# Legume Green Manuring

Soil productivity is an important concern for farmers. Green manuring is gaining popularity as a method that successfully improves soil productivity.

Green manuring involves growing a crop, that will be worked into the soil later. The addition of organic material improves soil tilth. At the same time, the nutrients used in plant growth are conserved and returned to the soil to enhance its fertility.

Almost any crop can be used for green manuring, but legumes are preferred because of their ability to fix nitrogen from the air. Green manuring with legumes (peas, clovers, lentils, etc.) is called legume green manuring.

Growing a legume crop to be worked into the soil is an old agricultural practice that is increasing in popularity again. It is used as a soil building practice that adds organic residues, conserves and recycles plant nutrients and protects the soil from erosion. It is a viable alternative to conventional summerfallowing and can reduce the amount of nitrogen fertilizer required. Legume green manuring is a management tool worth considering.

## History

References to legume green manuring to enhance soil productivity have been traced back to the days of Cato (234-149 B.C.). Cato suggested improvements to poor vineyard land by interplanting a legume crop. This crop was then turned under before the plants set seed.

In the early 1900s, Dr. W.E. Taylor, director of the soil culture department of Deere and Company in Moline, Illinois, referred to the use of legume green manuring. A 1913 publication, *Soil Culture and Modern Farm Methods*, stated legume green manuring could be profitably used on lands where it was not possible to add animal manures. Taylor gave examples of research results that showed benefits from legume green manures.

**Effect of Unfertilized Legume Green Manures on Cereal Crop Yields in Germany in the Early 1900s**

| | **Increased cereal yield,** | |
|---|---|---|
| **Type of legume** | **kg/ha** | **bu/acre** |
| White Lupine | 1514 | 23 |
| Crimson Clover | 1011 | 15 |

Early settlers on the Canadian prairies seldom used legumes in rotation because the newly cultivated grassland soils were generally fertile. However, the land's nitrogen status became depleted after years of cropping cereals with no addition of fertilizer. Growing legumes as green manures or as forage crops became an important practice for maintaining soil productivity. Sweet clover was commonly used as a biennial crop. It was underseeded in a grain crop and then harvested a

The role of nitrogen-fixing plants in cropping systems diminished in the 1940s when relatively inexpensive and abundant nitrogen fertilizers became available.

Recently the use of legumes in crop rotations has increased. Many farm managers are trying to reduce input costs and use farm techniques that reduce the application of commercially produced chemicals such as fertilizers and herbicides. In some cases, farm managers have stopped using chemicals.

## Benefits of Legume Green Manuring

Legume green manuring adds nitrogen and organic residues to the soil. It protects soil from erosion and is an alternative to conventional summerfallowing.

## Nitrogen fixation

The main benefit of using a legume as a green manure is that legumes fix nitrogen from the atmosphere and convert it into a form that is available to other plants.

Legumes form a symbiotic association with certain soil bacteria called rhizobia. These bacteria colonize the root hairs of the legumes and multiply causing swellings, which become nodules. The bacteria benefit from the relationship by obtaining carbohydrates (plant sugars) from the legume. The growing legume benefits from the nitrogen that is captured from the air and converted into ammonium within the nodules.

The incorporated legume residues are a biological source of nitrogen that reduces the amount of fertilizer required for the following crop. The amount of nitrogen fixed by a legume depends on the legume variety, the effectiveness of the legume-bacteria association in root nodules, soil fertility and climatic conditions. The table below shows levels of nitrogen fixation for selected annual legumes grown at one location in 1986 and four locations in 1987. The nitrogen fixed by the Sirius field pea was much greater at the Trochu site in 1986 because growing season precipitation was greater in that year. In 1987 the Oyen site received little precipitation (25 per cent of normal amounts). This accounts for the lower average levels of fixed nitrogen compared to the other three sites.

**Total Nitrogen Yield and Estimated Fixed Nitrogen (kg/ha) of Annual Legumes**

| | **Oyen** | **Provost** | **Trochu** | | **Rimbey** |
|---|---|---|---|---|---|
| Legume | 1987 | 1987 | 1986 | 1987 | 1987 |
| Sirius field pea | 12 | 48 | 80 | 53 | 30 |
| Indianhead lentile | 7 | 8 | 45 | 40 | 20 |
| Tangier flat pea | 10 | 9 | 46 | 17 | 15 |
| Site-year average | 10 | 22 | 57 | 37 | 22 |

Farming for the Future Project #87-0178. Major soil zone at each location:
Oyen - Brown; Provost - Dark Brown; Trochu - Thin Black; Rimbey - Gray

The table below shows estimates of yearly nitrogen fixation by perennial legumes. Compared to the annual legumes, perennial legumes have higher levels of nitrogen fixation when averaged over the life of the stand. A portion of this fixed nitrogen is removed as hay and does not remain in the soil. But what is left as root exudates, decaying roots and above ground stubble is significant and helps to maintain soil fertility.

