitrogen. All of them can help protect the soil from erosion and increase biodiversity on the farm.

Many common weeds are either edible (eg. lamb's quarters, pigweed, sorrel) and/or have medicinal properties (eg. red clover, St. John's wort, chamomile). Most provide habitat for beneficial insects, including predatory wasps and pollinating insects.

The challenge of course, is to prevent the weeds from spreading or competing with crops. Weed growth can sometimes be controlled by the same techniques used to reduce competition between living mulches and crops. For example, mowing can often delay weeds from going to seed. Caution: after being mowed, ragweed, lamb's quarters and wild mustard can produce abundant seeds even at low heights.

## RECOMMENDED READING

***The New Organic Gardener.* Eliot Coleman. 1989. Old Bridge Press. 269 pp.**

A great general reference guide for organic growers. It also discusses green manures and living mulches and how these can easily be incorporated into crop rotations. With Coleman's plan, the soil is constantly covered yet cash crops can be grown every year.

***Northeast Cover Crop Handbook.* 1994. Marianne Sarrantonio. Rodale Institute. 118 pp.**

An excellent book on cover crops. The handbook covers the advantages of growing cover crops with advice for farmers on how to choose the ideal cover crop. The appendix contains fact sheets on 19 cover crops. The book contains many useful tips and is quite accessible. Some of the information is quite technical (including detailed descriptions of how N-fixation works and a guide for farmers to calculate how much N and organic matter is added to the soil by cover crops). The information is aimed towards organic farmers in the American Northeast, and so much of the information can be used by Maritime farmers.

***The One-straw Revolution.* 1978. Masanobu Fukuoka. Rodale Press. 181 pp.**

A classic book on natural farming describing the techniques and philosophy of Fukuoka's organic no-till farming using cover crops, living mulches and straw mulches. Later, Fukuoka wrote *The Natural Way of Farming* (1985, Japan Publications, 284 pp.).

***Organic Field Crop Handbook, 2<sup>nd</sup> ed.* 2001. Janet Wallace (Ed.). Canadian Organic Growers ([www.cog.ca](http://www.cog.ca)). 198 pp.**

An invaluable resource for organic growers with practical (and organic) recommendations on how-to improve soils, control weeds and rotate crops. As well, it contains detailed descriptions on how to grow various grains and green manures. The book contains practical and technical information that can be used by both organic farmers who are working large mechanized farms and small-scale organic growers who want to incorporate field crops into their gardens.

***Overview of Cover Crops and Green Manures: Fundamentals of Sustainable Agriculture.* 2003. Preston Sullivan. ATTRA Publication #IP024. 16 pp.** Available for download at <http://attra.ncat.org/attra-pub/PDF/covercrop.pdf>

***Managing Cover Crops Profitably, 2nd Edition.* 2007. 244pp. The Sustainable Agriculture Network.** A useful booklet that describes how various cover crops are used in different regions of the USA. Also contains detailed planting info for 30 cover crops and 10 cover crop combinations. Available at [www.soilandhealth.org/03sov/0302hsted/covercropsbook.pdf](http://www.soilandhealth.org/03sov/0302hsted/covercropsbook.pdf).

***Getting Started with Cover Crops: Selection and establishment tips for on-farm research.* 2005. Dave Wilson. [www.newfarm.org/depts/notill/features/cover.shtml](http://www.newfarm.org/depts/notill/features/cover.shtml)**

***Quackgrass Control Methods in Organic Agriculture.* Jean Duval. [www.organicagcentre.ca/Docs/Quackgrass\\_final\\_rev\\_JD.pdf](http://www.organicagcentre.ca/Docs/Quackgrass_final_rev_JD.pdf)**

***Farmers and their Innovative Cover Cropping Techniques.* SARES. Video [www.uvm.edu/vtvegandberry/Videos/covercropvideo.html](http://www.uvm.edu/vtvegandberry/Videos/covercropvideo.html)**

## References

Donald, R, J Lewis, C Caldwell and N Goodyear. 1995. An evaluation of cover crops to reduce the potential for environmental damage from intensively cultivated soils. NSCDI/NSAC. 37pp.

Lemieux, N. 1995. Cover crops have their place. *Sustainable Farming*. 5(4):7-9.

MacLeod, JA and JB Sanderson. 1995. Effects of various catch crops after early potato harvest on the nitrogen status of the subsequent cereal crop. Proc. of First Atlantic Canada Agricultural Science and Technology Workshop. Truro, NS, April 1995.

Sanderson, JB and JA MacLeod. 1995. Effects of various catch crops on nitrate leaching after early potato harvest. *Proc. of First Atlantic Canada Agricultural Science and Technology Workshop*. Truro, NS, April 1995.

Sarrantonio, M. 1991. *Methods for Screening Soil-Improving Legumes*. Rodale Institute. Emmaus, PA.

Sarrantonio, M. 1994. *Northeast Cover Crop Handbook*. Rodale Institute. Emmaus, PA.

## GLOSSARY

**Allelopathy:** the production of allelopathic compounds which inhibit the germination of other plants. The compounds are produced while the allelopathic crops are growing and/or decomposing.

**Biomass:** living matter, including roots and above-ground growth of plants

**Blind-harrowing:** also called pre-emergent tilling, is harrowing after a crop has been planted, but before it emerges. Sometimes, a crop is overseeded after the main crop is blind-harrowed (and the field is harrowed again after broadcasting). Farmers without large equipment could do 'blind raking' to control weeds.

**Break crop:** a cover crop planted to interrupt or 'break' pest and weed cycles.

**Catch crop:** a cover crop planted to take up excess nutrients in the soil, thereby reducing nutrient leaching. The nutrients will be released when the catch crop is turned under.

**Companion planting:** planting different crops together to improve amount of ground cover, weed and pest control.

**Feeder (heavy, light or moderate):** amount of fertility needed for the crop (eg. heavy feeders need more fertile soil than light feeders)

**Frost-seeding:** broadcasting seeds onto frozen ground in the spring before the last frost. The seeds will be drawn into the soil by the freeze-thaw cycles. Legumes are often frost-seeded into winter grains or pastures.

**Green manure:** a cover crop planted and then tilled under to add nutrients and/or organic matter to the soil.

**Hardpan (plowpan):** an impenetrable layer of soil.

**Hard seed:** seed that won't germinate without being scarified (ie. breaking or scratching the seedcoat).

**Inoculant:** a commercial mix of N-fixing bacteria (rhizobia) added to legume seed so that the legumes (and bacteria) will fix nitrogen.

