Manitoba Agriculture and Food's

Date: October 1999

Soil Fertility Guide

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Five key practices must be implemented to achieve this goal:

1. apply only those nutrients that will result in economic yield increases
2. apply appropriate nutrient rates
3. apply appropriate sources of fertilizer nutrients
4. apply nutrients at appropriate timing
5. apply using the most effective and practical application techniques

so that practices are economically effective and practical while minimizing potential adverse effects on the quality of soil and water resources.

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Introduction

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Nutrient requirements and crop responses on Manitoba soils

At least 16 elements are "essential plant nutrients." An insufficient supply of any one or more of these nutrients can have a detrimental effect on plant growth and, ultimately, crop yields. All but three of these nutrients, carbon, hydrogen and oxygen, are derived mainly from the soil. Only four nutrients - nitrogen, phosphorus and, to a lesser degree, potassium and sulphur - are likely to be of any concern for crop production on mineral soils in most areas of Manitoba.

Table 1 lists the amount of nutrients typically removed with the harvest portion of several Manitoba crops. The soil often supplies the entire crop requirement for most nutrients.

Table 1. Nutrients removed in typical Manitoba crops (lb./ac).*

Crop and Yield	Crop Portion	Nitrogen N	Phosphate P_2O_5	Potassium K_2O	Sulphur S	Calcium Ca	Magnesium Mg	Chlorine Cl	Boron B	Copper Cu	Iron Fe	Manganese Mn	Zinc Zn
Spring wheat 40 bu/ac	seed	60**	23	17	4	-	-	4	0.04	<0.1	0.3	0.13	0.13
	straw	25	6	55	5			1.2	0.01	<0.1	0.1	0.20	0.07
	Total	85	32	72	9								
Barley 80 bu/ac	seed	78	34	25	7	2	4	8	0.1	<0.1	0.3	0.1	0.1
	straw	28	9	68	5	15	9	1	0.02	<0.1	0.01	0.7	0.1
	Total	106	43	93	12	17	13	9					
Oats 100 bu/ac	seed	61	26	18	5	3	4	1	-	<0.1	1.0	0.2	0.1
	straw	45	15	127	8	9	16	1		<0.1	0.2	0.2	0.4
	Total	106	41	145	13	12	20	2					

Corn 100 bu/ac	seed	97	44	28	7	1	9	1.3	0.5	<0.1	0.13	0.7	0.13
	stover	56	19	101	8	32	11	0.7	0.04	<0.1	0.7	1.1	0.20
	Total	153	63	129	15	33	20	2.0					
6t/ac	silage	156	63	202	13	33	20						
Canola 35 bu/ac	seed	68	41	21	12	9	11	-	0.9	-	-	-	-
	straw	44	17	72	10	-	-						
	Total	112	58	93	22								
Flax 24 bu/ac	seed	51	15	15	5	-	-	-	-	-	-	-	-
	straw	14	3	20	6								
	Total	65	18	35	11								
Sunflower 2000 lb./ac	seed	53	16	12	4	-	-	-	0.14	-	-	-	-
	straw	21	10	25	4								
	Total	74	26	37	8								
Peas 50 bu/ac	seed	117	35	35	7	-		-					
	straw	36	8	102	6								
	Total	153	43	137	13		29		0.07	<0.1	0.70	0.50	0.10
Potatoes 300cwt/ac	tubers	96	28	162	9	4	8	20	0.05	<0.1	0.70	0.15	0.10
	vines	75	22	62	5		22						
	Total	171	50	224	14		30						
Alfalfa 4 ton/ac	Total	230	55	240	24	123	27	42	0.7	0.24	2.0	0.8	0.6
Grass hay 3 ton/ac	Total	103	30	130	13	64	16	-	-	-	-	-	-

Data compiled from the Western Canada Fertilizer Association, Alberta Agriculture and Ontario Ministry of Agriculture , Food and Rural Affairs
***Crop nutrient removal is not equal to crop requirements. Crops often take up larger amounts of nutrients than are required (i.e. K and Cl).**
****Seed N for wheat is equivalent to 14.25% protein (%N x 5.7 = % protein for milling wheat)**

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Nitrogen (N)

Table of Contents:

- Fertilization of Annual Crops
- Nitrogen Fertilizer Efficiency
- Methods of N Placement
- Time of N application
- Relative Efficiencies of N Application
- Fertilization of Forage Grasses

Plants use both the ammonium (NH_4^+) and the nitrate (NO_3^-) forms of nitrogen (N) in the soil – but primarily the nitrate form. Nitrate-nitrogen (NO_3-N) levels vary considerably from field to field and year to year because of differences in soil types, climatic conditions and management practices.

Stubble fields generally contain inadequate N levels for optimum crop production. Residual nitrate tends to be higher in fields following the more heavily fertilized row crops, such as potatoes and corn, than the solid-seeded cereal and oilseed crops (Table 2).

Table 2. Residual soil NO_3-N levels in Manitoba as affected by previous crop and growing conditions.

Previous crop	Soil nitrate-N lb./ac in 0-24 in. depth	
	Drought years (1988-89)	1990-1998
Wheat	102	50
Barley	76	43
Canola	79	38
Flax	88	39
Corn	107	64
Potatoes	94	71
* Data from AGVISE Laboratories.		

Fields that have been heavily manured, repeatedly fertilized with high rates of N and/or affected by drought, or some other factor that has severely restricted yields, often contain higher than average residual nitrate levels. Extremely high N levels were encountered in the fall of 1988 and 1989 following droughts throughout a large part of the province.

Sometimes fallow fields contain enough available N for crop production. Fields where a green manure crop was "worked in," or fields in which a crop was "ploughed-down" because of drought, severe insect damage or hail, usually contain higher nitrate levels than stubble fields, but lower than fallow.

Following legume breaking (breaking after first cut of forage), soils will have considerable N content, which may satisfy all the crop's N requirements. Grass and grass-legume breaking provides a lower, but substantial level of N for following crops. Time and method of legume forage crop termination will determine the relative amounts of N available. Stands terminated before July 1 may meet all of the following crop needs. However, N rates should be reduced by 50-75 per cent when stands are terminated before September or 30-50 per cent when stands are terminated late in the fall or early in the spring. Stands terminated by herbicide (without tillage) will make N available at a somewhat slower rate than if tillage was used. For the following crop, use the lower value of the above ranges if herbicides alone were used.

Summerfallowing has a detrimental effect on soil quality and leaves the soil susceptible to erosion.

Therefore, except for certain emergency situations, summerfallowing is NOT a recommended practice in Manitoba. Any tillage should leave sufficient stubble cover to prevent soil erosion. Poorly maintained summerfallow or fields that have been broken or ploughed down late in the season usually contain available N comparable to, or lower than stubble fields.

Fertilization of Annual Crops

Effects of nitrogen and moisture supply on crop yield and quality

Most non-legume crops respond well to fertilizer N when the available soil levels are low. N fertilizer is effective in increasing both yield and protein content of crops on deficient soils. On soils low in available N, applications of moderate rates of N usually result in yield increases. When soil levels are high or high rates of N are applied, both yield and protein content are increased, as well as the risk of lodging.

Growing season moisture conditions also have a significant effect on crop response to available soil N and applied fertilizer N (Figure 1).

