Agdex 540-1

Crop Nutrition and Fertilizer Requirements

Essential Plant Nutrients

Proper nutrition is essential for satisfactory crop growth and production. The use of soil tests can help to determine the status of plant available nutrients to develop fertilizer recommendations to achieve optimum crop production. The profit potential for farmers depends on producing enough crop per acre to keep production costs below the selling price. Efficient application of the correct types and amounts of fertilizers for the supply of the nutrients is an important part of achieving profitable yields.

There are at least 16 elements known to be essential for plant growth. Carbon (C), hydrogen (H), and oxygen (O) are derived from carbon dioxide (CO_2) and water (H_2O). Nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca), magnesium (Mg), boron (B), chlorine(Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn) are normally derived from the soil in the form of inorganic salts. Ninety-four to 99.5 per cent of fresh plant material is made up of carbon, hydrogen and oxygen. The other nutrients make up the remaining 0.5 to 6.0 per cent.

Macronutrients refer to those elements that are used in relatively large amounts, whereas micronutrients refer to those elements that are required in relatively small amounts (Table 1).

Table 1. Essential Plant Nutrients

Supplied from air and water	Supplied from soil and fertilizer sources	
	Macronutrients	Micronutrients
Carbon (C)	Nitrogen (N)	Zinc (Zn)
Hydrogen (H)	Phosphorous (P)	Copper (Cu)
Oxygen (O)	Potassium (K)	Iron (Fe)
	Sulphur (S)	Manganese (Mn)
	Calcium (Ca)	Boron (B)
	Magnesium (Mg)	Chlorine (Cl)
		Molybdenum (Mo)
		Cobalt (Co)

All 13 elements must be present in the soil for plant use, in varying degrees of availability, to ensure both the immediate and long term needs of the crop.

Some of the commonly used terms to describe levels of nutrient elements in plants include:

Deficient When an essential element is at a low concentration that severely limits yield and produces more or less distinct deficiency symptoms. Extreme deficiencies will lead to death of the plant.

Insufficient When the level of an essential plant nutrient is below that required for optimum yields or when there is an imbalance with another nutrient. Symptoms of this condition are seldom evident.

Sufficient When the concentration of an essential nutrient is present in adequate amounts for optimum crop growth.

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Excessive When the concentration of an essential plant nutrient is sufficiently high to result in a corresponding shortage of another nutrient.

Toxic When the concentration of either essential or other elements is sufficiently high to reduce plant growth severely. Severe toxicity will result in death of plants.

Types of Fertilizers

Fertilizer refers to any compound that contains one or more chemical elements, organic or inorganic, natural or synthetic, that is placed on or incorporated into the soil or applied to directly onto plants to achieve normal growth. The main supply sources of plant nutrients include organic manures, plant residues, biological nitrogen fixation and commercial inorganic fertilizers.

The type of fertilizers that are most commonly used for crop production in Alberta are chemical fertilizers. Chemical fertilizers refer to commercially manufactured products containing a substantial amount of one or more plant nutrients.

The chemical fertilizers can be broadly classified into: nitrogen, phosphorus, and potassium fertilizers. A straight fertilizer contains only one of the nutrients. A compound fertilizer contains two or more nutrients. A complex fertilizer that is formed by mixing ingredients that react chemically, as opposed to a mechanical mixture of two or more fertilizers. A low analysis fertilizer product contains a low percentage of nutrients, usually 30 per cent or less and a high analysis fertilizer contains more than 30 per cent.

Types of popular chemical fertilizer products used in Western Canada and, average nutrient contents are indicated in Table 2.