**Estimated Annual Nitrogen Fixation (kg/ha) by Perennial Legumes from Agriculture Canada Research Station, Beaverlodge**

| **Legume** | **Gray Soil** |
|---|---|
| Red clover | 167 |
| Alsike clover | 151 |
| Alfalfa | 221 |
| Sweet clover | 107 |

***Nitrogen fixation estimates include nitrogen in the total plant***

Field studies have shown that between 10 and 20 per cent of the total annual legume nitrogen added to the soil as a green manure is used by the first subsequent cereal crop. An additional 64 per cent of the legume nitrogen can be found in the top 1.2 metres (4 ft) of soil 14 months after green manuring. This nitrogen becomes available as plant residues continue to decompose.

For example, a cereal crop requires 45 lb/acre of nitrogen for optimum growth. The cereal crop can obtain 12.5 lb/ac of nitrogen from the ploughed-down legume crop if the legume residue contains 62 lbs/acre of nitrogen. Assuming an additional 9 lbs/acre of mineral nitrogen is released from the soil reserves, then the cereal crop will require only 23.5 lbs/acre of fertilizer nitrogen. In most cases, as in this example, legume green manuring does not supply all the nitrogen for optimum crop growth but can reduce the amount of nitrogen fertilizer required.

## Additions of crop residues

Adding crop residues to the soil helps maintain soil organic matter. The increase in soil organic matter increases nutrient availability and improves the physical qualities of soil such as water infiltration, moisture storage capacity, aggregate stability, and resistance to erosion.

In comparison, neither organic residues nor plant nutrients are added by conventional summerfallowing. Soil organic matter decomposes whether a crop is growing or not. Decomposition of organic matter releases significant amounts of plant nutrients.

The intense tillage during conventional fallowing physically disrupts the soil and increases aeration, which accelerates the decomposition of crop residues and soil organic matter. Only a portion of the released nutrients remains in the soil and is used by the crop following the fallow year. When organic matter levels are relatively high, conventional summerfallowing can be used to supply nutrients to a crop. This decreases the need for fertilizer in the short term, but not without a long-term cost.

Without a crop to cycle nutrients back into the soil during the fallow year, significant losses of some nutrients, such as nitrogen, can result. In the crop-fallow system common to parts of the prairies, nitrogen removed from the soil has far exceeded that returned in crop residues or fertilizers. As a result, prairie soils, which originally had the potential to release up to 125 lb/acre/yr of mineral nitrogen, today may deliver as little as 9 lb/acre/yr. See Soil Organic Matter, Agdex 536-1.

This decreasing supply of plant available nitrogen results in poor crop growth and the need for greater additions of nitrogen fertilizers to obtain adequate crop yields.

## Protection from erosion

Green manures function much like cover crops. Both help protect the soil from wind or water erosion between normal cropping periods.

## Crop diversification

Growing legumes gives a producer several options besides green manuring. The crop can be a source of high quality feed in years of hay shortage, or it can be grown for seed and serve as a cash crop.

## An alternative to conventional summerfallowing

Conventional summerfallow is used to increase moisture levels in the soil and reduce weed populations, but it leaves the soil susceptible to erosion. Legume green manuring adds more crop residues to the soil, provides protection from erosion and helps to improve soil organic matter levels. Thus, a legume green manure can be considered as an alternative fallow system that has a soil-building cover crop on the land for part of the year.

Legumes use water while growing. Therefore, in comparison to conventional summerfallow, legume green manuring may reduce the amount of moisture available for the subsequent crop. However, annual legumes have been shown to use only one-half to two-thirds the water used by a normal crop of spring wheat. In moister areas where recropping is common (e.g., Black and Gray soils) this moisture reduction is usually not critical.
Even in the drier areas (Brown and Dark Brown soil zones) green manuring will not adversely affect yields if average rainfalls occur. This is shown from research results from Scott, Saskatchewan on a Dark Brown soil. Plant-available moisture the spring after fallowing or green manuring was 47 and 31 mm respectively. The grain yields of the subsequent wheat crop were 22.0 and 22.4 bu/acre respectively (Agriculture Canada Experimental Farm, Scott, Saskatchewan, April 1989).

However, under severe drought conditions, water loss due to growing legumes can depress the subsequent crop yields compared to conventional fallowing. An example of this occurred when cropping season precipitation was 25 and 46 per cent of normal levels at a research site near Oyen on Brown soil in 1987 and 1988. Barley yields after green manuring peas were 4 bu/acre and after fallowing they were 7 bu/acre. Moisture was so limited at this site that even though the crop after fallowing was considered very poor, the yield of the crop following green manuring was even lower.