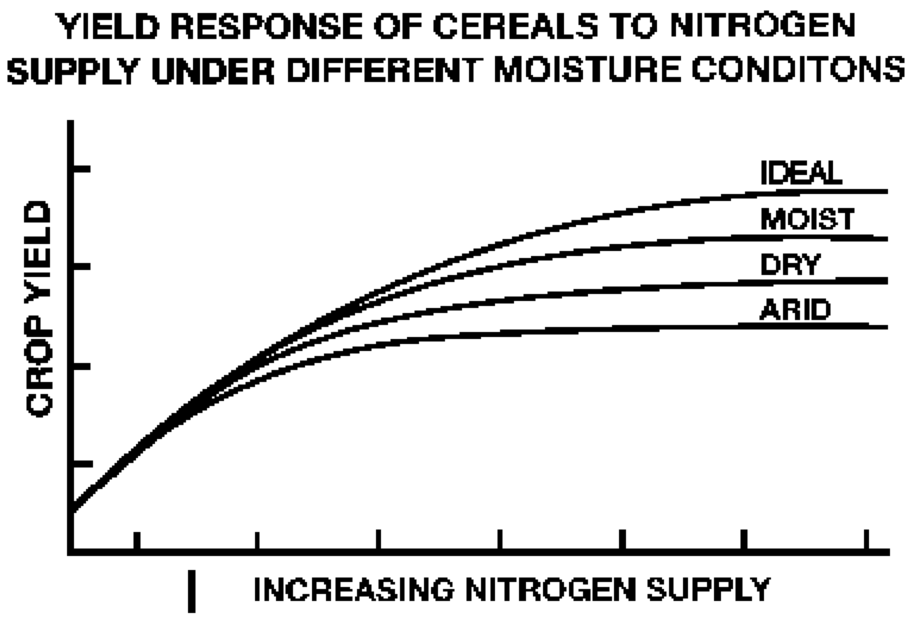

Figure 1.

Generally, higher moisture availability results in higher yields at comparable N supply levels, as well as a greater response to applied fertilizer N. Lower moisture availability not only restricts response and yield potential, but also results in higher crop protein contents, particularly at higher levels of available N.

High protein Canadian western red spring wheat can be grown in all areas of Manitoba if sufficient N is available to the crop from the soil and/or applied fertilizer. When sufficient N is present for near-maximum yield, wheat protein content is approximately 13.5 %. To determine if sufficient N was present for high yield, the grain protein content can be checked. If protein content is less than 13.5 %, insufficient N was added to optimize crop yield.

For a recommended malting barley to be acceptable for malting grade, the grain should contain 10.5 to 13 %. Protein levels in barley are determined by the amount of available N, seeding date, growing season moisture and temperature. Late seeding, high rates of N and/or limited growing season moisture may result in protein content above acceptable levels.

Very high levels of available N may have a negative impact on growth and, in some crops, quality. A heavy, lush crop resulting from high N levels may be prone to lodging and more susceptible to disease under certain climatic conditions. Seed set may also be reduced and maturity may be delayed. In oilseed crops, oil content tends to decrease as protein content increases in response to high N and/or low moisture conditions.

Nitrogen Fertilizer Efficiency

Fertilizer N efficiency is significantly influenced by certain soil properties, climatic conditions, and the time and method of placement. The efficiency gained in N management is primarily through reducing N losses from the following processes:

Denitrification occurs under flooded or saturated soil conditions when soil bacteria convert nitrate-nitrogen to nitrogen gas (N20 and N2). It is the most common way that N is lost and occurs slowly at soil temperatures slightly above freezing, becoming very rapid at temperatures above 15 °C. Losses in spring flooded soils may be 2-4 lb. N/ac/day. Losses in poorly drained fields between June and October can result in the loss of much of the available N in several days. Denitrification can be greatly limited by providing good field drainage and using fertilizer management practices that retain N in the ammonium form (e.g. subsurface banding).

Immobilization refers to the temporary loss of N as soil organisms work to decompose crop residues that have a low concentration of N (e.g. cereal straw). Nitrogen becomes available again when the organisms die and decompose. Immobilization can be limited by subsurface banding N fertilizer, which makes N more available to the crop and less available to soil organisms.

Nitrate leaching is the downward movement of the nitrate form of N by water moving through the soil profile. Nitrates are water-soluble and move readily since they are not held by soil particles. Nitrate leaching occurs most readily on coarse textured soils following significant precipitation. Nitrate leaching can be minimized by applying only enough N fertilizer to meet crop needs, applying fertilizer as close as possible to the time of crop uptake and using moisture efficiently.

Nitrate leaching during the growing season is highly unlikely even in very sandy soils under dryland conditions. Irrigation of sandy soils can often lead to leaching even during the growing season unless special management is practiced (i.e. split applications of nitrogen or via irrigation water).

Ammonia volatilization occurs when the ammonium-N from broadcast urea, urea-ammonium nitrate solutions (UAN) or manure converts into ammonia gas and dissipates into the atmosphere. Factors that increase volatilization losses are high temperatures, dry soil conditions, high soil pH and high levels of free lime or calcium carbonate. Ammonia volatilization can be limited by subsurface banding N fertilizers (especially urea) into the soil or incorporating broadcast applications. Research in Manitoba continues to evaluate the potential of urease inhibitors and slow release urea in reducing N losses to volatilization.

Methods of nitrogen fertilizer placement

Banding

There are several types of band applications:

- drilled with the seed
- side banded
- mid-row banded
- sub-surface banded into soil prior to seeding
- surface banded
- nested

Drilled with the seed - This method consists of placing the fertilizer with the seed in the seed row. Drilling fertilizer with seed in excess of recommended rates can cause seedling damage and reduce yields. Depending upon the equipment used, there can be a large variation in the concentration of fertilizer adjacent to the seed. Greater spreading of the fertilizer and seed, and lower rates of fertilizer, reduce the likelihood of seedling damage. A double disc press drill places the seed and fertilizer close together in a narrow furrow. A discer, air seeder or hoe drill can scatter the seed and fertilizer, depending on the opener used. Wider spacings between rows increases the concentration of fertilizer in each seed row.


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Placing fertilizer with cereal seed optimizes efficiency. However excessive rates of nitrogen fertilizer may lead to reduced germination and seedling damage due to ammonia toxicity or salt burn. Table 3 contains guidelines for safe rates of N placed with the seed of cereals and canola. For more details refer to the Manitoba Agriculture and Food fact sheet Guidelines for Safely Applying Fertilizer with Seed. Factors affecting safe N rates include crop type, row spacing, seed and fertilizer spread, soil texture, N source and soil moisture.

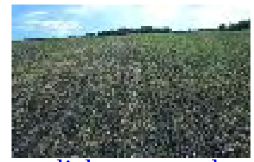
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Table 3. Rates of urea nitrogen (lb. N/acre) safely applied with cereal and canola seed if seedbed soil moisture is good to excellent.

Soil Texture	1 inch spread1 (disc or knife)2			2 inch spread1 (spoon or hoe)			3 inch spread1 (sweep)		
	Row Spacing								
	6"	9"	12"	6"	9"	12"	6"	9"	12"
	SBU3								
	17%	11%	8%	33%	22%	17%	50%	33%	25%
CEREAL SEED									
Light (sandy loam)	10	0	0	20	15	10	30	20	15
Medium (loam to clay loam)	20	15	10	30	25	20	40	30	25
Heavy (clay to heavy clay)	25	20	10	40	30	25	50	40	30
CANOLA SEED									
Light (sandy loam)	0	0	0	10	0	0	20	10	0
Medium (loam to clay loam)	0	0	0	20	10	0	30	20	10
Heavy (clay to heavy clay)	10	0	0	30	20	10	40	30	20

1 Width of spread varies with air flow, soil type, moisture level, amount of surface crop residue and other soil conditions, so it must be checked under field conditions.

2 Some openers give less than one inch spread. Urea should not be applied with the seed on light soils when a double disc opener is being used.

3 SBU, seedbed utilization, is the amount of the seedbed over which the fertilizer has been spread. Thus, it is a reflection of the relative concentration of fertilizer. SBU (%) is the width of spread, divided by the row spacing, multiplied by 100. For example, if the seeding implement has a 6-inch spacing and spreads the seed and fertilizer over two inches, the SBU would be 33 per cent (2/6 X 100 = 33). The higher the SBU, the more fertilizer that can be safely spread with the seed. Although some openers spread the seed and fertilizer vertically, SBU does not take this into account since it is generally recognized that all seed should be placed at an even depth for even germination and emergence.

For canola, ammonium nitrate and ammonium sulphate are just as damaging to the seedlings as urea. For cereals only, suggested N rates can be safely increased by about 20 lb. N/ac when ammonium nitrate is used. The urease inhibitor Agrotain reduces seed toxicity from seed-placed urea. Suggested N rates for cereals may be safely increased by 40-50% when urea is treated with Agrotain. Refer to manufacturer's instructions for more information. Ongoing Manitoba research continues to evaluate the use of urease inhibitors to reduce seed toxicity from seed-placed urea.