**Intercropping:** planting different crops together, often in alternating rows.

**Legumes:** a group of plants that are involved in N-fixation, including clovers, alfalfa, vetches and beans and peas.

**Living mulch:** a cover crop grown with cash crops to smother weeds.

**Lodging:** grains blown down by strong winds, particularly in high-fertility soils.

**N (nitrogen):** one of the most important nutrients for plant growth. It will usually limit plant growth before any other nutrient will.

**N-fixation:** the conversion of nitrogen gas to a useable form of nitrogen; this is accomplished by strains of bacteria (rhizobia) living in the nodules of legumes.

**Nodules:** growths on the roots of legumes where N-fixation occurs

**Nurse crop:** a cover crop planted to control weeds while another plant is becoming established (eg. oats are often used as a nurse crop for clover).

**Overseeding (underseeding):** broadcasting seed over existing crops

**Rhizobia (Rhizobium):** the strains of bacteria that fix nitrogen in the nodules of legumes.

**Smother crop:** a cover crop that grows quickly and is planted to control weeds

**Underseeding:** the same thing as overseeding

**Winter annual:** a crop which begins growing in the fall, lies dormant over the winter and flowers the following the spring.

**Winter cereal (winter grain):** a grain that is planted and grows in the fall and is harvested the following summer.

## COST OF COVER CROP SEEDS

To quickly compare the costs of cover crop seeds, we have calculated the cost per hectare of seed for various crops (cost/ha = price/kg \* seeding rate). The following tables are intended to be used as a rough guide to compare seed costs, since prices can vary considerably between seed sources, and over time. Seeding rates for this project were based on small-scale production, rather than field crops. Seeding rates may vary depending on your purpose. The price is based on the least expensive (usually the common) variety of each cover crop, and shipping costs are not included. For non-metric folk, one hectare=2.5 acres, and kg/ha\*0.9= lb/ac..

**Table 3 . Cost of legume cover crops.** The costs of various legume cover crops based on 2007 seed prices from a few seed houses.

<b>Cover crop</b>	<b>Seeding rate (kg/ha)</b>	<b>Source</b>	<b>Price (\$/kg)</b>	<b>Cost (\$/ha)</b>	<b>Cost (\$/ha)</b>
<b>Alfalfa</b>	20-28	Homestead	3.80*	<b>76-107</b>	<b>31-43</b>
<b>Birdsfoot trefoil</b>	11-17	Homestead	11.70	<b>129-200</b>	<b>52-81</b>
<b>Clover, alsike</b>	5-11	Homestead	3.24	<b>16-36</b>	<b>7-15</b>
<b>Clover, crimson</b>	35-45	Labon	3.36	<b>112-150</b>	<b>45-60</b>
<b>Clover, red double-cut</b>	13-20	Homestead	4.60*	<b>60-92</b>	<b>24-37</b>
<b>Faba beans</b>	100-135	Co-op	1.20	<b>120-162</b>	<b>42-56</b>
<b>Field peas</b>	78-245	Homestead	0.96*	<b>75-235</b>	<b>30-95</b>
<b>Soybeans</b>	90-190	Homestead	0.62-0.76*	<b>56-145</b>	<b>15-59</b>
<b>Sweetclover, yellow</b>	11-17	Various	2.68- 3.24	<b>30-55</b>	<b>12-22</b>
<b>Vetch, common</b>	32-45	Labon	3.00	<b>96-135</b>	<b>39-55</b>
<b>Vetch, chickling</b>	12-20	Farmers Supply	2.42	<b>29-48</b>	<b>12-20</b>
<b>Vetch, hairy</b>	32-45	Homestead	2.20	<b>70-100</b>	<b>28-41</b>



**Table 4 . Costs of grasses and cereals.**

<b>Cover crop</b>	<b>Seeding rate (kg/ha)</b>	<b>Source</b>	<b>Price (\$/kg)</b>	<b>Cost (\$/ha)</b>	<b>Cost (\$/A)</b>
<b>Barley</b>	70-140	Homestead	1-1.07*	<b>70-150</b>	<b>28-61</b>
<b>Fall rye</b>	100-150	Various	0.52*-0.82	<b>52-123</b>	<b>29-50</b>
<b>Japanese millet</b>	20-30	Various	1.00-1.14	<b>20-34</b>	<b>8-14</b>
<b>Oats</b>	85	Homestead	0.80-0.87*	<b>68-74</b>	<b>28-30</b>
<b>Ryegrass, annual plowdown</b>	25-40	Various	0.82-4.04	<b>20-162</b>	<b>8-66</b>
<b>Ryegrass, Maris Ledger</b>	25-40	Various	2.00-3.00	<b>50-120</b>	<b>21-50</b>
<b>Ryegrass, perennial</b>	25-40	Co-op	5.40	<b>135-216</b>	<b>56-90</b>
<b>Winter wheat</b>	100-160	Co-op	0.64	<b>65-175</b>	<b>26-71</b>

**Table 5 . Costs of brassica and herbs.**

<b>Cover crop</b>	<b>Seeding rate (kg/ha)</b>	<b>Source</b>	<b>Price (\$/kg)</b>	<b>Cost (\$/ha)</b>	<b>Cost (\$/A)</b>
<b>Buckwheat</b>	50-65	Homestead	0.62-0.96*	<b>31-62</b>	<b>13-26</b>
<b>Oilradish</b>	20-30	Homestead	4.20*	<b>84-126</b>	<b>34-51</b>

## SEED SOURCES

### **Bishop Seeds**

Box 171, 99 John St.  
Harriston, ON N0G 1Z0  
Phone: (519) 338-3840  
Fax: (519) 338-2510  
Email: [info@bishopseeds.ca](mailto:info@bishopseeds.ca)

Call for distributors in the Atlantic Provinces.

### **Co-op Atlantic** (headquarters)

PO Box 750,  
123 Halifax St. Moncton NB E1C 8N5  
Look in the phone book for your local Country  
Co-op Store.