Table 2. Percentage of Nutrients in Selected Fertilizers

	Analysis	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)	Sulphur (S)
Nitrogen Fertilizers					
Urea	46-0-0	46	0	0	0
Ammonium Nitrate-(Granular)	34-0-0	34	0	0	0
Ammonium Sulphate-Urea	34-0-0	34	0	0	11
Ammonium Sulphate	21-0-0	21	0	0	24
Anhydrous Ammonia (gas)	82-0-0	82	0	0	0
Urea-Ammonium Nitrate Solution	28-0-0	28	0	0	0
Phosphate Fertilizers					
Mono-Ammonium Phosphate	12-51-0	12	51	0	1.5
Mono-Ammonium Phosphate	11-55-0	11	55	0	0
Ammonium Polyphosphate Solution	10-34-0	10	34	0	0
Nitrogen Phosphates					
Ammonium Phosphate Sulphate	16-20-0	16	20	0	14
Ammonium Nitrate Phosphate	23-23-0	23	23	0	0
Ammonium Nitrate Phosphate	27-14-0	27	14	0	0
Urea Ammonium Phosphate	27-27-0	27	27	0	0
Urea Ammonium Phosphate	34-17-0	34	17	0	0
Potash Fertilizers					
Potash Chloride	0-0-60	0	0	60	0
Potassium sulphate	0-0-52-12	0	0	52	12
Sulphur Fertilizers					
Ammonium Sulphate	20-0-0-(24)	20	0	0	24
Gypsum (agricultural)	0-0-0	0	0	0	17
Elemental Sulphur*	0-0-0	0	0	0	90-99
Ammonium Thiosulphate Solution	12-0-0-(26)	12	0	0	26

* Elemental sulphur is suitable for application on perennial forage but is less suitable for annual crops because of slow-release characteristics. If used on annual crops it should be applied in the fallow year or in the fall to allow conversion to the sulphate form.

All fertilizers must show the guaranteed nutrient analysis on the label. This states the content of three main nutrients: nitrogen, phosphate (P_2O_5) (a form of phosphorous) and potash (K_2O)(a form of potassium). It is shown by a series of three numbers. For example, if the numbers 10-10-10 appear on a 30 kg bag of fertilizer it means that the bag contains 10 per cent of each raw material (3 kg of nitrogen, 3 kg of phosphate and 3 kg of potash). Agriculture and Agri-Food Canada inspectors make regular checks of fertilizer facilities to ensure that all requirements are met. In addition, the sale of all fertilizer materials in Canada is regulated by the Agriculture Inspection Directorate of Agriculture and Agri-Food Canada under the authority of the *Fertilizer Act*.

Soil Nutrient Content and Soil Testing

Nitrogen and phosphorus are the most commonly deficient nutrients in Canadian prairie soils. Potassium and sulphur deficiencies occur in particular areas and soil types. Calcium and magnesium are contained in lime which is plentiful in most prairie soils and therefore deficiency problems are rare. Research has found micronutrient deficiency problems are not common on the prairies. However, specific soil conditions have been identified where inadequate levels of micronutrients occur. In central Alberta, on the Black, Gray-Black transition soils and organic soils, Copper (Cu) deficiency problems and significant responses to Cu fertilizer have been observed.

Soil sampling and testing can give an excellent inventory of plant available nutrients and other soil chemical factors important for crop production. This inventory is a basis for recommending additional nutrients for crop production on an individual field basis.

Soil nutrient levels vary from year to year, and frequently will vary within fields, even on fields that seem to be uniform. It is therefore necessary to follow certain recommended steps for soil sampling and testing to develop a sound ongoing soil fertility management program.

An understanding of general nutrient status can be obtained for a field if soil tests are conducted. Nitrogen soil testing is recommended annually as the available nitrogen can change considerably from year to year. Changes are dependent upon environmental conditions such as rainfall and temperature patterns during a growing season, type and yield of crop harvested, date of harvest, fall tillage, amount of fertilizer applied to the previous crop. Potassium and phosphorus levels do not change substantially in a soil over a period of several years. Therefore, sampling for phosphorus and potassium may be conducted every 2 or 3 years, or when changing crop type. Sampling for sulphur should be done annually, unless a previous test indicates that the available levels to 60 cm (24 in) are in excess of 55 kg/ha (50 lb/ac). In the latter case, a test for sulphur every 2 to 3 years is adequate.

While it is recognized that soil testing is not an infallible guide to crop production and that other factors also come into play, soil tests help to reduce the guesswork in fertilizer practices. In the past, Alberta farmers that have soil tested, have generally applied significantly more fertilizer than farmers that did not soil test. Past observations suggest that Alberta farmers that do not soil test in many instances may be applying less nitrogen fertilizer than needed to obtain the most economical yield.