Where seedbed moisture is low or when weather is hot and windy, reduce the rates in the table by approximately 50 per cent.

Side band placement - This method consists of placing the fertilizer in a narrow band 2 to 3 inches to the side and/or 2 to 3 inches below the seed during seeding. The efficiency of side banding is equivalent to placement with seed and higher rates can be used safely.

Nitrogen requirements of most crops can be met without causing seedling damage when solution or dry fertilizer is placed at least 2 inches from the seed row.

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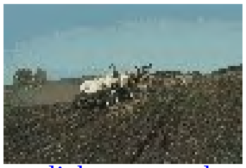
Anhydrous ammonia cannot be placed in or near the seeder. However, in recent years equipment has been modified to allow anhydrous ammonia to be applied at seeding time in a band or other arrangement that is separated from the seed. The anhydrous ammonia should be separated from the seed by at least 2-3 inches and placed below and to the side of the seed or to the side of the seed. It should not be applied directly below or above the seed. The anhydrous ammonia tends to follow the furrow upward, so attempts at placing it below the seed will likely lead to seed damage.



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Mid-row banding – This method places fertilizer between every second seed row as part of the seeding operation. The fertilizer is banded with knives, discs or coulters to a depth of 3 to 4 inches. This system is an efficient method of N placement, which allows the application of high rates without risk of damage to germinating seedlings.

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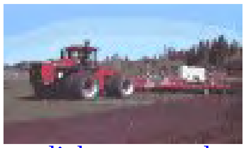
Banding into soil prior to seeding - This method places the fertilizer below the soil surface in a band behind a shank at a depth of 3 to 6 inches. It is often referred to as "deep banding."



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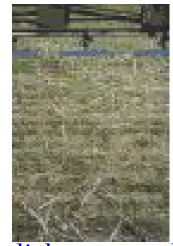
Band spacings should not exceed 18 inches when applying nitrogen fertilizer. The efficiency of this method of N placement in spring is equal to side banding or seed placing fertilizer.

Anhydrous ammonia should be applied only when soil conditions permit a good seal behind the applicator shanks. Seeding can be done immediately after anhydrous ammonia application, provided there is at least a 4-inch vertical separation of the injection point and the seed. Crop emergence may be slightly reduced directly over the anhydrous bands, particularly for small seeded crops and if soils are sandy or dry. However, plants will tiller or branch and yield will not be affected. The ammonia bands should be perpendicular to the direction of seeding.

Surface banding - This application method places a band or stream of liquid fertilizer on the soil surface. The equipment used include fertilizer floaters and field sprayers outfitted with dribble nozzles or streamer bars. Surface banding improves nitrogen efficiency as compared with broadcast methods because volatilization and contact with residues, and possible immobilization, are reduced. The liquid stream also penetrates a crop canopy better than a broadcast application, and as a result, more fertilizer reaches the soil surface.



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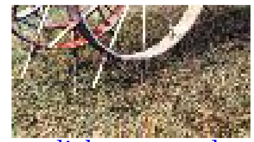
Nesting – This method uses a spoke wheel injector to place regularly spaced pockets or nests of liquid fertilizer into the soil. N losses by volatilization and immobilization are avoided. Disturbance of soil and crop residue is minimal and post-seeding applications may be made into the growing crop.



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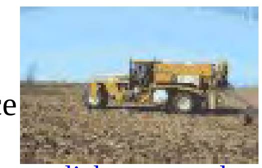
Broadcast



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Broadcast and incorporated - Granular or solution fertilizer is broadcast on the soil surface and incorporated into the soil with a tillage implement. Nitrogen fertilizers, especially urea and liquid or dry fertilizers containing urea, should be incorporated as soon as possible to minimize gaseous losses by volatilization.

Broadcast without incorporation - This method usually results in the least efficient use of fertilizer N. Fertilizer left on the soil surface increases the risk of loss by runoff, erosion and ammonia volatilization (especially with fertilizers containing urea). This is the most commonly used method to fertilize established pasture or hay land, and is frequently used in zero tillage production.

Ammonium nitrate (34-0-0) is a better N source than urea (46-0-0) for broadcast applications without incorporation. Losses of urea are higher than losses of ammonium nitrate under conditions favouring volatilization (e.g. high temperatures and high soil pH). Loss of urea can be minimized by applying during periods of low temperature or just before it rains. The urease inhibitor Agrotain reduces seed toxicity from seed-placed urea. Suggested N rates for cereals may be safely increased by 40-50% when urea is treated with Agrotain. Refer to manufacturer's instructions for more information. Ongoing Manitoba research continues to evaluate the use of urease inhibitors to reduce seed toxicity from seed-placed urea.

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Time of nitrogen fertilizer application

At or near time of seeding - Nitrogen fertilizer applied at or near time of seeding is usually the most effective for increasing yields.

After seeding - Under moist conditions, applying N up to two weeks after emergence is a good alternative to applying nitrogen in the fall. However, if N fertilizer is broadcast without incorporation on dry soils, N utilization may be delayed. If urea (46-0-0) is used, gaseous N losses may occur. Ammonium nitrate

(34-0-0) is the preferred N source for broadcast application after seeding.

Leaf burn may occur if N solution is sprayed onto leaf surfaces. Canola, flax, corn and sunflowers are particularly susceptible to damage. In trials, cereals at seedling stages have been sprayed with N solution at 40 lb. N/acre with minimal damage and no reduction in yield. Leaf burn is minimal under cool, wet conditions. Rain or irrigation immediately following N application washes all leaf surfaces free of fertilizer and results in little or no damage. Broadcasting granular fertilizers does not cause damage unless the foliage is wet.

N fertilizers can be applied to row crops following crop emergence. All banded fertilizers should be applied about 6 to 8 inches from the row. Use care so that plants are not damaged by equipment.

The application of N fertilizer after seeding is a method to hedge on costs until you have a better idea of crop price and growing conditions. Mid-season applications of N fertilizer can also be used to increase the protein content in grain. Nitrogen application to the growing crop through irrigation water has greater efficiency than placing all the nitrogen at the time of seeding.

Fall-applied nitrogen does not usually give yield and/or protein increases as great as those obtained when equal amounts are added in spring. However, in many cases, the differences in yield between fall and spring applications are small, particularly under dry soil conditions. Losses due to leaching, volatilization, Denitrification, immobilization and weed growth are usually higher for fall-applied N and account for differences in yield and protein content.

Relative efficiencies of nitrogen applications

The relative efficiency of N fertilizers, as affected by the time and method of application, varies greatly with factors such as soil moisture, soil temperature, soil type and weed growth. Average relative values for Manitoba based on time and method of placement, when spring broadcast N is given a value of 100, have been calculated as follows in Table 4.

Table 4. Nitrogen efficiency based on application time and placement.

Time and method	Relative values
Spring broadcast	100 %
Spring banded	120 %
Fall broadcast	80 %
Fall banded	100 %

Efficiency values are calculated based on N uptake by plants. Broadcast values assume urea-based N carriers are incorporated, where necessary, to minimize losses through ammonia volatilization. This is particularly important on soils with a high pH or which contain free lime in the surface.

Banded values are based on any subsurface band application. This includes with-the-seed band, as long as the rate applied does not exceed the safe limit at which damage to germination and seedling emergence may occur. For maximum benefit, bands should not be disturbed prior to or during the seeding operation.

Nitrogen losses due to leaching, gaseous loss, immobilization and weed growth are probably higher for fall-applied than for spring-applied nitrogen. These losses may be greater if the nitrogen is applied too early in the fall (prior to mid-September) or when soil temperatures at the 4 inch depth are greater than 5°C. Loss of N accounts for much of the difference in efficiency. Under dry soil conditions, the efficiency of nitrogen banded in late fall can approach that of spring banded. Efficiency of fall-applied N can be substantially lower than those indicated in Table 4 under excessive moisture conditions in spring or fall, and/or an early fall application before soils have cooled to 5°C.

In a practical sense, time and method of application should be based not only on the needs of the crop and potential losses from the soil, but also on co-ordination of the soil fertility program with an efficient overall farm management system. Select a time and method of N application that permits preparation of a good seed bed, conserves soil moisture, aids in prevention of soil erosion, allows for timeliness of operations and maximizes net returns.