### **Farmer's Service & Supply Ltd.**

Chickling vetch: AC Greenfix  
12446 Route 114  
Penobsquis, N.B., E4G 2Z2,  
Phone: 506-432-6467  
Email: [goodfoodfarm@nb.aibn.com](mailto:goodfoodfarm@nb.aibn.com)

### **Halifax Seed Co. Inc.**

Halifax and Saint Johns locations  
Phone (NS): 902-454-7456  
[www.labon.net](http://www.labon.net)

### **Mapleseed and Pickseed**

Box 304, 1 Greenfield Rd.,  
Lindsay, ON K9V 4S3  
Phone: 1-800-661-4769  
Fax: 705-878-9249  
[www.pickseed.com/en/index.php](http://www.pickseed.com/en/index.php)

### **Outsidepride.com** (US)

Oregon, USA  
On-line seed retailer  
[www.outsidepride.com](http://www.outsidepride.com)

Phone (NB): 506-633-2032

Email (NS): [info@halifaxseed.ca](mailto:info@halifaxseed.ca)

Email (NB): [Saintjohn@halifaxseed.ca](mailto:Saintjohn@halifaxseed.ca)

[www.halifaxseed.ca](http://www.halifaxseed.ca)

### **Homestead Organics**

Field crops (grain, forage and cover crops)

1 Union St., Berwick ON, K0C 1G0

Phone: 1-877-984-0480

Fax: 613-984-0481 [www.homesteadorganics.ca](http://www.homesteadorganics.ca)

### **Johnny's Selected Seeds**

Source for many organic seeds.

Winslow, Maine

Contact: Chris Siladi

Phone: 1-877-564-6697

[www.johnnyseeds.com](http://www.johnnyseeds.com)

### **Labon Inc.**

Unusual forage and cover crop seeds.

1350 Newton St., Boucherville QC J4B 5H2.

Phone: (514) 641-1050

Fax: (514) 641-4979

For more Ontario listings, visit [www.efao.ca/pages/directories.html](http://www.efao.ca/pages/directories.html)

# **A Farmer's Guide to Reducing Nutrient Loss using Catch Crops**

**written by Janet Wallace**

**research by Pat Dixon, Jennifer Scott & Janet Wallace**

**published by Nova Scotia Organic Growers Association, 1998**

## **Nutrient loss**

Nutrient contamination of ground and surface water is a common problem in agricultural areas. When fertilizer (either synthetic or organic) is applied in excess of crop demand, nutrients can leach from the soil. Common practices (such as leaving the soil bare between fall harvest and spring planting, and applying manure to bare soil) contribute to both erosion and nutrient run-off.

In the Maritimes, soils are particularly vulnerable to nutrient leaching due to the heavy spring and fall rains that occur when soil is often bare. The lack of a constant snow cover and frequent freeze-thaw cycles in the winter allow for nutrient loss during the winter as well.

Nutrient loss has several potential environmental effects. The nutrients can enter groundwater and surface water bodies. Nitrate, phosphate and other nutrients can trigger excessive algal growth and eutrophication in lakes and estuaries, affecting both estuarine and freshwater habitats. As well, there are potential health risks of nutrient contamination of drinking water. Long-term consumption of nitrite in drinking water has been linked with cancer and miscarriages (Bruning-Fann & Kaneene, 1993; Kross et al., 1993).

For farmers, nutrient loss can represent a loss of an investment of time and money. More fertilizer (synthetic or organic) is needed to replace the nutrients that have leached away. Fortunately, catch crops, crop rotation and manure management techniques can reduce nutrient loss, and protect the investment of farmers.

Nutrient loss takes several forms. Nutrients can be leached out of the soil by water (rainwater, meltwater or irrigation) and end up in streams, lakes, estuaries or groundwater. Surface run-off also occurs, where both nutrients and top-soil are washed off fields and into nearby water bodies. In saturated soils or when organic fertilizers are left on the soil surface, nutrients such as nitrogen can be lost to the air.

In general, nutrient loss from cropland occurs when nutrient supply exceeds crop demands. The potential for nutrient leaching and run-off is greatest when the soil is saturated with water and the soil is bare, sandy and low in organic matter. Farmers can control the rate of nutrient loss by using slow-release organic fertilizers and adjusting application rates to the crop needs. As well, nutrient loss is reduced by maintaining ground cover of either cover crops or crop residue (particularly during times of heavy rains and snow-melt), increasing the level of organic matter in the soil and using cover crops to take up excess nutrients after a crop is harvested.

## **Nutrients - short-term and long-term supplies**

### **Quick and easy nutrients**

Nutrients can be transformed from soluble to insoluble states, and some nutrients can be changed into a gas. For example, when a crop of clover is tilled into the soil, the nitrogen in the tissue isn't soluble, but soil microorganisms quickly transform some of the nitrogen into nitrate which is soluble (and can be used by crops). If the soil pH is greater than 7.0, or manure is left on the soil surface, the nitrate can be converted to a gas and will be lost with the wind.

Plants use nutrients that are soluble (can be dissolved in water). Nutrients that can be used by plants can also be leached out of the soil.

Nutrients can be added directly to crops by foliar sprays (e.g. fish emulsion), side-dressing or by applying readily available nutrients to the soil just before planting. Kelp meal and fish meal are concentrated sources of nutrients and minerals that can be readily used by the crop. Tilling in a green manure also adds a boost of nutrients within a few weeks of ploughdown.

### **Forms of nutrient loss:**

- Leaching - soluble nutrients are washed out of the soil
- Erosion - nutrients in the topsoil are washed or blown away
- Loss to the air – *for example, nitrogen can be converted to a gas and lost when nitrogen-rich material, such as manure or legume crop residues, is left on the soil surface.*

### **Ways to reduce nutrient leaching:**

- tie up nutrients in soil by tilling in straw, grasses, or other carbon-rich material
- use catch crops to take up excess nutrients after crop harvest
- adjust the type, timing and amount of nutrient applications so that sufficient nutrients are made available when plants need them, but not excessive amounts
- increase soil organic matter
- maintain living soil cover as much as possible (through intercropping, living mulches and catch crops) □ maintain soil cover year-round (e.g. mulches or catch crops during the winter)

### **Ways to reduce erosion**

- maintain soil cover year-round (e.g. mulches or catch crops during the winter)
- maintain living soil cover as much as possible (through intercropping, living mulches and catch crops)
- increase levels of soil organic matter
- use catch crops to cover the ground after harvesting crop
- on sloping land, plant crops across the hill (to prevent water from running straight down the hill) and use contour ploughing

## **FACTORS AFFECTING NUTRIENT LOSS**

### **Weather conditions**

Nutrient losses by leaching or run-off are greatest during heavy rains. The plants cannot take up all of the available rainwater; consequently, some of the water percolates through the soil and takes nutrients with it (leaching). In addition, in heavy rainfall, the top layers of the soil become saturated; the rain then runs off the soil, carrying away nutrients and topsoil.