# Managing a Legume Green Manure

Perennial, biennial and annual legumes have all been successfully used as green manures. The choice of legume depends on soil type and climate, especially levels of precipitation. In regions with adequate precipitation, underseeding of a perennial legume to be green manured in the second or even third year is a common practice. In drier regions, annual legumes grown for six to seven weeks before incorporation at full bloom do not excessively deplete soil moisture reserves for the subsequent crop.

Perennials and biennials used for green manure include red clover, alsike clover, alfalfa, and sweet clover. Annual legumes presently used for green manure include field peas, flat peas (sweet pea family), and lentils.

# Type of legume

A legume used for green manure should meet the following basic requirements: provide adequate ground cover to protect against soil erosion, either over winter, as in the case of an underseeded perennial, or in the late spring, as in the use of early seeded annual, have a high rate of nitrogen fixation and good biomass production, have high water-use efficiency when used in drier regions. The legume should use as little water as possible while still producing substantial quantities of top-growth, compete well with weeds (especially broadleaved) because the choice of herbicides is limited for legume crops.

The use of a herbicide may not be cost-effective for a non-cash crop used as a green manure. Herbicides are usually not required in green manure crops because all plant growth, crops and weeds are worked down before the weeds set seed.

### Legumes Commonly Used for Green Manuring

| Legume | Variety | Species | Growth Type | Seeding Rate lb/ac | Cost of Seeding $/ac |
|---|---|---|---|---|---|
| Black lentil | Indianhead | *Len culinaris* | annual | 20 | 5 |
| Field pea | Sirius | *Pisum sativum* | annual | 80 - 100 | 18 - 22 |
| Chickling vetch | A.C. Greenfix | *Lathyrus sativus* | annual | 90 | N/A * |
| Sweet clover | Norgold | *Melilotus officials* | biennial | 6 - 8 | 4 - 5 |
| Red clover | Altaswede | *Trifolium pratense* | short-lived perennial | 6 - 8 | 5 - 7 |

** Soon to be released variety. Accurate seed costs are not available but it is expected to be intermediate between lentil and field pea seed costs.*

### Seeding rates

Seeding rates and initial management of legumes for green manure are similar to those for growing legumes for forage or for seed. Guidelines are for a stand density of about 50 plants $m^2$ for large-seeded legumes (e.g. peas) and about 110 plants $m^2$ for small-seeded legumes (e.g. clovers).

## Cost of seed

The cost and availability of legume seed is another consideration. Smaller seeded legumes are generally less expensive. For example, the small-seeded clovers cost less to seed than annual legumes (e.g. peas) which are all relatively large-seeded.

## Inoculation

Since nitrogen fixation is one of the main benefits of using legumes as green manures, it's important to maximize this effect through proper inoculation. See Inoculation of Legume Crops, Agdex 100/23-1. Different legumes require specific species of rhizobia for the symbiotic relationship to work. To ensure that effective nodules are formed, properly inoculate the legumes with the correct rhizobia.

The most popular inoculant uses finely ground peat moss as a carrier material, which helps to protect the live rhizobia. To be effective the inoculant must cling to the seed to ensure the rhizobia are close to developing roots. The best method is to use a sticker solution to promote adhesion between inoculant and seed. Commercial and non-commercial stickers, such as gum arabic, skim milk and corn syrup, serve to feed the rhizobia and protect them from drying on the seed. Follow the directions for inoculation as stated on the packages of purchased inoculant. Seed the legumes within a day or two after inoculation.

## Soil fertility

If a legume can readily obtain nitrogen from the soil, such as after a nitrogen fertilizer application, the atmospheric nitrogen fixation process will be inhibited. As a result, the incorporated legume will not add "new" nitrogen to the soil but rather recycle nitrogen that was already in the soil. Do not add nitrogen fertilizer to a legume green manure crop.

Phosphorus, potassium and sulphur fertilizers may be required on deficient soils See the ***Alberta Fertilizer Guide*** (Agdex 541-1). Soil pH below 6.0 may also have to be amended with lime for acid sensitive varieties.

## Timing of incorporation

The timing of legume incorporation should maximize top-growth and nitrogen fixation while minimizing soil moisture depletion. The present recommendation is incorporation at full bloom. After full bloom the plant material becomes tougher and will take longer to decompose and release plant nutrients for subsequent crops. Very young plant material, on the other hand, may decompose too quickly after incorporation, leaving the released nitrogen vulnerable to leaching and volatilization.

## Implements used for incorporation

Traditionally the mouldboard plough was used for legume incorporation. Ploughing turned over the soil, burying up to 90 per cent of the legume residue in a single tillage operation. It also left soil exposed. Without residues on the surface soil is prone to erosion and moisture loss.

