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Soil and Nutrient Management of Alfalfa

Ensuring adequate soil fertility levels and effectively managing nutrients are two keys to growing alfalfa successfully in Alberta.

Alfalfa can produce from 2 to 7 tons of dry matter per acre depending on water and nutrients levels. Climate, soil type and management will also affect alfalfa's potential yield.

Alfalfa has a high demand for nutrients compared to other crops. Table 1 gives the approximate amount of each nutrient removed per ton of dry matter alfalfa. Alfalfa also requires 4 to 5 inches of water for each ton of dry matter produced.

Successful alfalfa production requires effective nutrient management, including the identification of nutrient deficiencies and excesses. Soil sampling and soil testing are excellent tools for checking soil nutrient levels and are critical in developing a fertilizer management plan.

Table 1. Nutrient removal per ton of dry matter alfalfa

Nutrient	Amount removed (lbs/ac)
Phosphorus (P)	4 - 6
Phosphate (P_2O_5)	10 - 15
Potassium (K)	40 - 55
Potash (K_2O)	50 - 65
Calcium (Ca)	30
Magnesium (Mg)	5 - 7
Sulphur (S)	5 - 7
Boron (B)	0.08
Copper (Cu)	0.01
Iron (Fe)	0.3
Manganese (Mn)	0.1
Molybdenum (Mo)	0.002
Zinc (Zn)	0.05

Achieving a balance of nutrient inputs and removal outputs means knowing both the nutrient requirements and the nutrient removal. Reliable nutrient recommendations for alfalfa depend on accurate soil tests and crop nutrient calibrations based on extensive field research.

Soil sampling and testing: when, where and how

Field sampling and soil testing are important in significant ways:

- for assessing soil fertility and developing proper fertilizer recommendations
- to monitor soil changes resulting from cropping practices or to diagnose specific production problems

The biggest roadblocks to effective soil testing are improper and non-representative samples. Proper soil sampling will provide accurate soil test results and reliable nutrient recommendations.

When should soil samples be taken?

Ideally, it is best to sample fields after the beginning of October or in early spring. The drawback to spring sampling is that there is often very little time to take samples, have them analyzed and then order and apply fertilizer.

Problem soil areas may be sampled anytime.

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Where should soil samples be taken?

Soil variability is a major concern when deciding how to collect a representative soil sample. Getting a representational soil sample is important as soil properties can vary greatly over short distances, resulting in differences in crop quality and yield, and in erratic performances of fertilizers and herbicides.

Take samples from an area where yield is typically average to ensure soil test results are representative of the field. Results may not be representative if the person taking the soil samples does not take enough time to do a proper job or does not have the first-hand knowledge of the field to take samples from an appropriate location.

There are three methods for determining where to take the samples:

- random soil sampling
- managed random soil sampling
- benchmark sampling

Random soil sampling is the traditional approach for uniform fields with little variation. This sampling technique provides an average of all cores taken throughout a field.

Managed random sampling is different from random sampling as it involves taking samples from average production areas. Managed random sampling is recommended when it is impossible to identify a dominant production area in the field. Normally, 15 to 20 soil samples must be taken to have a good representation of the field.

Benchmark sampling is recommended for fields with a lot of variability, such as those containing hills or potholes.

Benchmark sampling reduces the variability of a field by reducing the area sampled. A small area (generally about one-quarter of an acre) representing the majority of the field is sampled the same number of times as with random sampling. This location is the reference area from which fertilizer recommendations are made.

This benchmark site should be marked with a global-positioning system (GPS) or other means so that samples can be taken in subsequent years. Sampling from the same area will reduce variability, creating a better picture of year-to-year changes. More than one benchmark is recommended where it is impossible to identify a dominant production area in the field.

When picking a benchmark area, use observable features such as soil color and landscape to identify where different soil types occur. Select a site that has characteristics similar to most of the field or the dominant soil type.

Some other suggestions:

- sample each field with the same crop and management history separately
- size up each field and observe variations in yield and crop growth, texture, color, slope, degree of erosion, drainage and past treatment
- separately sample sizable areas of fields where growth is significantly different from the rest of the field
- avoid unusual areas such as dead or back furrows, old straw, hay or manure piles, waterways, saline spots, eroded knolls and old fence rows
- select 15 to 20 sampling sites representative of the portion of the field to be tested

How should samples be taken?