In warm soils, microbes quickly transform nitrogen into nitrate (which is soluble). If the soil is covered with plants, they can take up some of the nitrate and limit the amount that is vulnerable to leaching.

During the winter, run-off of nutrients and topsoil occur during periods of thaws and melting. When the soil is frozen, meltwater and rain cannot percolate into the soil and instead run over the soil surface into nearby water bodies. The practice of applying fresh manure to frozen and snow-covered fields often leads to contamination of nearby lakes and rivers.

### **Soil type and condition**

Leaching is most common in highly permeable soils where the water quickly percolates through the soil. Sandy soils with low organic matter are the most susceptible to leaching. Nitrates are most easily lost from soils where there is low organic matter, and little carbon-rich (brown, woody) material.

The potential for leaching can be reduced by increasing the level of soil organic matter (OM). An increase in soil organic matter has many benefits.

Stable soil organic matter, (sometimes called humus) holds and releases nutrients very slowly in response to plant needs. Humus improves the ability of the soil to hold water and nutrients, binds the soil together, and increases the friability and porosity of the soil. In general, a soil high in organic matter is much easier to work than soils with low OM. The soils with high OM are (1) easy to till, (2) less likely either to become waterlogged or to dry out, (3) more fertile and (4) less prone to both leaching and erosion than soils with low organic matter.

There are many ways to increase and maintain soil organic matter including applications of compost and aged manure. Crop rotations and cover crops can also increase soil OM, particularly when grasses, grains and/or crop residue are incorporated into the soil. Organic matter can be maintained by keeping the soil covered with crops, cover crops or mulch. No-till or minimum tillage practices also help to maintain soil organic matter.

## **Fertilizer and Nutrient Applications**

Different types of fertilizers and soil amendments vary in their tendency to leach. On organic farms, nitrogen and other nutrients are usually added to the soil as aged manure, compost or legume ploughdowns (green manures). Composted manure contains half the available nitrogen of raw manure (NRAES, 1992) and the nutrients are slowly released. Both compost and aged manure release their nutrients slowly in comparison to synthetic fertilizers; however, soluble nutrients such as nitrates and potassium can be leached from aged manure.

Green manures release nitrogen fairly slowly. However within two weeks of turning under green manures (legume cover crops), there is an initial flush of available nitrogen in the soil, as much as 150 lb/ac. of N (Sarrantonio, 1994). During this period, the nitrogen is most susceptible to leaching. The remaining nitrogen is released slowly. In warm, well-aerated soil, only half of the nitrogen is released during the year after a green manure is plowed under (Sarrantonio, 1994).

Slow-releasing forms of nutrients are less likely to be lost than readily available nutrients. If nutrients are slowly released, crops or cover crops can more readily use the available nutrients. If either the nutrients are released more quickly than the plants can use them, or there are no crops growing at the time, the nutrients can be lost.

Carbon-rich material can tie up certain nutrients including nitrate. Carbon-rich material includes dry, woody material (called 'browns' by composters) such as straw, hay and dry leaves. If these compounds are either mixed with high-nitrogen material (eg. manure), the nitrogen will be immobilized. The nitrogen will be slowly released over time.

The roots and stems of grains and grasses are also carbon-rich, and tie up nitrogen. Consequently, when cover crops such as oats, fall rye, or annual ryegrass are turned under, the crop residue retains nitrogen. When these cover crops are combined with legumes (eg. clover, alfalfa or soybeans), the cover crop combination increases both soil fertility and organic matter and provides a slow release of nutrients.

## **USING CATCH CROPS TO RETAIN NUTRIENTS**

Catch crops are cover crops planted after cash crops are harvested or after legume ploughdowns. Frequently, an abundance of nutrients are available in the fall from either fall applications of manure or 'left-over' nutrients from spring or summer applications of manure. Catch crops take up available nutrients at a faster rate than other crops. Not only can they scavenge leftover nutrients from the previous crop, but they can also use nutrients from direct applications of compost or liquid manure. The catch crops take up and hold the nutrients in their tissues, preventing the nutrients from being leached out of the soil. The nutrients are slowly released as the catch crop decomposes the following spring, at which time the crops can use soluble nutrients.

The catch crops are typically planted in the fall and provide ground cover during the fall and winter until the land is ploughed the following spring. While the crops are growing in the fall, they also take up rainwater, and thereby reduce the amount of water that can cause leaching.

## **Types of Catch Crops**

### **General Features of Catch Crops**

- fast-growing cover crops
- highly competitive against weeds
- take up a lot of nitrogen

### **Brassicas**

- include oilseed radish, white mustard
- grow well in cool weather
- are frost-hardy but don't survive Maritime winters
- provide dense ground cover soon after planting
- decompose quickly, (e.g. fall catch crops have decomposed by the spring)
- have thick tap roots that help break up hard-pans or clay soil (if there is ample nitrogen)
- may be difficult to incorporate into vegetable crop rotations, since these catch crops are related to cole crops and other vegetable brassicas
- look very similar to wild radish and wild mustard
- don't add much organic matter to the soil

### **Grains & Grasses**

- spring grains (eg. oats, barley, spring wheat) winterkill
- winter grains (e.g. fall rye, winter wheat) usually survive Maritime winters
- some of the grasses are perennial (eg. fine fescues) but other grasses often, but not always, winterkill (eg. both perennial and annual ryegrass)
- fall catch crops produce thick mulch that covers the soil over the winter, and may inhibit growth of the following crop (if crop is planted in the mulch or immediately after the mulch is incorporated in the soil).
- contain carbon-rich material ('browns') that is slow to decompose and may tie up soil nitrogen after being turned under
- have dense, extensive root systems that improve soil structure
- add organic matter to the soil
- can be difficult to incorporate (eg. thick mats of ryegrass or six-foot tall crop of rye)

### **Herbs**

- include buckwheat, phacelia and chicory.
- grow well in warm weather (especially buckwheat)
- most of the common herb catch crops winterkill (eg. phacelia, buckwheat), but chicory sometimes survives Maritime winters
- good bee crops
- quickly decompose, leaving little mulch
- some herbs (especially buckwheat) grow very quickly in warm weather and can be used in between spring and fall crops

The time of planting often restricts the choice of cover crops. Buckwheat is killed by light frosts

and can only be planted in the summer. Phacelia is killed by moderate frosts. Brassicas and

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spring grains are all killed during the winter. The brassicas, grains and grasses can all be planted in late summer to early fall. This will give them time to grow enough to take up nutrients, but not enough time to set seed. Fall rye can be planted late into the fall.