Fertilization of forage grasses

Nitrogen rates

Forage grasses respond well to N fertilization. Unfortunately hayfields in Manitoba often receive little to no fertilization, which can limit the protein content and yield potential of the crop. In Manitoba, the optimum amount of N recommended for established stands of grass hay is in the range of 90 to 110 lb./acre. It is likely that these rates of N application are too low with good rainfall and too high when moisture is limiting.

Manitoba studies show that moisture availability in the soil and the selling price of baled hay are key factors in determining the most profitable rates of N application. In these studies, the level of N supply that gives maximum profit is called "the economic optimum N supply," and can vary with different grass species and moisture conditions. By subtracting soil test values for nitrate-N from the values for economic optimum N supply, producers can determine the most profitable rates of N-fertilizer application.

In Figure 2, Manitoba soils are categorized into 3 groups according to the amount of available moisture, which modifies the yield response to N fertilizer. Moist soils are typical of the clay soils of the Red River Valley and the Grey Wooded soils which have high water-holding capacity or are in the cooler soil areas but are subject to periodic dry conditions. Dry soils include the sandy soils in southwestern Manitoba and are intermediate in water-holding capacity and are subject to dry weather conditions. Arid soils are well drained, coarse-textured soils that have a poor ability to hold water and are subject to dry conditions on a regular basis. Most soils in the province are in either the moist or dry category.

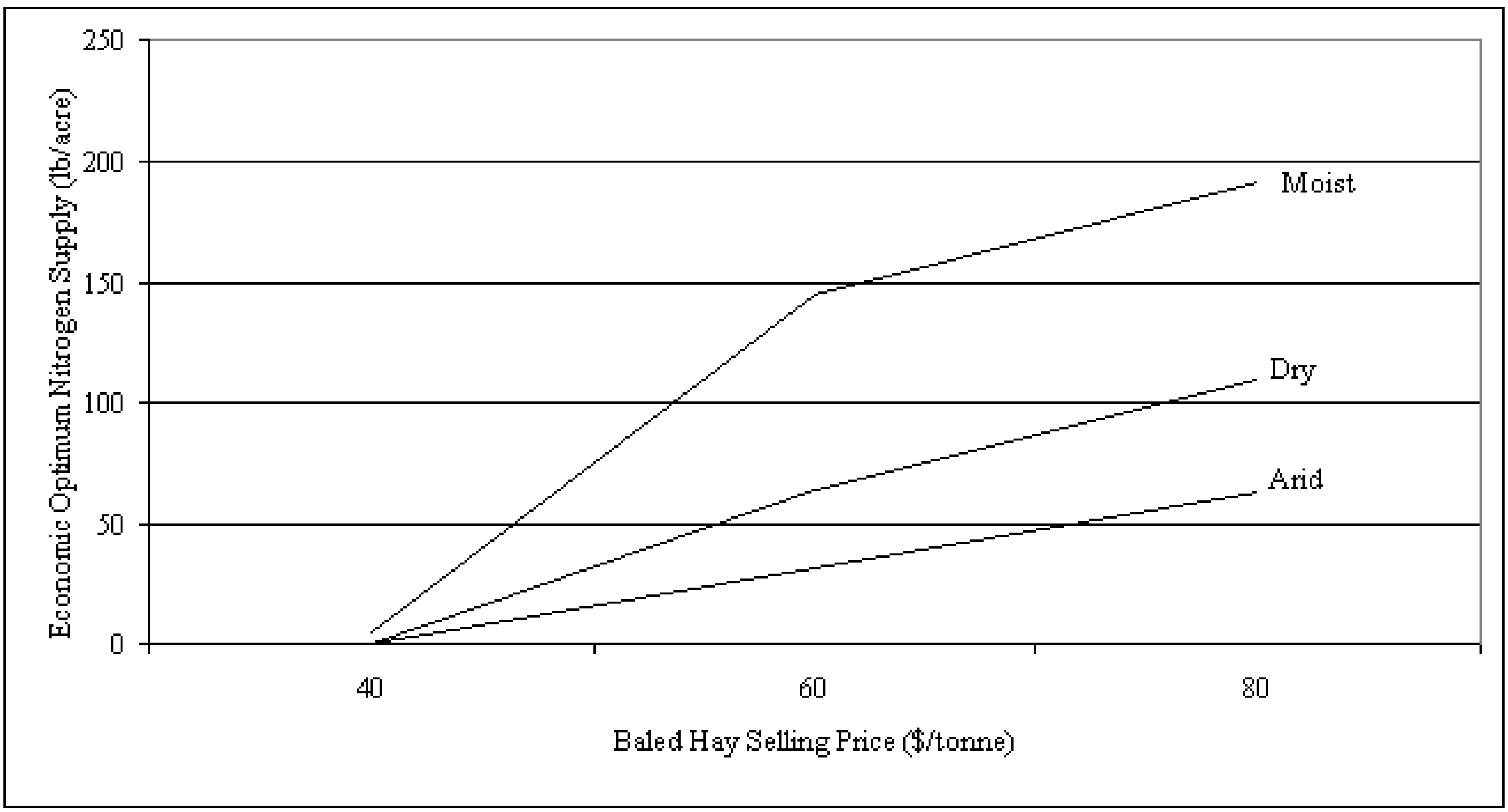

Figure 2. Economic optimum nitrogen supply and expected yield under various moisture conditions and selling prices of smooth bromegrass hay.

- Assumes N fertilizer at $0.25 per pound of N and hay handling (cutting, baling, and hauling) costs at $20.00 per tonne.
- Expected yield for a 3-year old stand over a range of soil types.

The timothy hay export market is a new opportunity for Manitoba hay producers. Recommended N rates may be lower than that required for optimum hay or seed yield due to quality concerns. The primary quality factor for export hay is greenness. High N rates promote lodging and leaf disease in the crop which will reduce the green colour.

Sources of Nitrogen

Ammonium nitrate is generally 10-15% more efficient than urea in increasing yield of the first cut of early season grasses. Manitoba studies have found that under conditions of minimal volatilization loss, urea forms are equal or superior to ammonium nitrate for fertilizing late season grasses in multiple harvest systems and grass pasture. In these instances, hay or pasture grasses fertilized with urea have higher crude protein levels than those fertilized with ammonium nitrate.

Volatilization losses of surface applied N may be very high if rainfall is not received soon after application. Volatilization losses are greatest when urea is applied to a moist thatch cover, followed by warm, windy weather.

Broadcast N solutions are not satisfactory for established forages. To increase efficiency, N solutions should be surface or dribble banded or injected into the soil with equipment such as the spoke wheel applicator.

Time of application

Grass for hay or pasture: The relative efficiency of broadcasting granular N fertilizer on established grass is as follows:

Spring application	April to early May	100 %
Fall application	October	78 %

The efficiency of split-rate N applications (applying one-half the required N in the spring and the other half immediately following the first cut) is similar to a single spring application. The split-application technique has the added advantage of equalizing the production of forage with a relatively high protein content during the growing season. It is also useful for pasture production where rotational grazing is practiced. Split application of less than 45 lb. N/ac is not recommended.

Grass for seed production: Timing of N fertilizer application for grass seed production is very important and varies with species.

Table 5. Nitrogen timing for grass seed production.

Grass species	Time of application
Meadow fescue	October or April
Timothy	October or April
Bromegrass	Right after harvest
Russian wild ryegrass	Right after harvest
Wheatgrasses	Right after harvest

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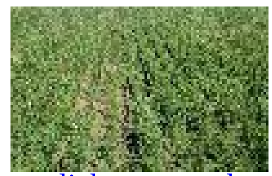
Phosphorus (P)

The majority of Manitoba soils cannot supply adequate phosphorus (P) for optimum yields. Over the past 25 years, more than 50 % of fields have been rated consistently as very low and low in P. Unlike nitrogen, phosphorus levels do not change from year to year in response to climatic conditions or most crop rotation or crop management practices.