To obtain samples:

- take soil core from 0 to 15 cm or 0 to 30 cm at each of 15 to 20 sampling sites
- for improved sulphur evaluation or where problem soils are encountered, separate samples should be taken from the 0 to 15, 15 to 30 and 30 to 60 cm depths at the same 15 to 20 sites
- place cores in clean pails or bags, then mix cores taken from the same depths, crushing lumps in the process
- keep samples taken from individual depths separate from one another

It is best to use a core-sampling tool for getting representative soil samples, and it is essential when sampling at depths below 15 cm. Soil samplers may be available on request from fertilizer dealers, private labs or crop advisors. Many fertilizer dealers offer soil-sampling services.

Sample preparation

Samples must be properly prepared for laboratory analysis:

- air-dry soil samples by spreading the soil in a thin layer on a clean piece of paper, plastic sheets or clean shallow containers in a clean room at room temperature
- do not dry samples with artificial heat
- remember that while some laboratories accept moist samples, delivery to the laboratory must be on the same day that samples are collected
- provide complete information for each soil sample set on laboratory sheets provided by the lab, including unusual soil or crop problems
- keep a record of the completed field plan of the area showing where each sample was taken

Laboratory analysis

Producers should talk with their laboratory about the type of analyses the laboratory will be doing on the soil samples.

Research in Alberta indicates that the typical soil analyses package for surface (0 - 15 or 0 - 30 cm) agricultural soils should include the following soil tests:

- nitrate-nitrogen
- available phosphorus
- available potassium
- extractable sulphur
- soil pH and salinity (electrical conductivity)

If possible, the sulphur analysis should be completed for subsurface soil samples (15 - 30 and 30 - 60 cm).

Producers may also request additional analyses for micronutrients (boron, chlorine, copper, iron, manganese or zinc) or organic matter for the surface soil samples. Some laboratories may provide additional analyses as part of their routine analysis package as a basis for more accurate interpretations and recommendations.

Considerations for soils with a history of manure application

Collecting a representative soil from a field that has had manure applied on it can be a challenge.

Unlike commercial fertilizers where the nutrients are readily available during the current year, manure releases its nutrients slowly over several years. The danger is that nutrients from organic sources may not show up in a chemical soil test; in this situation, conventional analysis may lead the producer to add too many nutrients.

To develop fertilizer recommendations, soil test labs need to take into account a field's commercial fertilizer and manure application history. A gross accounting procedure of manure nutrients and fertilizer inputs versus nutrient removal, along with soil testing, helps to monitor the nutrient balance for fields that receive manure.

Nutrient requirements and management of alfalfa

Nitrogen

Established alfalfa rarely needs nitrogen fertilizer. Alfalfa is a legume crop that can "fix" its own nitrogen (N) with the help of *Rhizobium meliloti*, which is a bacterium that lives on alfalfa roots.

The bacteria form nodules on the plant roots and live in association with the roots. The bacteria convert nitrogen gas (N_2) from the air into a form that plants can use. Alfalfa is very effective at fixing N. For example, a 5-ton/ac alfalfa crop can fix up to 250 lb/ac of N per year.

Since most soils in Alberta are low in natural N-fixing bacteria, alfalfa seed should be inoculated with the proper rhizobium strain *R. meliloti*. Alfalfa seed is often pre-inoculated before sale. Inoculated seed should be stored in a dark, cool place to ensure the bacteria survive until seeding time.

Improper inoculation may result in poor N-fixation. As well, alfalfa's ability to fix nitrogen may decline after a stand is four or five years old. If alfalfa is not performing properly, re-seed with an annual crop for several years before re-seeding with a recommended variety of alfalfa.

Phosphorus

Alfalfa has a high requirement for of phosphorus (P). A 5-ton/ac crop requires approximately 50 lb/ac of phosphorus (P_2O_5).