Catch crops are most effective at taking up nutrients when they are growing vigorously. They are inefficient if planted late in the fall, and most effective when planted in mid- to late summer. Consequently, catch crops can't simply be planted after each crop is harvested. For example, after late potatoes are harvested, there *may* be time to plant fall rye, but it will be too late for oilseed radish.

### **Catch crop residue**

On organic farms, farmers try to reduce the amount of time soil is left bare (and exposed to wind and rain). Cover crops are used to cover the ground between harvest of one crop and the planting of the next crop. The residue of fall catch crops is often left on the soil throughout the winter, and turned under the following spring.

Many cover crops, such as oilseed radish, buckwheat and crimson clover, will be almost completely decomposed by the time the land can be worked in the spring. The grains and grasses, however, may have a thick mulch on the soil, and/or dense root masses.

Grains and grasses are high in carbon-rich material, both in their roots and above-ground growth. Young growth is only slightly carbon-rich but as the crop ages and becomes more fibrous, the carbon to nitrogen ratio increases and the material becomes more carbon-rich. The C/N ratio is greatest for dry straw and dense root masses of mature grains and grasses. Grains and grasses can be used both as catch crops and to increase soil organic matter. Brassicas and herbs don't add organic matter,

Carbon-rich material (e.g. oat straw) breaks down more slowly and increases soil organic matter more than the breakdown of more nitrogen-rich material (e.g. fresh clover). Carbon-rich material is often dry, fibrous material (which composters refer to as 'browns') and has a high ratio of carbon to nitrogen (C/N ratio).

Grains and grasses are great for adding organic matter to the soil. This is a long-term benefit of growing cover crops such as annual ryegrass, fall rye, oats or barley. The more residue left on the land (either disked in or left on the surface), the greater the increase in soil organic matter.

However, when straw or other carbon-rich material is worked into the soil, it ties up nitrogen temporarily. Carbon-rich material is high in the carbon to nitrogen ratio (C:N), and while it is being decomposed, soil microorganisms use up soil nitrogen. So, after field of straw is disked in the soil in the spring, there will be virtually no available nitrogen for the following crop for at least a few weeks.

In contrast, brassicas, legumes and herbs are all relatively low in the C/N ratio. The high content of nitrogen in these plants is revealed by their rather fleshy, not too fibrous, rather moist tissue. Legumes are particularly high in nitrogen. All these cover crops quickly decompose and might not increase the level of soil organic matter.

Nitrogen-rich cover crops can be grown with carbon-rich cover crops to both add readily available nutrients and increase soil organic matter. Crimson clover & annual ryegrass, and oats & red clover are cover crop combinations that increase both short-term and long-term fertility.

but they also don't leave a thick mulch on the soil in the spring. These catch crops are best used when the land will be worked early in the



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spring. Catch crops have a valuable role in crop rotations, it just takes a bit of trial and error to find the most appropriate catch crop for certain conditions.

### **NSOGA Project**

In 1996, the Nova Scotia Organic Growers Association (NSOGA) began a two-year project to encourage farmers to try using catch crops.

Trial plots were established on 16 organic farms in Nova Scotia. The farmers volunteered their land and labour; they helped plant and monitor the crops. We compared the efficacy of fall rye, oats, oilradish and ryegrass to provide ground cover and reduce nutrient loss (the treatments were compared to bare soil controls).

Some of the catch crop plots failed due to the drought. On farms where dry land was disked in August, and the cover crops planted, the cover crops suffered poor germination, establishment and growth. The most successful cover crops were grown in areas that had been previously mulched, for example after harvesting garlic or early potatoes. Low moisture levels may frequently be a problem for cover crops planted in July or August, however in typical years, soil moisture levels are likely sufficient for fall-planted catch crops.

The NSOGA Catch Crop study demonstrated that fall catch crops can reduce soil nitrate levels by about 33% and thereby retain approximately 150 kg/ha of nitrogen. The study was conducted on organic farms on fields with slow-release forms of nitrogen were used, such as composted manure.

The catch crops varied in their ability to take up nitrates and cover the ground. As well, the cover crops differed in their growth patterns, the amount of residue left after the crops were killed, and the speed at which the crops decomposed

## **CONCLUSION**

Although our research plans were hindered by the weather, we learned more about the practical barriers to using fall catch crops. The fall of 1996 was too wet and cold for most farmers to be able to plough their land. The fall of 1997 was too dry. Obviously, fall catch crops are not a viable option after all crops, and we should identify and recognize how the cover crops can best fit into a cropping sequence. For example, summer catch crops can follow harvesting of peas, spinach and other early crops, and fall catch crops can follow the harvest of beans, garlic and early potatoes.

Due to the drought of 1997, fall catch crops could not be planted in many areas. However, the catch crops grew very well where the soil had been mulched (eg. after garlic, broccoli, early potatoes and greens). We found that:

- Oilseed radish and annual ryegrass were the best at taking up nitrates.
- Oilseed radish planted after mid-September had limited growth. The oilseed radish still provided ground cover and weed control, but didn't take up much nitrogen. Perhaps oilseed radish should be planted in early to mid-August -- however if the autumn is warm and long, the oilradish may have to be cut down or turned under in the fall to prevent it from setting seed.
- Fall rye was the only cover crop that provided a thick ground cover when planted late in the fall (eg. October-November).
- Oats grew the best (ie. tall, lush growth) under a variety of soil and moisture conditions.
- The earlier cover crops are planted, the more they take up available nitrogen and provide a thick soil cover.

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In summary, catch crops did what they were supposed to do — they used up excess nutrients, and they provided ground cover — but the catch crops were only successful when they had adequate moisture and time to grow.

We learned that catch crops can't simply be planted after each crop is harvested. For example, after late potatoes are harvested, there *may* be time to plant fall rye, but it will be too late for oilseed radish. But catch crops do have their place in crop rotations, it just takes a bit of trial and error to find the best catch crop for certain conditions.

Summary of success of various types catch crops (based on findings of the NSOGA study and of other studies reported in the literature).