Poor soil sampling technique is a major problem which causes variation in fertilizer recommendations. Soil testing is only as good as the quality of the soil samples. Therefore, good soil sampling procedures must include:

1. Determine where and how to soil sample each field.
2. Use proper equipment and supplies.
3. Sample at the proper time of the year.
4. Obtain samples from the correct soil depths.
5. Handle soil samples properly.

Being familiar with the proper soil sampling procedures is important whether you are doing the sampling yourself or it is being done by a custom operator.

Determine where and how to soil sample each field

Soil sampling should be done on an individual field basis. Samples from different fields should not be mixed. Begin by evaluating each field to determine representative areas. Sample hilly fields with knolls, slopes, or depressions, separatedly from mid slope positions to ensure any potential sulphur or other nutrient problem is detected.

Major areas within fields having distinctly different soil properties such as texture should be sampled and fertilized as separate fields because of different nutrient requirements.

Problem areas such as saline spots, poorly drained depressions, and eroded knolls should not be sampled unless they represent a significant portion of the field. If they do, separate samples should be obtained. In addition, other abnormal areas such as old manure piles, burnpiles, haystacks, corrals, fence rows or farmstead sites should be avoided. At least 15 to 20 sampling sites are required for each field to give a good representative sample. Samples taken from only four or five sites in a field are generally not representative and often result in incorrect fertilizer recommendations.

There are four basic methods for taking soil samples:

1. **Benchmark Soil Sampling:** This method involves selecting uniquely different areas within a field and sampling each area separately.
   Unique areas are selected based on soil types, topography and crop growth. Once sites are selected, the producer will take soil samples from each specific area each year to use as a guide of fertilizing all similar areas within the field. This method is rapidly gaining popularity in Alberta, particularly with farmers that are adopting precision farming techniques. This is the current recommended method which has the best chance to maximize you're economic yield.
2. **Grid Soil Sampling:** With this method, a field is sampled in an organized grid pattern. Soil sample frequency may range from taking one sample in 0.5 acre units of the field to one sample for each 5.0 acre units of the field. The smaller the soil sampling unit the greater the accuracy of the sample. The advantage of this method is that a field map that can be prepared for each nutrient and be used for variable rate fertilization and precision farming. The cost of taking the soil samples and the soil analysis is very high and therefore is not economical for many producers.
3. **Topographic Soil Sampling:** With this method, a producer selects the separate soil sampling sites based on topography. A set of soil samples is taken from each uniquely different topographic area within a field.
4. **Random Soil Sampling:** This involves taking soil samples in a random pattern across a field, generally avoiding unusual or problem soil areas within a field. Generally the field should not be more than 80 acres in size and has been cropped uniformly in the past. Normally, 15 to 20 sites must be sampled to obtain a representative soil sample of the field. This is the most common method of sampling presently used in Alberta.

Use proper equipment and supplies

A soil sampling probe is best for taking samples to the 60 cm (24 in) sampling depth. Use clean labelled plastic pails for collecting samples. Metal pails should not be used if micronutrient testing is to be done. Soil sample augers can also be used but it can be difficult to accurately separate soil samples into 0-15, 15-30 and 30-60 cm depths.

Tools may be borrowed from a fertilizer dealer, your local Alberta Agriculture district office, or may be purchased from some soil testing laboratories or fertilizer dealers. Information sheets, soil sample cartons, and shipping boxes are available from soil testing laboratories.

Sample at the proper time of the year

Ideally, samples should be taken just prior to seeding. However, from a practical standpoint, this is difficult because little time is left to plan a fertilizer program and purchase fertilizer in time for seeding. The best alternative is to obtain soil samples taken in the fall once soil microbial activity has declined. The proper sample time in the fall is after the soil surface temperature drops to less than 7°C. At this temperature soil processes such as mineralization (breakdown of soil organic matter into plant available nutrients) that cause changes in soil nutrients proceed quite slowly and therefore changes in plant available nutrient levels are normally not great. Generally, it is safe to soil sample in most areas of Alberta after the beginning of October. By sampling in the fall, there is sufficient time to properly process samples, provide test results and recommendations and develop a fertilizer program for that fall or the next spring.