A soil test is strongly recommended to determine phosphorus requirements before seeding alfalfa for two key reasons:

- most soils in Alberta are naturally low in plant available P
- residual P levels vary in soils because many fields have received phosphate fertilizer or manure regularly for years

The most effective way to add P to soil is by applying a large batch of phosphate fertilizer or manure or compost before establishing the alfalfa:

- depending on normal yield potential, an application of 100 to 200 lbs/ac of P_2O_5 will meet crop requirements for four to five years
- in drier areas (which have a lower yield potential), an application of 100 lbs/ac of P_2O_5 is often enough
- in higher production areas or under irrigation, an application of 200 lbs/ac of P_2O_5 should be considered

Phosphate fertilizer can be either banded or broadcast-incorporated before to seeding alfalfa.

An Alberta Agriculture survey of 100 irrigated alfalfa fields showed the following:

- 70 per cent tested low in soil P
- only 44 per cent tested low in tissue P

Further research is needed to accurately determine when alfalfa will respond to added P fertilizer. However, as a general rule, soil testing is far more accurate in determining P fertilizer requirements than is tissue analysis. Results from tissue testing can vary considerably depending several factors:

- growth stage of the crop
- part of the plant sampled
- time of day samples are taken

Potassium

Alfalfa also has a high requirement for potassium (K). Most southern Alberta soils (Brown and Dark Brown soils) have adequate amounts of available K (greater than 250 lbs/ac of ammonium acetate-extractable K). Black and Gray Wooded soils in central and northern Alberta occasionally test low in soil K. Potassium fertilizer is recommended if soil K levels are less that 200 lbs/ac in the 0 to 15 cm depth. The fertilizer may need to be applied annually.

As a general rule, K is most commonly deficient on very sandy, intensively cropped soils. A soil test will help determine if K levels are deficient.

An Alberta Agriculture survey of 100 irrigated alfalfa fields showed the following:

- no fields tested low in K
- 79 per cent tested low in tissue K

Further research is needed to accurately determine at what point alfalfa might respond to added K fertilizer.

Sulphur

Alfalfa has a high requirement for sulphur (S).

Most Brown and Dark Brown soils have more than enough sulphate sulphur in their subsoils and are rarely S deficient.

Thin Black and Black soils are occasionally deficient in S, while Gray Wooded soils are often low in plant-available S. Soil testing is necessary to 24 inches to determine both S levels and S fertilizer recommendations for these soil types.

Irrigated soils are rarely deficient in S. Irrigation water naturally contains dissolved sulphate-sulphur (SO_4-S), which is the form required by plants. Approximately 30 lbs/ac of SO_4-S is contained in every 12 inches of irrigation water applied, which meets crop requirements.

On fields marginally deficient in sulphur, alfalfa may not show obvious visual deficiency symptoms, but this lack can seriously reduce yields. A deficiency of sulphur will cause a yellowing of younger leaves in the initial stages. In some cases, it will also cause leaves to be poorly developed, with a slight purple color on their backs. In these situations, growth will be delayed and prolonged, resulting in delayed maturity.

Calcium

Calcium (Ca) is a macronutrient that is absorbed in relatively large amounts by alfalfa. It is sometimes referred to as a “secondary” nutrient, probably due to uncommon deficiencies. However, due to ample soil reserves, these deficiencies are extremely rare in Western Canada.

There is promotion of Ca fertilizer use in Alberta, claiming that exchangeable Ca reserves are not readily available. However, at present, Ca fertilization is not recommended for alfalfa production in Alberta.

Magnesium

Magnesium (Mg) is another macronutrient required for alfalfa growth. Like calcium, magnesium deficiencies are rare in Alberta.

Little information is available on alfalfa’s Mg requirements. There are also no reports of alfalfa response to Mg fertilizer in Western Canada. As such, no reliable soil or alfalfa tissue test criteria are available. However, Mg deficiency appears unlikely in slightly acidic to neutral soils unless there are excessive amounts of root zone Ca, K or NH_4^+ (ammonium nitrogen).

Micronutrients

Micronutrient requirements for alfalfa:

- boron (B)
- chlorine (Cl)
- copper (Cu)
- iron (Fe)
- manganese (Mn)
- molybdenum (Mo)
- zinc (Zn)

There have been no scientifically documented responses from alfalfa to micronutrient fertilizers in Alberta. However, only a few research trials with micronutrients have been conducted in Alberta.