Catch Crop		Characteristics				Increase in soil organic matter
		Ground cover		Nitrogen uptake		
		Fall	Spring	Fall uptake	Spring release	
Grains	Fall rye	good	living cover	moderate-good	no N release if rye is left living	excellent
	Oats	good	dead residue	good	may tie up N if straw is incorporated	good
Grasses	Annual ryegrass	excellent	heavy mulch, possibly surviving	excellent	may tie up N	excellent
Brassicas	Oilradish	moderate-good	no residue	excellent	excellent	poor
Herbs	Phacelia	moderate	no residue	moderate	moderate	poor
	Buckwheat	moderate	no residue	moderate	moderate	poor
Mixes	Oilradish + oats	excellent	some residue	good	good	moderate

## *A Farmer's Guide to Reducing Nutrient Loss with Catch Crops*

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# Make the Most of Legumes to Fix and Keep Nitrogen in your Soil

by Janet Wallace

*“Legumes are an integral part of crop rotations; they provide nitrogen to other crops...”*

We've all heard this and we all grow legumes to add nitrogen, but can we rely upon legumes to *always* add nitrogen?

It's true that legumes *can* add relatively large amounts of nitrogen to the soil, but simply growing a legume does not ensure nitrogen will be added.

Sometimes legumes don't nodulate and the nitrogen is not fixed. Other times, the plants fix nitrogen but the nitrogen is removed at harvest. For example, if peas are grown and the plants pulled up when they are harvested, there is probably no net gain of nitrogen to the soil. At other times, some of the nitrogen can be leached away, unless captured by catch crops or carbon-rich material. Fortunately, there are many steps farmers and gardeners can take to help add and retain nitrogen.

## ***Nitrogen Fixation***

Nitrogen fixation occurs when specialized strains of bacteria (rhizobia) infect the roots of legumes (beans, peas, clover, vetch, alfalfa, lupins, sweet clover, etc.).

Nodulation occurs when the legume roots form a growth, called a nodule, around the bacteria. Within the nodules, the bacteria convert atmospheric nitrogen into usable plant compounds (such as ammonia and nitrate). After the plant flowers, the nitrogen moves from the roots into the seeds.

Eventually the legume dies and releases the stored nitrogen as it decomposes. About half of the nitrogen will be released within a year after incorporation into the soil. The rest of the nitrogen will be released over a period of a few years.

## ***Inoculation***

Legume seed should be inoculated to ensure contact between rhizobia and the seed. Farm and garden supply stores often sell a few types of inoculant, each of which inoculates several related legume species. These inoculants are readily available, but not as effective as inoculants specific to only one species. Inoculant should be kept refrigerated until used and replaced each year. To inoculate seed, moisten the seed with water (or with a very dilute sugar and water solution) and mix in the inoculant. Plant the seed immediately after mixing as the inoculant will die if it dries out.

Rhizobia can survive in the soil for a couple of years, so if you are planting a legume in the same place it grew two to three years ago, assuming it nodulated successfully, rhizobia are probably still in the soil. Also, if you are planting a legume that is closely related to a common weed on your farm, there are likely rhizobia present in the soil. In these cases, inoculation with a commercial inoculant is not necessary for N-fixation, but it does provide a cheap and easy way to possibly increase the amount of nitrogen fixed.

You can also acquire their own inoculant by collecting soil from around the roots of nodulating legumes. Store the soil in a cool place over winter and next spring, mix the soil with seed of the same legume species. This is not as convenient as using

commercial inoculant, but it seems to work.

### ***Seeding & Establishment***

Most legumes need well-prepared seed beds that are firm, level and weed-free. After seeding, the seed should be harrowed (or raked) and tamped in. Legumes need weed-free beds since they are relatively slow to become established and are vulnerable to weed competition.

Frost-seeding and overseeding are effective ways to help legumes become established. To frost seed, broadcast seed onto frozen ground in the spring, just before the soil starts to thaw. The freeze-thaw movement of the ground will pull the seed into the soil. Frost-seeding gives the seeds an early start; they can be growing while the rest of the ground is still too wet to be worked. To overseed, broadcast seed into an existing stand of other crops. For example, red clover is often overseeded into grain fields in the spring after the grain has become established. After the grain is harvested, the clover can continue growing for another season. Legumes can also be overseeded a few weeks before dieback of the main crop. This way, the canopy begins to open just as the legumes need more light.

Legumes combined with grains or grasses provide excellent green manures. The legumes can be overseeded or broadcast with the grasses. The grasses or grains control weeds, add organic matter and can provide structure for viny legumes (e.g. vetch) to climb on; the legumes provide nitrogen. After the green manure is turned under, the carbon in the grains or grasses will tie up some of the fixed nitrogen, preventing it from being leached. After trying a number of green manure combinations, I was most impressed by crimson clover mixed with annual ryegrass, and oats mixed with common vetch. (To combine green manures, cut the grain/grass

seeding rate in half and mix with the legume at 2/3 the regular legume seeding rate.)

Ideally, the legume seedbed is kept moist for several weeks after planting. Many legume seeds are close to the surface and take a couple of weeks to emerge. Consequently, the seeds are quite susceptible to drying. Also, the bacteria in the inoculant will die if the inoculant dries out. For these reasons, legumes are often planted in the spring or overseeded or planted just before rain is expected.

### ***Checking for nodulation***

So, now the legume is growing, but is it fixing nitrogen? If you are curious, carefully dig up the roots of a few legumes that are about to flower (4-8 weeks old). Look for round or oblong growths on the roots: these are nodules, the site of nitrogen fixation. Their presence indicates that the legume was successfully inoculated and probably is (or was) fixing nitrogen.

Ideally there should be a few large nodules or many small nodules. For example, a hundred small nodules on a clover plant or two dozen large faba bean nodules is excellent. To see if the plant is actively fixing nitrogen, break a few nodules in half. Active nodules are red or pink inside; inactive ones are green or black. You might want to pull up some leguminous weeds to see what their nodules look like; weeds often provide excellent examples of nodulation.

If a legume isn't nodulating, there are a number of possible explanations. The legume may be too young or too old – nodulation peaks just before flowering. The legume may have been stressed – legumes slough off the nodules when stressed by drought, mowing or other adverse conditions. The soil may also be too rich – legumes are lazy. If there is a considerable

amount of nitrogen in the soil, the legumes will simply use the soil nitrogen rather than fix nitrogen. Legumes fix the most nitrogen when no nitrogen source has been added to the soil for the last two years.

### ***Incorporating green manures***

There's a common assumption among gardeners that you can plant peas or beans to add nitrogen to the soil *and* harvest a crop from them as well. Unfortunately, there's a trade-off involved.