The P content of seedling plants need to be high in order to achieve maximum yields. Placing P fertilizer where developing roots can access it rapidly is critical in attaining these high P levels in young plants. Additionally, the high pH calcareous soils that predominate in Manitoba tend to "fix" or reduce the availability of applied P and slow the build up of soil test levels. For these reasons, P use is most efficient when soil contact with fertilizer is limited, such as by banding with or close to the seed. Phosphorus efficiency is greatest when applied with the seed, providing the amount does not injure the germinating seedling. Some crops, such as oilseeds and pulse crops, are sensitive to seed-placed phosphate, whereas cereals can tolerate their total fertilizer P requirement placed with the seed (Table 6). Monoammonium phosphate (12-51-0, 11-52-0) has a low salt index and does not produce much ammonia, so it has relatively low toxicity to seedlings.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- Phosphorus fertilization of seeding alfalfa
- seed-placed (left) vs broadcast (right)

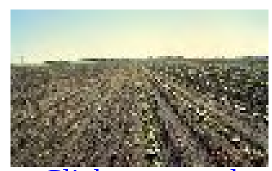
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Table 6. Maximum safe rates of seed-placed phosphate (P_2O_5) fertilizer as monoammonium phosphate[1].

Crop	Actual P_2O_5 (lb./ac)[2]
Cereals	50
Canola[3], peas[3], field beans, fababeans, buckwheat	20
Flax, black beans	0

[1] Divide values in table by 0.51 or multiply by 1.96 to get lb. of 12-51-0 per acre.
[2] Rates are based on disk or knife openers with a 1-inch spread, a 6-7 inch row spacing and good to excellent soil moisture.
[3] When P soil test values are medium to high, no phosphorus should be placed with canola or pea seed.

Phosphate fertilizer banded near the seed (beside and/or below) results in the greatest yield increase per unit of P when recommended rates exceed that tolerated with seed-placed application. Such side-banded applications are recommended for most oilseeds, annual legumes and row crops.

picture J

Deep banding phosphate at the 4-6 inch soil depth and in spacings of 12 inches or less before seeding or mid-row banding during seeding are more effective in increasing yields than broadcast and incorporation methods. Banding nitrogen with the phosphate will increase fertilizer P availability. Band these fertilizers together when both N and P are needed. Application of 10 to 15 lb. P_2O_5/acre with or near the seed may also be required to ensure adequate P supplies for early growth before roots can proliferate in the fertilizer bands. Application of additional phosphate with or near the seed may be especially beneficial when soils are cold and/or very deficient in phosphate or when the phosphate is dual banded with a high rate of urea N in spring.

Broadcast and incorporated phosphate results in the lowest yield increase per unit of P fertilizer. Broadcast application of P may be uneconomical on many soils, since the amount required in the first few years is two to four times that of seed-placed P to achieve similar yield increase.

Most crops will respond to properly applied fertilizer phosphate when the available soil P level is low. The probability and degree of response, as well as the amount of fertilizer P required, will decrease as the level in the soil increases. Up to a third of the time, cereal crops will respond to a small amount (e.g. 10 lb./acre) of seed placed phosphate even when the soil test level is relatively high. This is commonly called the "pop-up effect" and occurs particularly under cold, dry soil conditions at seeding time.

Repeated applications of relatively high rates of phosphate fertilizer may slowly increase available P content of some soils. Manured fields tend to have higher P soil test values, often related to the frequency, amount and type of manure applied.

A seed-applied inoculant called JumpStart is a natural occurring fungus (*Penicillium bilaii*) that grows on plant roots and makes residual soil P more available for plant uptake. It is registered for use on wheat, peas, lentils, canola, mustard, sweet clover and alfalfa. When used on soils testing low or medium in P, accompanying fertilizer phosphate rates should not be reduced. On high to very high P testing soils, JumpStart may be used in place of the starter phosphate fertilizer. JumpStart is not residual and needs to be applied annually.

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Potassium (K)

Most Manitoba soils contain adequate amounts of available potassium (K) for crop production. Soils likely to be low in K are coarse-textured sands, sandy loams and organic soils. Potassium may be required on about 6% of arable Manitoba soils for maximum production of commonly grown annual crops such as cereals, canola and flax. About one-third of Manitoba soils require additional K for the production of special crops such as corn, potatoes and small fruit or vegetable crops.

Like phosphorus, K levels do not change significantly from year to year in response to climatic conditions or crop management practices. An exception would be when high yields of forage are repeatedly removed from coarse textured soils (see Table 1 for removal rates).

Where required, applied potash (KCl) can increase crop yield and quality. Depending on the type of crop, it may also increase frost and disease resistance, palatability, storage quality and other characteristics.

For most efficient use by cereal crops, K fertilizer should be placed with the seed. For most row crops, potash should be side-banded to the side and/or below the seed. The efficiency of broadcast and incorporated potash is about 50% that of potash banded with the seed or side-banded. If potash is broadcast, the recommended rate for seed placement or side banding should be doubled to obtain equal crop response. Broadcast K fertilizer should also be incorporated into the soil.

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Sulphur (S)

Low levels of available sulphate-S may occur in any non-saline soil in Manitoba. Sulphur (S) deficiencies are most frequently found on well-drained and grey wooded soils. Soil testing is the best available tool for determining S fertilizer needs. Testing should be done to a 24-inch depth to account for sulphate not at the surface, but still available for crop use.

Sulphate concentrations within a field can vary, depending upon soil type and slope position. On rolling land, sample hilltops, mid-slope positions and low-lying areas separately. Sandy, coarse textured soils should be sampled separately from heavier soils. This is important since it is not uncommon for low lying, heavy soils to contain many times more sulphate-S than light-textured hilltops. Sampling a variable field as a whole would typically result in a recommendation that no S fertilizer is needed, yet crops in some areas may be highly S-deficient. For this reason an "insurance application" of S fertilizer may be advisable on variable soils or where high value, high S-demanding crops, such as canola, are to be grown.

Click to expand

Available sulphate levels are often low following the breaking of a perennial legume or grass-legume stand, due to their high S removal rates (see Table 1).

Sulphate forms of S fertilizers, primarily ammonium sulphate or liquid ammonium thiosulphate, are equally effective when applied as a surface application, banded or incorporated. Elemental S must be oxidized by soil micro-organisms to form sulphate before plants can use it. Elemental S should be applied at least one year before it is needed by the crop and left on the surface as long as possible before incorporation, as rainfall and weathering help disperse the fertilizer granule and speed the conversion to the sulphate form.

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Micronutrients

Seven of the 16 essential plant nutrients are referred to as micronutrients; not because they are less important for plant growth and development, but because they are required in relatively small amounts (Table 1). They include: boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn).

In Manitoba, most soils are adequately supplied with micronutrients. However, the following soil and environmental conditions may reduce micronutrient availability:

- soils low in organic matter (B, Cu, Zn)
- sandy soils (coarse texture) are more likely to be deficient than clay soils (fine textured) (Cl, Cu, Zn, B, Mo)
- peat soils or soils with over 30% organic matter (Cu, Mn, B)
- cool, wet soils reduce the rate and amount of micronutrients that can be taken up by the crop
- high soil pH reduces micronutrient availability (for all except for Mo and Cl)
- highly calcareous, high lime content soils (Zn, Fe)
- soils with exposed subsoil due to erosion or a result of land leveling (Zn)
- soils with excessive phosphorus levels (Zn)

Certain crops and even varieties may vary in sensitivity to micronutrient deficiencies. Table 7 lists crops in their response to micronutrient fertilizers when a deficiency occurs.

Table 7. Response of crops to micronutrient fertilizers.

Crop	Boron	Copper	Manganese	Molybdenum	Zinc
Alfalfa	High	High	Medium	Medium	Low
Barley	Low	High	Medium	Low	Medium
Canola	High	High	Medium	Low	Medium
Clover	Medium	Medium	Medium	High	Medium
Corn	Low	Medium	Low	Low	High
Oats	Low	High	High	Medium	Low
Peas	Low	Low	High	Medium	Low
Rye	Low	Low	Low	Low	Low
Wheat	Low	High	High	Low	Low
Potatoes	Low	Low	High	Low	Medium

Highly responsive crops often respond to micronutrient fertilizer if the micronutrient concentration in the soil is low. Medium responsive crops are less likely to respond, and low responsive crops do not usually respond even at the lowest micronutrient levels.In Manitoba studies, the frequency of crop response to micronutrients on mineral soils has been small.