Boron (B) is the only micronutrient that may become a problem in the near future. Boron deficiencies first appear on sandy, low organic matter soils that are more intensively cropped. Extreme care is required when using boron because a 3 lb/ac application may be toxic to alfalfa (as well as to other crops), particularly if applied on acid soils. A soil specialist should be consulted before using costly micronutrient fertilizers.

For more detailed information on micronutrients, see ***Micronutrient Requirements of Crops (***Agdex 531-1), available on-line at: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex713

Alfalfa and problem soil management

Acid soils

Soil acidity can be a major deterrent to high alfalfa production. Acid soils in Alberta occur primarily in the Gray Wooded soil regions of central Alberta and in the Peace River region.

The pH of some Black soils has declined as a result of cropping practices and the use of soil nitrogen fertilizer. Soils in the pH range from 5.6 to 6.0 are moderately acidic and below 5.5, they are strongly acidic. Poor growth of a sensitive crop such as alfalfa may indicate an acid soil condition. However, a soil test is the only reliable way of determining whether soil is acid or not.

Soil acidity directly affects the growth and survival of rhizobium bacteria, which is the bacterium that fixes nitrogen in association with legumes. The rhizobium bacteria associated with alfalfa and sweet clover are especially sensitive to acidity.

Acid soils often contain soluble forms of aluminum (Al) and manganese. As soil pH decreases, soluble Al and Mn increase to toxic levels producing several effects:

- aluminum toxicity restricts root growth and phosphorous uptake
- manganese toxicity causes cupping of leaves of alfalfa
- aluminum and manganese toxicity often reduce the yield of crops grown on acid soils

The application of lime reduces soil acidity (pH increases). Lime lowers soluble Al and Mn to non-toxic levels and creates a suitable environment for rhizobium bacteria.

The first step in the management of acid soils is to identify the extent and severity of the problem. With careful sampling of fields, soil tests can be used for the following:

- determine the extent and severity of soil acidity
- determine the rate of lime required to restore non-toxic levels
- estimate the crop's response to lime

An estimate of both crop response and the cost of lime provides a basis for assessing whether or not it is worthwhile to apply lime to the field.

Each field to be limed should be sampled carefully. Divide a field into areas on the basis of soil type or differences in crop growth, and sample each of these areas separately. Some areas of a field may require higher rates of lime than others, and some areas may not require any. A lime requirement test should be requested to determine the amount of lime required to bring the soil to pH 6.5.

The rate of lime needed depends on the amount of pH change required and the buffering capacity of the soil. Buffering capacity refers to the amount of lime required to change pH a given amount. Sandy soils and soils low in organic matter have low buffering capacities. Clay soils and soils high in organic matter have high buffering capacities. Approximately 2 to 3 tons of lime is typically required on fine-textured Gray Wooded soils.

For more detailed information on soil acidity, see ***Liming Acid Soils*** (Agdex 534-1) available on-line at available on-line at: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3684

Soil salinity

Saline soils are those with a high concentration of soluble salts. Saline soils can be identified using soil tests to determine the electrical conductivity (EC), which is the amount of electrical current a soil extract will conduct. EC measurements are usually expressed in deciSiemens per metre (dS/m). Soils that have an E.C. of greater than 4 dS/m are considered saline. However, surface soils with an E.C. of 2 are slightly saline and can affect the establishment of alfalfa.

A high salt level interferes with the germination of seeds and severely affects young seedlings. Salinity acts like drought on plants, preventing roots from performing their osmotic activity where water and nutrients move from an area of low concentration into an area of high concentration in the roots. Higher salt concentrations in the soil reduce or prevent the uptake of water and essential nutrients by plant roots; this, in turn, restricts plant growth and reduces crop yield.

In Alberta, approximately 1.6 million acres of dryland are affected by secondary salinity, with an average crop yield reduction of 25 per cent. The problem is caused by groundwater redistributing salts and accumulating them at the surface.