Nitrogen fixation in legumes peaks at flowering. After that, the nitrogen moves to the seeds. In the seeds, the nitrogen is converted into amino acids, the building blocks of protein. (This explains why the dried seeds of legumes such as beans are high in protein.) When the beans or peas are removed, most of the fixed nitrogen is harvested as well. If the rest of the plant is removed, there is likely no net gain of nitrogen. Removing the plants and the roots could result in a loss of nitrogen.

To add the most nitrogen to your soil, green manures should be incorporated when they start to flower. Legumes break down quickly, and the nitrogen is released into the soil as nitrates. Nitrates are readily available for plants, but are also susceptible to leaching. So, even if a green manure is successfully established, nodulated and incorporated, the nitrogen may still be lost. If a green manure is turned under in late summer or early fall, and the soil stays bare

throughout from the fall rainy season through the next spring rain, much of the nitrogen may be leached.

There are many ways to retain the nitrogen in the soil. The nitrogen can be taken up by living plants such as catch crops. Catch crops can be planted after the legume is turned under, and will take up the nitrogen and hold it in their tissues until they decompose. The catch crops are incorporated the following season. Excellent catch crops include fall rye, ryegrass, oats, white mustard, oilseed radish, buckwheat and phacelia.

The other way to hold nitrogen in the soil is by adding carbon-rich material to bind up the nitrogen. (Carbon-rich material is what composters call 'browns'.) For example, straw can be tilled into the soil. Another way to incorporate carbon-rich material is to grow the legume with a grass or grain. When the combined green manures are incorporated in the soil, the nitrogen will be tied up by the grain or grass, and there should be no problem with leaching.

In the farm or garden, legumes can be used as green manures by incorporating a plowdown crop into the crop rotation every three to four years. Legumes can also be used for intercropping or companion planting. For example, soybeans can grow between corn rows, clover can be a living mulch around brassicas or nightshades, and clover can be overseeded into grain stands.

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# Green manures in the garden rotation

By Janet Wallace

*“My garden is too small for green manures; I can’t devote growing space to them...It’s too difficult to fit green manures into my garden schedule...They are too labour intensive...I don’t have the proper equipment...I don’t need them; I use compost instead.”*

Although green manures are an integral part of organic farming, many gardeners don’t use them. There are a number of reasons for this. Many gardeners don’t realize how easily green manures can fit into their gardening routine and how beneficial they can be, in both large and small gardens. Green manures can be grown in most gardens without displacing vegetable crops. Instead, green manures can grow when the soil would otherwise be bare such as early spring or after fall harvesting (see table below). Green manures can also be used as living mulches and grow in the bed along with the crop.

It’s easy to grow green manures. For many green manures, all that is needed is a rake and a garden fork (though a rototiller and lawnmower can also be used). Many gardeners feel that they don’t need to use green manures because compost provides all of the nitrogen, carbon and organic matter they need. Although this may be true, green manures have many other advantages. They control weeds, reduce nutrient leaching, and cycle nutrients from deep in the soil. Green

manures protect the soil from erosion, provide habitat for beneficial organisms, and break pest cycles. Gardeners can use compost to provide nutrients and add organic matter, and use green manures for their many other benefits.

## **Cultivation of green manures**

To plant green manures, simply rake the soil and broadcast the seed. Small seeds, like clover, can then be just pressed or tamped into the soil. Larger seeds, like oats, can be covered by raking and tamping. To increase rates of nitrogen fixation, inoculate legume seed with a rhizobial inoculant before planting. For organic production, genetically-modified legume inoculants must be avoided.

Mowing can stimulate, suppress or even kill green manures, depending on when and how low the crop is mowed. A lawnmower, whipper-snipper, hedge trimmer or scythe can be used. The choice of tool depends on how level the ground is and the height of the cut.

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To kill green manures, mow them close to the ground under severe growing conditions (eg. just before hard frosts, or during dry, hot weather). In this way, the cover crop can be killed without tilling and the ground will remain covered. In contrast, during periods of vigorous growth, mowing can be used to stimulate green manures and give them a competitive edge over weeds. For example, ryegrass and clover usually grow more vigorously after being mowed (if they are mowed quite high, before flowering and during good growing conditions).

### **Incorporating cover crops**

Green manures are incorporated into the soil using a garden fork or rototiller. When the crop residue is incorporated into the soil, the soil life goes wild consuming the crop residue. This burst of activity requires nitrogen, and consequently the soil nitrogen is tied up for weeks. As well, the decomposing material releases ethylene gas that inhibits germination. For these reasons, gardeners should wait a few weeks after incorporating a green manure, before planting a new crop (at least 2 weeks after a legume or buckwheat, and 3-4 weeks after a cereal or grass). Small-seeded crops are most susceptible to these effects, and transplants are less likely to be affected.

After the green manure has been killed by severe mowing or by frost, the mulch can be left on the surface and crops planted into it. This no-till approach avoids many negative consequences of tilling, keeps the soil covered and makes it easier to fit green manures into the garden schedule. However, by simply leaving the mulch on the soil, some nitrogen may be lost to the air and decomposition may be slower (due to less contact between mulch and soil organisms, and often poor temperature and moisture conditions). As well, this approach should

only be used where weeds are well controlled.

### **Choices of green manures**

Many green manures can be used in the garden—choose varieties that are compatible with your gardening tools and methods. For example, gardeners who are just starting to use green manures might want to try the types that winterkill. In contrast, perennial and vigorous green manures (e.g. fall rye, ryegrass, sweetclover and vetch) are most suitable for growers with considerable experience and equipment. A selection of green manures is described below.

### **Oats**

Oats are an excellent green manure for the garden, being both easy to grow and unrelated to garden crops. Oats grow quickly, providing good weed control. They improve the soil in a number of ways, including increasing the levels of soil organic matter. Oats are said to heal depleted soil by adding calcium, improving soil structure and stimulating soil life. They also provide an excellent ground cover throughout the growing season and over winter.

Oats are winterkilled throughout most of Canada (zones 1-7); this makes them perfectly suited to the home garden. They can be planted any time from early spring to autumn.

However if planted early, there is a risk that they might set seed. To avoid this, cut the oats when the grain starts to form.

The simplest way to use oats is to plant them in midsummer or early fall. For example, oats can be planted after harvesting early crops (e.g. garlic, greens, peas or broccoli). They grow until winter, protecting the soil



and controlling weeds. The oats winterkill and next spring, the crop residue can be turned into the soil. Or, if the bed isn't weedy, seedlings can be transplanted right into the residue.