Diagnosing Micronutrient Deficiencies

The relatively high cost of micronutrient fertilization demands accurate identification of possible deficiencies. The following steps should be taken to determine if micronutrient fertilization is warranted.

- Eliminate other possible causes of poor growth (drought, flooding, salinity, disease, herbicide injury, shortages of nitrogen, phosphorus, potassium or sulphur).
- Determine if a particular soil or crop is likely to be deficient in a micronutrient. Critical levels for several micronutrients are listed in Appendix Table 15.
- Determine if crop visual symptoms are similar to typical deficiency symptoms for specific micronutrients
- Take separate soil and tissue samples from both affected and unaffected areas. Submit samples to a reputable lab for complete nutrient analysis. For micronutrients, tissue sampling is general superior to soil analysis to confirm deficiencies.
- When indications suggest a micronutrient deficiency, apply such nutrients in field test strips. Evaluate crop recovery and yield compared to untreated areas.

Foliar micronutrient applications are often quite effective if deficiencies can be diagnosed early in growing crops. Refer to manufacturer's recommendations for rates and materials.

For more information, see the Manitoba Agriculture and Food fact sheets *Micronutrients in Crop Production* and *Copper Fertilizer Requirements on Peat Soils*.

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The Fertilizer Act and Quality Standards

In Canada, agricultural fertilizers, specialty fertilizers, fertilizer/pesticide mixes and supplements manufactured, sold or imported are controlled and regulated by the Fertilizer Act and Regulations. The primary purpose of this federal legislation is to make sure these products are free of substances harmful to crops, animals, humans and the environment, contain necessary plant nutrients, are effective, and are labeled to avoid fraud. This protects the farmer and the general public against potential health hazards and fraud in marketing.

The guaranteed analysis for fertilizer indicates the amount of individual plant nutrient expressed as a percentage of the total weight of the fertilizer product. Total nitrogen (N), available phosphoric acid (P_2O_5), soluble potash (K_2O) and total sulphur (S) are expressed as % N - % P_2O_5 - % K_2O - % S.

All legume inoculants and pre-inoculated seed products are also registered under this Act. Inoculant products are monitored for minimum standards in bacteria numbers and results are published annually in the *Canadian Legume Inoculant and Pre-inoculated Seed Product Testing Report*.

Many fertilizer manufacturers and blend producers are part of the Canadian Fertilizer Quality Assurance Program (CFQAP). Fertilizer samples are voluntarily submitted to accredited labs and the Canadian Food Inspection Agency summarizes results. Ratings are published annually in the *Canadian Fertilizer Quality Assurance Report.* A customer can ask for a supplier's CFQAP rating.

Both of the above mentioned reports can be obtained from the Fertilizer Section, Canadian Food Inspection Agency, 59 Camelot Dr., Nepean, Ontario K1A 0Y9.

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Calculating fertilizer rates from nutrient recommendations

Soil test recommendations are given in lb./acre or kg/ha of nutrients. To determine the fertilizer rate for a particular nutrient, multiply the rate of the desired nutrient by 100 and divide by the percentage of the nutrient in the fertilizer.

Example 1

Recommended rate of N is 80 lb./ac.

Using 46-0-0, the rate of fertilizer required is:

(80 x 100) / 46 = 174 lb./acre

Example 2

Recommended rate of P_2O_5 is 40 lb./acre.

Using 12-51-0, the rate of fertilizer required is:

(40 x 100) / 51 = 78 lb./acre

78 lb./acre of 12-51-0 would also supply (12/100) x 78 = 9 lb./acre of N.

Example 3

Recommended rate of K_2O is 15 lb./acre.

Using 0-0-60, the rate of fertilizer required is:

(15 x 100) / 60 = 25 lb./acre.

Converting fertilizer prices into price per unit of nutrient

The cost of a fertilizer is related to its plant nutrient content. If a nitrogen fertilizer such as 34-0-0 is being purchased, the cost should be about three-quarters that of 46-0-0. When buying fertilizer, one should compare prices on the basis of cost per pound of "actual" nutrient, not the price per tonne of fertilizer material.

Example 1

If urea (46-0-0) costs $253/tonne, the cost per pound of nitrogen (N) is calculated as follows:

Nitrogen in one tonne (1,000 kg or 2,204 lb.) of 46-0-0 (containing 46% N):
(46/100) x 2,204 = 1,014 lb.

Cost per lb. of N is:
$253/1,014 = $0.25

Example 2

(Based on 12-51-0 at $403/tonne)

In order to calculate the cost of phosphate in 12-51-0, the value of nitrogen must first be subtracted.

Nitrogen in one tonne (1,000 kg or 2,204 lb.) of 12-51-0 is (12/100) x 2,204 = 264 lbs.
The value of nitrogen is 264 x $0.25 = $66 (from example 1, which calculated the value of N to be $0.25/lb.)

Cost of phosphate per tonne is $403 - $66 = $337.

Phosphate in one tonne (1,000 kg or 2,204 lb.) of 12-51-0 is:
(51/100) x 2,204 = 1,124 lb.

Cost per lb. of P_2O_5 is :
$337/1,124 = $0.30

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Fall/spring fertilizer price differences

Generally, fertilizer prices are lower in fall than in spring. Producers should take these price differences into consideration when planning their fertilizer program. Another factor to consider if purchasing in the fall is the interest and storage cost for carrying over to spring. Table 8 summarizes the provincial average price comparisons between fall and spring for the major phosphorus and nitrogen fertilizer products.

Table 8. Average prices of fall versus spring purchased nitrogen and phosphate fertilizer (1989-1998*).

Fertilizer	Cents/lb. N	
	Fall	**Spring**
Urea (46-0-0)	24.3	28.2
Anhydrous ammonia (82-0-0)	16.9	19.3
UAN solution (28-0-0)	24.7	28.7
	Cents/lb. P_2O_5	
Monoammonium phosphate (11-52-0, 12-51-0)	23.0	24.2
Ammonium polyphosphate (10-34-0)	31.3	33.1
*** Compares spring fertilizer price to the previous fall price. Information is based on provincial fertilizer price surveys.**		

Fertilizer application costs

Table 9 provides a general summary of costs related to fertilizer application. It includes the major fertilizer forms as well as method of application.

Table 9. Custom fertilizer costs (1998 values).

Application method	Custom applied $/acre
Anhydrous ammonia banding	$6.50
Liquid broadcast or surface dribble banding	$4.20
Granular broadcast	$4.15

Liquid banding	$9.10
Granular banding	$9.50
Spoke wheel liquid injection	$6.00
***This includes equipment, fuel and labour cost, including equipment and fertilizer delivery to the field. Values are based on a fertilizer dealer survey.**	

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Common fertilizers and their characteristics

Table 10. Common fertilizers and their characteristics

Name	Nutrient	Physical Properties	Comments
Fertilizers used primarily as sources of nitrogen:			
Anhydrous Ammonia	82-0-0	• Compressed gas • High affinity for water • Pungent odour • Corrosive	Must be placed at 4-6 in. depth. Hazardous (safety precautions are required). High pressure equipment required.
Urea*	46-0-0	• Granular	Applied prior to or after seeding. Much less corrosive than other nitrogen fertilizers. Avoid mixing with ammonium nitrate as attraction for moisture causes mixture to turn to slush. More subject to volatilization losses than ammonium nitrate when not incorporated in the soil. Volatilization losses are enhanced when urea is broadcast without incorporation under warm and windy conditions on alkaline, calcareous or drying soils.
Nitrogen Solution (UAN)	28-0-0	• Solution • 50% of the nitrogen is in the urea form and 50% is in the ammonium nitrate form • contains 0.79 lb N/litre or 3.57 lb N/Imp gal.	Can be applied prior to or after seeding but may be injurious to crops when applied after emergence. Can be applied with certain pesticides. Urea portion is subject to volatilization losses when nitrogen solution is surface-applied and not incorporated. Losses are enhanced when solution is surface-applied without incorporation under warm and windy conditions on alkaline, calcareous or dry soil.
Ammonium Nitrate*	34-0-0	• Granular • Prilled	Larger amount than urea can be applied with the seed of cereal crops. Can be applied prior to or after seeding. Avoid mixing with urea as attraction for moisture causes mixture to turn to slush. Less subject to volatilization losses than urea when broadcast without incorporation.
Fertilizers used primarily as sources of phosphorus:			
Monoammonium Phosphate (MAP)	12-51-0 11-52-0 10-50-0	• Solid, granular, does not absorb moisture during storage, fairly resistant to breakdown during handling.	Most commonly used high analysis dry phosphorus fertilizer.