While alfalfa seedlings are very sensitive to salts, established alfalfa plants are more resistant. As such, alfalfa can be successfully used to help control soil salinity and aid in the reclamation of salt-affected soils.

More information about soil salinity is available on-line at the following web sites:

- http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag3304?
- http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag3267?
- http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex9314

Fertilizer management of established alfalfa

Nitrogen

Alfalfa yields have increased slightly when given nitrogen fertilizer when N-fixation:

- is inadequate
- declines as an alfalfa stand gets older and less productive

However, no research has been done to find out if applying N fertilizer on alfalfa is economical. In fact, N fertilizer encourages the growth of grasses in alfalfa stands, which may eventually dominate the stand.

Applying nitrogen fertilizer on healthy alfalfa stands is not recommended.

Phosphorus

If P fertilizer was not applied before seeding or is limiting production, a grower should consider an annual maintenance application of 25 to 50 lb/ac of P_2O_5 to meet crop removal rates. This approach may not be as effective as pre-plant incorporated phosphate fertilizer because P is immobile and moves very slowly into soil. However, under moist conditions or irrigation, alfalfa has feeder roots near the soil surface that can take up broadcast P reasonably efficiently.

There are presently only two practical methods for applying fertilizer to dryland fields:

- broadcasting granular phosphate fertilizer
- dribble-banding liquid phosphate fertilizer

Irrigation farmers have the option of doing a fertigation application (fertilizer through an irrigation system) using liquid phosphate fertilizer (10-34-0). Phosphate fertilizer is most effective when done very early in the spring.

Table 2 provides general phosphate fertilizer recommendations for the major soil zones in Alberta. Compost is an excellent source of both phosphorus and potassium.

Table 2. Annual phosphate fertilizer recommendations for alfalfa

	Phosphate (P_2O_5) recommendations(lb/ac)					
Soil test phosphorus (P) (0-15 cm depth) (lb/ac)	**Irrigation**	**Brown soil**	**Dark Brown soil**	**Thin Black soil**	**Black soil**	**Gray Wooded soil**
0 - 10	60	40	45	50	50	50
10 - 20	50	35	40	45	45	45
20 - 30	45	30	35	40	40	40
30 - 40	40	25	30	35	35	35
40 - 50	35	20	25	30	30	30
50 - 60	30	20	20	25	25	25
60 - 70	20	20	20	20	20	20
70 - 80	10	20	20	20	20	20
>80	0	0	0	0	0	0

Note: Based on the Kelowna soil P test method.

Potassium

Annual applications of potash (K_2O) fertilizer may be necessary in fields testing deficient in potassium. The soil test recommendation should be followed (Table 3).

Occasionally, if conditions are unseasonably wet and cool, fields that have sufficient K soil levels may respond to a 50 lb/ac application of K_2O fertilizer in early spring. Under these conditions, soil K is less available and less mobile in the soil.

However, Alberta research trials have shown that a response to K_2O fertilizer is uncommon. Applications should first be tried in carefully marked test strips to see if the crop responds favourably.

Sulphur

Much of the sulphur in the topsoil is contained in the soil organic matter and is slowly released as sulphate-sulphur (SO_4-S), which is the sulphur form that plants require.

Sulphate-sulphur is similar to nitrate-nitrogen in that it is very mobile in soil. Sulphate-sulphur can also be highly variable across fields. When a field is uniformly low in S, a soil test is very useful to estimate S fertilizer needs. However, if 10 to 20 per cent of a field is low in S, it can be difficult to identify the deficient areas without intensive soil sampling.

Table 4 can be used as a guide to determine if sulphur fertilizer is required.

Table 3. Potash fertilizer recommendations for irrigated alfalfa

	Potash (K_2O) recommendation(lb/ac)					
Soil test potassium (K) (0-15 cm depth) (lb/ac)	Irrigation	Brown soil	Dark Brown soil	Thin Black soil	Black soil	Gray Wooded soil
0 - 50	125 - 160	105 - 140	110 - 145	110 - 145	115 - 150	115 - 150
50 - 100	90 - 110	70 - 100	75 - 110	75 - 110	80 - 115	80 - 115
100 - 150	55 - 90	35 - 70	40 - 75	40 - 75	45 - 80	45 - 80
150 - 175	40 - 55	20 - 35	25 - 40	25 - 40	30 - 45	30 - 45
175 - 200	20 - 40	20	20 - 25	20 - 25	20 - 30	20 - 30
200 - 225	0 - 20	0 - 20	0 - 20	0 - 20	0 - 20	0 - 20
225	0	0	0	0	0	0

Note: Based on the ammonium acetate soil K test method.