Obtain soil samples from the correct depths

Many soil testing labs suggest that a 0 to 30 cm (0 to 12 in) depth sample is adequate for developing fertilizer recommendations. However, for ideal plant nutrient evaluation it is suggested that samples be taken from the 0 to 15 cm (0 to 6 in) and 15 to 30 cm (6 to 12 in), separately and also take samples from the 30 to 60 cm (12 to 24 in) depths. Keep samples from each depth in a separate container.

Phosphorus and potassium recommendations are based on a measure of the amounts of the available forms of each of these nutrients contained in the 0 to 15 cm (0 to 6 in) depth sample. Generally, most of the plant available P in soil is confined to the plow layer as P is very immobile. Nitrate-nitrogen (NO_3-N) and sulphate-sulphur (SO_4-S) are both mobile nutrients may be found in significant amounts in the 30 to 60 cm depth. Therefore, N and S fertilizer recommendations based on a 0 to 15 cm (0 to 6 in) depth sample usually suggest a higher than necessary fertilizer application rate. For this reason, recommendations regarding nitrogen and sulphur are based on a measure of the amount of nitrogen and sulphur from depth (0-60 cm) soil samples.

Handle Soil Samples Properly

As mentioned, soil from each depth should be placed in separate containers. Immediately after the samples have been taken:

1. Mix the soil in each container thoroughly in order to obtain a homogeneous mixture.
2. Remove the soil and spread on a piece of clean paper.
3. Allow the soil to completely air dry at a temperature of not more than 30°C. Do not dry in an oven or at a high temperature since this can change the levels of some nutrients.
4. Care should be taken to avoid contamination of the samples with fertilizer materials such as commercial fertilizers, manure, salt, water and dust. Samples should

not be dried on old fertilizer or feedbags or areas where fertilizers have been handled.
5. A fan may be used to ensure constant air flow over samples to enhance drying.

Once the samples are thoroughly dry, fill the soil sample cartons. Label each carton with correct field number and sample depth. Complete an information sheet on cropping and fertilizer history and mail to a reputable soil testing laboratory. The services of soil testing and fertilizer recommendations are not free. Consult your Alberta Agriculture crop specialist for details of private soil testing laboratories that are available.

Fertilizer Recommendations

Fertilizer recommendations are based on the results of the soil test analyses and on the nutrient requirement of the crop to be grown. Recommendations on time and method of fertilizer application are also included. Each soil testing lab has its own philosophy for making fertilizer recommendations. Two examples are:

1. Recommendations which indicate the nutrient requirements and yield potentials for optimum economic production based one or more moisture conditions of the field.
2. "Target Yield Recommendations" which indicate the nutrient requirements for a range of various lower and higher yield potentials under the same moisture conditions. With this information the producers have the flexibility of selecting a fertilizer application rate or target yield that best suits their individual situation.

Producers must keep in mind that optimum yields of high quality spring wheat can not be obtained without adequate fertilization if the crop to be grown on soils deficient in essential elements. Fertilization, however, will neither increase yield or quality of wheat if other management inputs and cultural practices are not optimal, nor will it increase yield if the added nutrients are not required. Therefore, the most successful fertilizer program will be based on a knowledge of soil nutrient status combined with optimum crop and fertilizer management practices.

For more information on fertilizer recommendations and methods of application consult with your local Alberta Agriculture crop specialist and refer to the following publications: *Alberta Fertilizer Guide* Agdex No. 541-1, *Fertilizing Irrigated Grain and Oilseed Crops*. Agdex No. 100/541-1.

Plant Tissue Analysis

Plant tissue analysis measures nutrient levels in the plant during their growth. The supply of available nutrients is reflected in the nutrient content of the crop. Therefore use of plant tissue analysis allows a producer to evaluate the effectiveness of fertilizer recommendations from a soil testing service. Producers who do not soil test can still use routine plant tissue analysis to evaluate their fertilizer management program to determine whether they used the correct kinds and amounts of nutrient.