Oats are available from certain seed houses and feed stores, however certified seed for oats (*n.b.* this is not the same as certified organic seed) is often treated with fungicides. If untreated seed oats are unavailable, oats for livestock feed can be used. In particular, feed oats for horses have high germination rates.

### **Buckwheat**

Buckwheat is a green manure that can fit into short gaps in the crop rotation. It grows quickly in warm weather and provides excellent weed control. Although buckwheat does not increase levels of soil organic matter, it does improve soil fertility by bringing up nutrients from deep in the soil. It accumulates phosphorus, potassium and calcium, making these nutrients available to following crops. After buckwheat has been grown, earthworms thrive and the soil becomes very friable. Buckwheat is an excellent bee crop; a patch of flowering buckwheat literally buzzes with activity. Note that traditional varieties of buckwheat must be used; in breeding new hybrid varieties, the nectar gene was inadvertently lost.

Buckwheat sets seed only six weeks after planting. The blossom time is extended and the buckwheat can sneakily set seed at the bottom of the plant by the time you notice the flowers at the top of the plant. To avoid problems with volunteer buckwheat, cut or incorporate buckwheat before it sets seed or plant it late enough to be frost-killed before setting seed. It is killed by the first frost, and the succulent tissue quickly decomposes. Late-planted fall crops, such as garlic, can be planted right into the buckwheat residue.

### **Phacelia**

Phacelia controls weeds, covers the soil and attracts bees. It fits easily into crop rotations because it is unrelated to vegetable crops, although it is sometimes used as an ornamental flower. It has a remarkable effect on the soil. After incorporating phacelia, the soil is amazing to work—soft and friable with beautiful soil structure. The seed is available from a few seedhouses or from beekeepers. To save money, a small bed can be grown in one year and the seed can be saved for future planting. Phacelia is winterkilled but can tolerate light frosts.

### **White clover**

White clover plays several roles in organic gardens. Dutch, or common, white clover is a low-growing (6 in. high) perennial legume, winter hardy in zones 4+. It is a tough little plant that can handle foot and wheelbarrow traffic. Because of this, white clover is often used for pathways in gardens and is increasingly recommended for a mow-free, herbicide-free lawn.

Whereas bare soil pathways quickly become compacted, white clover paths have excellent soil structure and soil life. In following years, the pathways can be used for garden beds. In lush gardens, the clover may creep into crop rows, but it can be controlled by hoeing or hand-weeding.

White clover can also be used as a living mulch planted around the crops. The clover provides nitrogen, while protecting the soil and controlling weeds. To avoid competition between the clover and the crop, the crop should be well-established before planting clover. For example, white clover can be broadcast around brassicas a week or so after transplanting, into corn that is 4-6 in. tall, or into onions in midsummer.

### **Crimson clover**

Crimson clover is a beautiful legume that grows to 12-16 in. tall. It is too tall for a living mulch, but can be used to add nitrogen and improve soil quality. Unlike most other clovers, crimson clover is winterkilled in zones 1-5. This is an asset for vegetable growers, because it facilitates using crimson clover for just one season. The next year, the residue can be raked off for composting, or seedlings can be transplanted right into the mulch.

### **Ryegrass**

Ryegrass is a fast-growing grass with a fibrous root system, unrelated to the fall or cereal rye. Whereas fall rye is a cereal crop that produces both straw and grain, ryegrass is a leafy grass that is rarely more than two feet tall. Ryegrass has a disturbing resemblance to quackgrass, but with darker, glossier leaves. It is an excellent crop for adding organic matter and controlling weeds. It can even compete with quackgrass, particularly if the ryegrass is mowed several times in the season. The mowing stimulates ryegrass, giving it a competitive edge over the quackgrass.

Both annual and perennial varieties can overwinter in areas in zones 5+ and can be quite a problem in the spring. To eradicate ryegrass, gardeners mow the ryegrass very low or rototill it just before a hard frost (in either the fall or spring). In the spring, it may require a couple of mowings or tillings to kill it.

### **Fall rye**

Fall rye, also called cereal or winter rye, is an excellent choice for late fall planting. In many areas, fall rye is the only green manure that can be planted following the fall vegetable harvest. For example, in zone 5, rye is planted any time from mid-August to mid-October. Rye can be used for

overwinter cover, and incorporated in early spring. Or, it can be left to grow throughout the season. By mid-July, the rye will be up to five feet tall and will soon set seed. If cut with a scythe, the gardener will have a supply of organic matter that can be either left on the bed, used as mulch or livestock bedding, or added to the compost pile.

### **Sunflowers**

Sunflowers can be used as a warm weather green manure to control weeds and break pest cycles. They control weeds both by smothering weeds with their fast growth and large leaves, and also by allelopathic suppression (release of chemicals that inhibit the germination of neighbouring plants).

Sunflowers can be planted after the last frost in the spring and turned under in mid-summer. Or, they can be planted in mid-late summer and allowed to winterkill. To reduce costs, sunflower seed intended for birdseed can be used as seed.

### **Weeds**

Weeds can be used as green manures. In addition to improving soil quality, weeds can also provide a diverse habitat for beneficial organisms. Keen observation and careful management is critical. To avoid terrible weed problems in the future, incorporate or cut the weeds before they go to seed or spread. Annual weeds, such as mustard, lamb's quarters and pigweed, can be easily used as green manures. However, this approach is unsuitable if there are many perennial weeds.

So, whether you are farming a quarter section or gardening a quarter of an acre, try growing a green manure. You might be surprised at how easy it is, and how great the benefits are.

Crop sequence Green manure	Spring	Summer	Autumn	Winter	Spring
Potatoes <b>T</b> Beans Fall rye	plant potatoes	potatoes growing	harvest potatoes; plant fall rye	fall rye is dormant	till in rye, wait 3 weeks, plant beans
Garlic <b>T</b> Peas Oats	garlic growing	harvest garlic in late summer	plant oats	oats winterkill	plant peas into winterkilled mulch
Spinach <b>T</b> Kale <b>T</b> Peas Buckwheat	plant spinach in early spring	after spinach is done, plant buckwheat	till in buckwheat; plant fall kale	harvest kale in early winter	plant peas into winterkilled mulch
Cabbage <b>T</b> Tomatoes White clover	transplant cabbage and broadcast clover seed	cabbage grows surrounded by clover	harvest cabbage; leave clover	soil covered by clover	till in clover, wait 2 weeks, plant tomatoes

*Source: Gaining Ground: Making a Successful Transition to Organic Farming, Canadian Organic Growers. 2006.*



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