Diammonium Phosphate (DAP)	18-46-0	• Solid, granular	Phosphorus availability to plants similar to monoammonium phosphate. More toxic than MAP when placed with the seed.
Ammonium Polyphosphate Solution (APP)	10-34-0	• Liquid • contains 0.31 lb N and 1.06 lb P_2O_5/litre or 1.42 lb N and 4.83 lb P_2O_5/ Imp gal.	Phosphorus availability to plants similar to monoammonium phosphate.
Phosphoric Acid	0-54-0	• Liquid • contains 1.87 lb P_2O_5/litre or 8.50 lb P_2O_5/Imp gal.	Burns skin upon contact. Requires specialized delivery systems which can withstand corrosiveness of product. Primarily used for dual band applications with nitrogen fertilizers.
Triple Super Phosphate	0-45-0	• Solid • Granular	Phosphorus availability less than for phosphorus fertilizer containing ammonium.

Fertilizers used primarily as sources of potassium:			
Potassium chloride (Potash)	0-0-60 0-0-62	• Crystalline • Hygroscopic • Soluble	Most commonly used potassium fertilizer in Manitoba. Can be mixed with other fertilizers. Contains chloride which is a nutrient and may help to reduce the incidence of some plant diseases.
Fertilizers used primarily as sources of sulphur:			
Ammonium Sulphate	21-0-0-24 20-0-0-24 19-2-0-22	• Crystalline • Granular • Granular	Applied prior to seeding. Contains sulphur in the sulphate readily available form. Corrosive. A highly acidifying fertilizer, which should not be used continuously or at high rates on acidic soils.
Ammonium Thiosulphate	12-0-0-26 15-0-0-20	• Liquid contains 0.35 lb N and 0.76 lb S/litre or 1.60 lb N and 3.46 lb S/Imp gal. contains 0.43 lb N and 0.57 lb S/litre or 1.96 lb N and 2.62 lb S/Imp gal.	Non-corrosive. Contains sulphur in a readily available form.
Elemental Sulphur	0-0-0-90	• Can be blended with most dry fertilizers except ammonium nitrate.	Must be oxidized to sulphate before the plant can use it. Apply one year in advance of crop use.
Combination or blended fertilizers: Note: When blending fertilizer, it is important to use fertilizer sources with evenly matched particle sizes. Using inconsistently sized sources will result in segregation of different fertilizers and may result in lost productivity and crop damage.			
Ammonium Nitrate and Monoammonium Phosphate*	23-22-0 28-13-0	• Solid, granular, a blend of 34-0-0 and 11-52-0.	Suitable for nitrogen and phosphorus-deficient soils. Phosphorus availability same as monoammonium phosphate.
Urea and Monoammonium Phosphate*	27-27-0 34-17-0, etc.	• Solid granular, a blend of 46-0-0 and 11-52-0. Fairly stable during storage and handling.	Suitable for nitrogen-and phosphorus-deficient soils. Nitrogen component can cause germination damage to seed at above recommended rates.

Monoammonium Phosphate and Ammonium Sulphate	16-20-0-14 17-20-0-15	• Solid, granular, sources are mixed into a common granule.	Suitable for sulphur-deficient soils. Phosphorus availability same as monoammonium phosphate. Suitable size for blending.
***Warning:** Contact between urea (46-0-0) or urea blends and ammonium nitrate (34-0-0) or ammonium nitrate blends will cause the fertilizer to absorb moisture, turning into a "slush." Thoroughly clean all equipment and storage bins before switching from one product to another. Some micronutrient fertilizer may have similar compatibility problems with dry and liquid fertilizers, so consult manufacturer's instructions.			

Table 10. Selecting fertilizer for required amounts of nutrients

The number in the columns after a particular fertilizer formulation represents the number of pounds of that fertilizer needed to supply a required amount of nutrient. For liquid fertilizers the number of litres needed to supply that required amount of nutrient is stated inside brackets.

Fertilizer Formulation	Pounds of Nitrogen (N) Required									
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
20-0-0 (24)	50	100	150	200	*	*	*	*	*	*
21-0-0 (24)	48	96	144	192	*	*	*	*	*	*
28-0-0 liquid	36 (13)	71 (25)	107 (38)	142 (51)	179 (63)	214 (75)	250 (89)	286 (101)	321 (114)	357 (127)
34-0-0	29	59	88	118	147	176	206	235	265	294
34.5-0-0	29	58	87	116	145	174	203	232	261	290
46-0-0	22	44	65	87	109	133	156	178	196	217
82-0-0	*	24	37	49	61	73	85	96	110	122
28-13-0	36	71	107	143	179	214	250	*	*	*
27-27-0	37	74	111	148	185	222	259	296	*	*
18-46-0	55	110	165	222	*	*	*	*	*	*
24-22-0	42	83	125	167	206	250	292	333	*	*
34-17-0	29	58	87	116	145	174	203	232	*	*
12-51-0	83	166	249	*	*	*	*	*	*	*
10-34-0	100	200	300	*	*	*	*	*	*	*
16-20-0 (14)	63	125	188	250	312	375	*	*	*	*
19-3-0 (22)	52	104	156	208	*	*	*	*	*	*
17-20-0 (15)	59	118	177	336	*	*	*	*	*	*
12-0-0 (26)	83	167	250	333	*	*	*	*	*	*
15-0-0 (20)	67	133	200	267	*	*	*	*	*	*

Fertilizer Formulation	Pounds of Phosphate (P_2O_5) Required

	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
10-50-0	10	20	30	40	50	60	70	80	90	100
11-52-0	10	19	29	38	48	58	67	77	86	96
11-55-0	9	18	27	36	45	54	63	72	81	91
12-51-0	10	20	29	39	49	59	69	78	88	98
18-46-0	12	23	35	45	55	65	75	85	100	115
24-22-0	23	46	68	91	114	136	159	182	*	*
27-27-0	18	37	56	74	92	111	130	148	167	185
28-13-0	38	77	115	154	192	*	*	*	*	*
34-17-0	29	59	88	118	147	176	*	*	*	*
10-34-0 liquid	15 (5)	29 (9)	44 (14)	58 (19)	73 (24)	88 (28)	103 (33)	116 (38)	131 (42)	146 (47)
0-54-0 liquid	9 (3)	19 (5)	28 (8)	37 (11)	46 (13)	56 (16)	65 (19)	74 (21)	83 (24)	92 (27)
16-20-0 (14)	25	50	75	100	125	150	175	200	*	*
17-20-0 (15)	25	50	75	100	125	150	175	200	*	*

Fertilizer Formulation	**Pounds of Potash (K_2O) Required**									
	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
0-0-60, 0-0-62	8	17	25	33	42	50	56	68	72	85
10-30-10	50	100	150	200	250	300	*	*	*	*
8-24-24, 6-24-24	20	40	60	80	100	125	140	160	180	200

Fertilizer Formulation	**Pounds of Sulphur (S) Required**									
	5	**10**	**15**	**20**	**25**	**30**				
20-0-0 (24% S)	20	40	60	80	100	120				
21-0-0 (24% S)	20	40	60	80	100	120				
19-3-0 (22% S)	23	45	68	90	113	135				
16-20-0 (14% S)	36	71	107	143	180	*				
12-0-0 (26% S) liquid	19 (7)	38 (13)	58 (20)	77 (26)	96 (33)	115 (39)				
Gypsum (18% S)	27	55	82	110	137	165				
0-0-0 (90% S)	6	11	17	22	28	33				
15-0-0 (20% S) liquid	25 (9)	50 (17)	75 (26)	100 (34)	125 (43)	150 (52)				

***Some other fertilizer formulation is more desirable to supply this large quantity of nutrient**

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Fertilizer recommendation guidelines

Soil testing is the only way to determine the available nutrient status of a field and receive specific fertilizer recommendations. General recommendations for those without a soil test are outlined in the appendix of this guide. These recommendations can only provide "ball park" fertilizer requirements and are estimated for average conditions that may not occur in individual fields.