Plant tissue analysis can be used to diagnose crop nutrition production problems. For example, at times, a plant growth problem occurs and can not be explained. Soil, climatic and other environmental conditions seem favourable, essential plant nutrients were supplied, and other sound management practices were followed, plant tissue analysis can indicate if nutrient levels may be associated with the problem. Hidden hunger is illustrated in Figure 1.

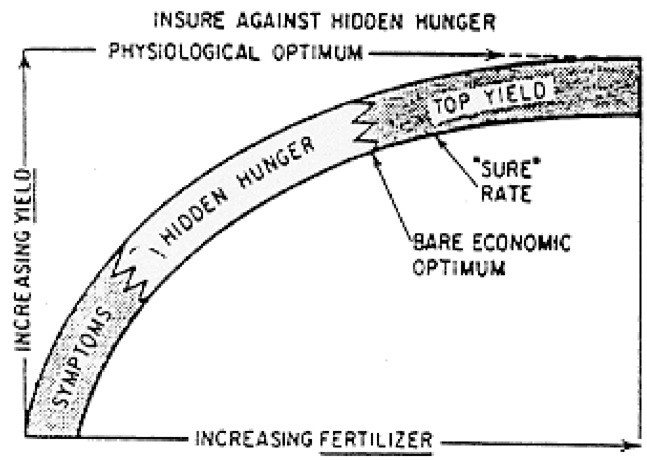

Figure 1. *Hidden Hunger is a term used to describe a plant that shows no obvious symptoms, yet the nutrient content is not sufficient to give the top profitable yield. fertilization with the "sure" rate rather than the bare economic optimum for an average year helps to obtain the top profitable yield. (Courtesy of the Potash & Phosphate Institute, Atlanta, Ga.)*
Source: Tisdale, et al., 1985

For reliable results and useful interpretation, producers must follow proper procedures for plant sampling and sample handling. The sample must represent the crop it was taken from. Management decisions based on plant tissue analysis results reflect the quality of the sample provided.

In sampling wheat plants, parts to sample are the entire above-ground plant. Ideally, tissue samples must be taken when the plant is at Zadok's growth stage 30. Growth stage 30 is when the leaf sheath of wheat has begun to lengthen and are strongly erected, but before the first node of the stem is visible at the base of the plant. If the sample is taken prior to growth stage 30, nitrogen is more concentrated in the leaf, so the prescription would call for too little nitrogen to be applied. If taken after growth stage 30, rapid growth has begun and nitrogen content will be diluted by increases in dry matter resulting in excessive nitrogen fertilizer estimates.

An adequate sample must contain 20 to 50 individual plants. Samples should be taken in the morning (or on cool or cloudy days) because heat and moisture stress often occurs during the mid-day and mid afternoons, on hot sunny days or immediately following a rain. Plant samples should be cut with a clean, sharp, rust free knife, blade or scissors. Clean plastic containers should be used for sample collection. In subsequent handling, clean brown paper bag can be used.

After sampling:

1. Remove loose soil particles with a clean, dry cloth or brush.
2. Do not wash the sample.
3. Lay out the sample on clean paper until completely air dried at normal room temperature (25 to 35°C).
4. Do not oven dry samples.

Completely dried samples can then be placed in a plant tissue sample bag or clean brown paper bag. Information Sheets from a testing lab should be completed for each sample as this information helps when interpreting the results. The sample bag and the corresponding information sheet should each be carefully labelled with the same identity so that samples and sheets can be matched in the laboratory.

The laboratory will determine the levels of each nutrient in the plant sample, and will indicate if each nutrient level is excessive, adequate, marginal or below a critical level. The critical concentration of a nutrient is the point where crop growth may be 10 per cent or less than the maximum. This system uses a previously established set of standards for nutrients in a specific plant part, sampled at a particular growing stage and then compared those normals to the findings in the sample. The principle of this system lies in the relationship between nutrient concentration and crop yield (Figure 2).