Table 4. General sulphur fertilizer recommendations for alfalfa in different soil zones

Soil test S level (lb/ac)	Sulphate-sulphur recommendations (lb/ac)		
(0 - 6 + 6 - 12")	Brown & Dark	Black & Gray	Irrigation
0 - 5	20 - 25	25 - 30	25
5 - 10	15 - 20	20 - 25	20
10 - 15	10 - 15	15 - 20	15
15 - 20	5 - 10	10 - 15	10
20 - 25	0 - 5	5 - 10	0
>25	0	0	0

If a sulphur fertilizer is required, types that contain 24 per cent SO_4-S (for example, ammonium sulphate [21-0-0-(24)]) are best. These fertilizers contain sulphate that is immediately available to the crop.

Fertilizers that contain elemental (pure) sulphur can be used for a long-term building program. Elemental sulphur must be converted by soil microorganisms to the sulphate form before it can be utilized by plants. Normally, this conversion time is too long for the fertilizer to be able to help alfalfa on deficient soil in the year of application.

Manure and compost

Manure and compost supply relatively large amounts of phosphorus and potassium.

When manure is used as a fertilizer on established alfalfa fields, it can burn the leaves, reducing the yield and quality of the alfalfa. In addition, manure application equipment may reduce yields by compacting soil and damaging alfalfa crowns. Generally, it is best to apply manure before establishing alfalfa or during the cereal crop part of an alfalfa-cereal crop rotation.

The nitrogen in manure may stimulate grass and even weed growth in alfalfa stands; as such, manure performs better on non-legume crops. If no other land is available, spread the manure on the oldest alfalfa stand or a field with the most grass.

Solid manure should be well broken up and applied at a rate no higher than 10 tons/ac. Apply it immediately after a cut, so the manure contacts the soil rather than the crop. To reduce soil compaction, the manure should be applied on relatively firm, dry soil. Irrigating after a manure application will minimize crop damage and reduce nitrogen loss.

If animal manure is to be applied to alfalfa, it should ideally be in compost form.

Plant-tissue analysis

Plant-tissue analysis may provide additional information on soil fertility and the nutritional health of the crop. At the bud-stage, healthy alfalfa plants contain a minimum of certain nutrients:

- 3.0 per cent nitrogen
- 0.2 per cent phosphorus
- 1.7 per cent potassium
- 0.2 per cent sulphur

Table 5 shows the levels of each nutrient in the top 15 cm of plant tissue at 5 per cent bloom.

Table 5. Levels of nutrients in the top 15 cm of alfalfa tissue at 5 per cent bloom

Nutrient	Low	Sufficient per cent (%)	High
Nitrogen	<3.0	3.0 - 5.0	>5.0
Phosphorus	<0.20	0.20 - 0.70	>0.70
Potassium	<1.70	1.70 - 3.80	>3.80
Calcium	<0.25	0.25 - 3.0	>3.0
Magnesium	<0.20	0.20 - 1.0	>1.0
Sulphur	<0.20	0.20 - 0.50	>0.50
	Parts per million (ppm)		
Boron	<20	20 - 80	>80
Copper	<5	5 - 30	>30
Iron	<20	20 - 250	>250
Manganese	<20	20 - 200	>200
Molybdenum	<0.5	0.5 - 5.0	>5.0
Zinc	<20	20 - 70	>70

Tissue analysis can help determine if nutrient deficiencies are present before visual symptoms appear. Coupled with soil tests, tissue analysis may allow producers to establish a more comprehensive alfalfa fertilizer management program.

For additional information on soil or nutrient management of alfalfa, contact the Alberta Ag-Info Centre toll-free at 1-866-882-7677.

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