More recently, heavy duty discs have become the implement of choice for incorporating all but the heaviest perennial stands. Disc implements adequately mix the legume residues into the soil, promoting even decomposition and nutrient release near the soil surface, while leaving some surface residues for erosion control.

Good soil erosion protection can be obtained by leaving all the top-growth of legumes on the surface by using a wide blade cultivator or a desiccating herbicide. Unfortunately this can result in excessive nitrogen losses through ammonia volatilization. Another alternative to complete incorporation is the practice of leaving strips of legumes standing. These strips can be used to produce seed for future green manure crops or for trapping snow over the winter.

## Examples of Legume Green Manuring

A farm manager in any location in Alberta could use an annual or perennial legume as a green manure crop. In most instances, however, annuals are better suited to the drier areas. The following examples show how legume green manuring can be used in the Dark Brown soil zone near Lethbridge or the Gray Luvisolic soil zone near Peace River.

## Dark brown soil zone

In parts of the Dark Brown soil zone of Alberta (i.e., from Lethbridge to Provost) the average annual precipitation is close to 400 mm (18 in.). The soil can be susceptible to erosion because the normally dry conditions produce low amounts of crop residue to protect the soil. As a result only moderate amounts of organic matter are returned to the soil. Green manuring with an annual legume can be used instead of conventional summerfallowing.

Following a single mid-May tillage operation with a cultivator and harrows, inoculated field peas are seeded at 71 lb/acre using a hoe drill. Herbicides are not required because the initial cultivation takes care of early weeds and later emerging weeds are not likely to set seed over the seven-week growing period before the peas are incorporated.

When the peas reach full bloom, they are worked down with a tandem disc. In a fairly dry year, the peas do not reach their potential yield but could still produce 2,580 lb/acre of dry matter. Total yield of nitrogen in the pea top-growth is 58 lb/acre of which 43 lb/acre is fixed nitrogen from the atmosphere. About 20 per cent of the total legume nitrogen, or 11.8 lb/acre, will be available to the next year's crop, reducing next year's nitrogen fertilizer requirement. The cost of field pea green manuring, using the variety Sirius, is compared to that of cultivated summerfallow in the table below. Keep in mind that a dollar value has not been assigned to the improvements in soil tilth and erosion control.

**Comparison of Costs and Benefits of Legume Green Manuring and Summerfallow**

| | **Sirius Field Pea** | **Red Clover* (Perennial)** | **Cultivated Summerfallow** |
|---|---|---|---|
| Tillage** | 4.00 | 4.00 | 20.00 |
| Seed *** | 20.00 | 4.41 | |
| Inoculant# | 2.48 | 0.41 | |
| Seeding | 3.50 | 3.50 | |
| Discing | 5.00 | 5.00 | |
| Total cost: | $ 34.98 | $ 5.77 ($ 17.32/3 yr) | $ 20.00 |
| Value of fixed N## | 11.52 | 35.07 ($ 107.01/3 yr) | |

* Assuming a three-year red clover stand, the costs and benefits are divided by three to represent the yearly average.
** Pre-seeding tillage for legumes. Five tillage operations on summerfallow.
*** Seed cost based on prices for Sirius field pea @ $0.25/lb and seeding rate of 100 lb/ac, Indianhead lentil @ $0.28/lb and seeding rate of 31 lb/ac and Common No.l red clover @ $0.63/lb and seeding rate of 9 lb/ac.
#Inoculant cost $1.71 to treat 55 lb (25 kg) of seed.
##Nitrogen value $0.24/1b.

## Grey Luvisolic soil zone

In the Peace River region the Grey Luvisolic soils (formerly known as grey wooded soils), require special management. Annual precipitation of about 500 mm (20 inches) is usually adequate for continuous cropping. However, the soils are inherently low in organic matter and tend to harden and crust when drying after rainfall.

Many farmers use a form of legume green manuring by including a short-lived perennial legume, such as red clover, in rotation. In the first year, the red clover is usually underseeded in another crop such as wheat or barley. In the second year the red clover can be grown as a forage crop or used for seed production.

During the last year of the stand an early cut of hay in mid to late June is taken. The remaining stand is incorporated by ploughing later in the season when the legumes have again regrown. In some years a producer may incorporate the stand by the end of June in the final year without first taking a cut of hay. A red clover stand yielding 3,115 lb/acre can be expected to contain about 90 lb/acre of nitrogen in the top-growth. This is in addition to the nitrogen that was cycled through the soil over the two years that the stand was in production (Table 3). About 20 per cent of this nitrogen, or 18 lb/acre, will be available to the following crop. Improvement in the physical quality of the soil has also been noticed after green manuring, and the tendency to crust is reduced. Table 5 includes the costs involved in green manuring red clover.

Source: Agdex 123/20-2