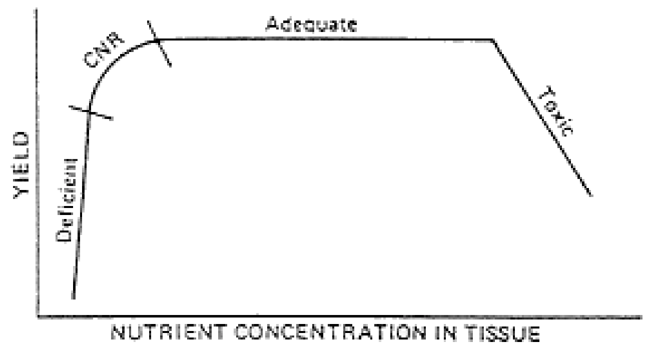

Figure 2. *Relationship between nutrient concentration in plant tissue and top yield, showing the proposed critical nutrient range. (CNR)*

Source: Dow and Roberts, 1982

The most meaningful definition of critical nutrient concentration for efficient growers is the level of a nutrient below which crop yield, quality, or performance is unsatisfactory. In spring wheat, 2.0-3.0% N, 0.26-0.5% P, and 1.5-3.0% K in the whole plant prior to filling are considered sufficient (Table 3).

Table 3. Plant Tissue Analysis Interpretative Critera
Crop Cereals Plant Part/Growth Stage Whole Plant Prior to Filling

Nutrient		Low	Marginal	Sufficient	High	Excess
	Spring	1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0
Nitrogen (N) %	Winter	1.25	1.25 - 1.75	1.75 - 3.0	3.0 - 4.0	4.0
Phosphorous (P) %		0.15	0.15 - 0.25	0.26 - 0.5	0.5 - 0.8	0.8
Potassium (K) %		1.0	1.0 - 1.5	1.5 - 3.0	3.0 - 5.0	5.0
Sulphur (S) %		0.1	0.1 - 0.15	0.15 - 0.40	0.40 - 0.8	0.8
Calcium (Ca) %	Other	0.10	0.10 - 0.2	0.2 - 1.0	1.0 - 1.5	1.5
	Barley	0.20	0.2 - 0.3	0.3 - 2.0	2.0 - 2.5	2.5
Magnesium (Mg) %		0.1	0.1 - 0.15	0.15 - 0.50	0.5 - 1.0	1.0
Zinc (Zn) ppm		10	10 - 15	15 - 70	70 - 150	150
Copper (Cu) ppm	Barley	2.3	2.3 - 3.7	3.7 - 25	25 - 50	50
	Wheat	3.0	3.0 - 4.5	4.5 - 25	25 - 50	50
	Oats	1.7	1.7 - 2.5	2.5 - 25	25 - 50	50
Iron (Fe) ppm		15	15 - 20	20 - 250	250 - 500	500
Manganese (Mn) ppm		10	10 - 15	15 - 100	100 - 250	250
Boron (B) ppm		3	3 - 5	5 - 25	25 - 75	75
Molybdenum (Mo) ppm		0.01	.01 - .02	.03 - 5	5 - 10	10

Source: Manitoba Provincial Soil Testing Laboratory, 1987.

The CNC (critical nutrient concentration) system is the commonly used method in interpreting plant tissue analysis in the prairie provinces as well as other parts of the world. However there are some limitations associated with this system. Some of the limitations include:

Low Sensitivity: The diagnosis requires that the nutrient concentration of plant tissue be compared with previously set values, usually in the form of permissible ranges of variation for each element at a particular stage of growth. These ranges are often very wide, and are therefore not very sensitive.

Inconvenience: It is not always convenient to take samples at a particular physiological stage of the plant's life.

Plant Growth Stage: Inadequacy in dealing with the variations in nutrient concentration with the stage of the plant growth and which plant parts that are sampled.

Multiple Growth Stress: Inability to establish the relative importance of the limiting factors in terms of yield when more than one nutrient being diagnosed is deficient. If other stresses such as drought, salinity, diseases or insects are causing plant growth problems, these can affect plant nutrient concentration in the tissue.

However, the critical nutrient concentration system, when used together with soil testing and careful visual observations can be a useful tool for diagnosing crop problems.

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