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- Soil Testing
    - Sampling Patterns
        - Traditional Composite Sampling
        - Benchmark Soil Sampling
        - Grid
        - Landscape Directed
- Proper Soil Analysis Techniques
- Plant Tissue Analysis

As a result, these recommendations may lead to under-fertilization where optimum yield potentials and maximum economic returns will not be achieved. Conversely, these recommendations may lead to over-fertilization resulting in unnecessary costs, excessive vegetative growth, delayed maturity, lodging, reduced quality factors (protein, oil, etc.) and soil and water contamination problems.

Sound fertilizer recommendations for Manitoba are based on soil fertility analysis and fertilizer response. Research is conducted in the province, or under similar soil, climatic and cropping conditions as occur throughout the other parts of the Prairie region. Fertilizer recommendations based on soil testing are also included in the appendix of this guide.

Soil testing

Yield and economic return from fertilizer can be optimized, and potential soil and water pollution minimized, when nutrient application is geared to the needs of a particular crop grown on a specific field. An effective on-farm soil testing program is one in which every field is properly sampled and tested every year. This gives the producer an inventory of the nutrient levels in each field, plus specific recommendations as to the kinds and rates of fertilizer nutrients to apply for each crop. Recommendations may be based on specific times and methods of application and may provide information to modify application rates for different times and methods of application.

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Reliable soil test results and recommendations depend upon:

- proper soil sampling and sample processing procedures
- proper soil analysis techniques
- sound fertilizer recommendation guidelines

Soil sampling and sample processing

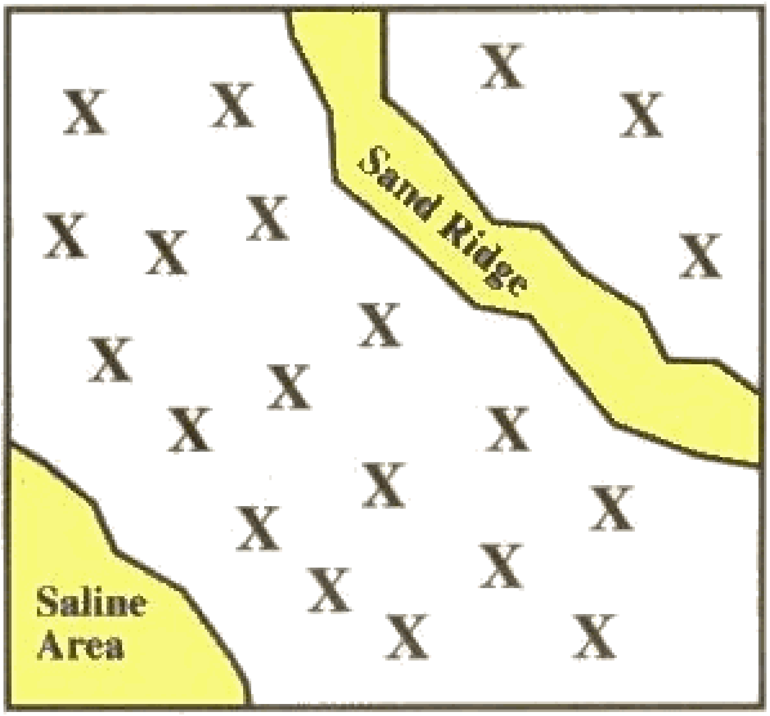
Soil sampling is the key to a sound soil testing program and the one step over which producers have complete control. Generally, it is important to follow the procedures recommended by the soil testing lab that is analysing the sample. The following general procedures are usually recommended to ensure representative samples are provided for laboratory analysis.

- Samples should be taken prior to seeding in spring, or in the preceding fall after soil temperatures drop below 5°C.
- Samples should be taken to the full 24 in. depth to get a proper and complete measure of the amounts of nutrients (particularly nitrogen and sulphur) available. All crops usually extract nutrients and water to at least the 24 in. depth over the course of a growing season.
- Samples should be kept cool and shipped immediately to the soil lab for analysis. Alternatively, samples should be laid out to dry completely within 24 hours at a temperature less than 35°C or samples should be frozen immediately until they can be dried or analyzed. High-temperature drying, or use of a microwave oven, will invalidate test results and fertilizer recommendations.
- Samples should be kept clean. Substances such as fertilizer dust, cigarette ashes and manure can contaminate samples and result in erroneous test results and fertilizer recommendations.

Sampling Patterns

Traditional Composite Random Sampling

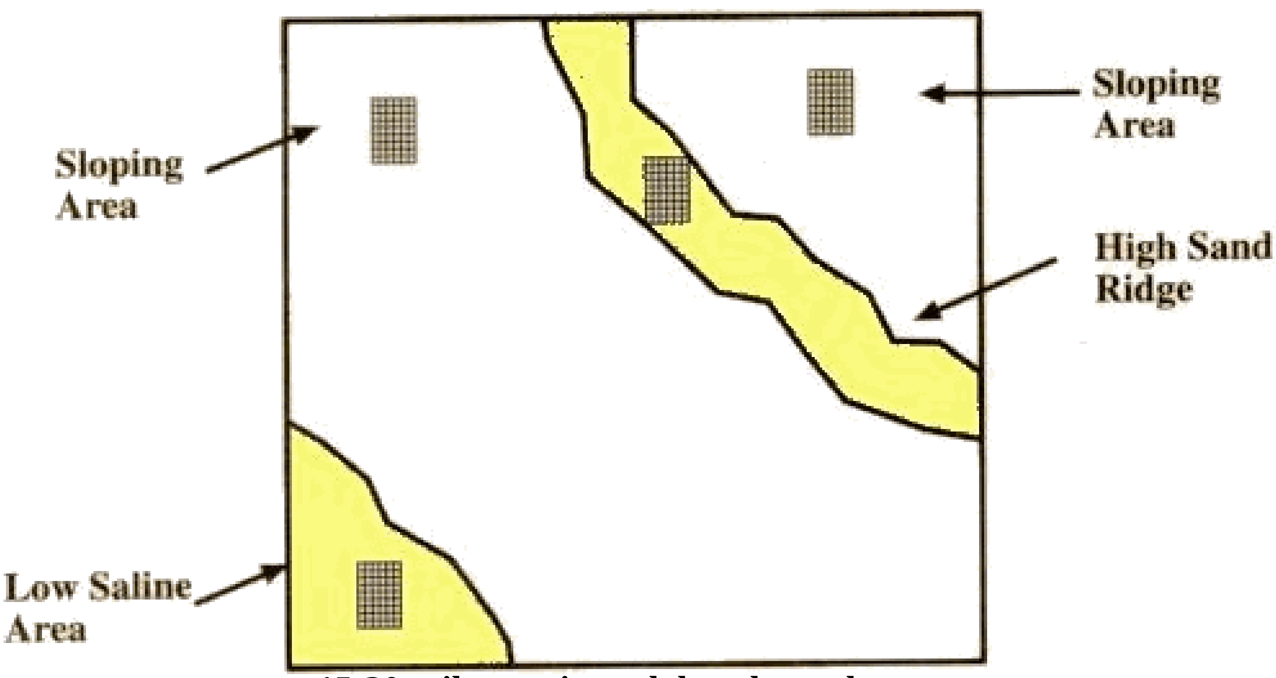
- 15-20 cores are randomly taken throughout a field, thoroughly mixed, subsampled and sent to the lab as a single sample.
- Representative sampling areas should be sampled. For hilly fields with knolls, slopes or depressions, take samples from mid-slope positions to get average results. Level fields appear relatively easy to sample.
- Avoid sampling obvious areas of unusual variability, such as saline areas, eroded knolls, old manure piles, burnpiles, haystacks, corrals, fence rows or old farmsteads, on headlands, within 50 feet of field borders or shelterbelts and within 150 feet of built-up roads.



X = single soil probe sites

Benchmark Soil Sampling

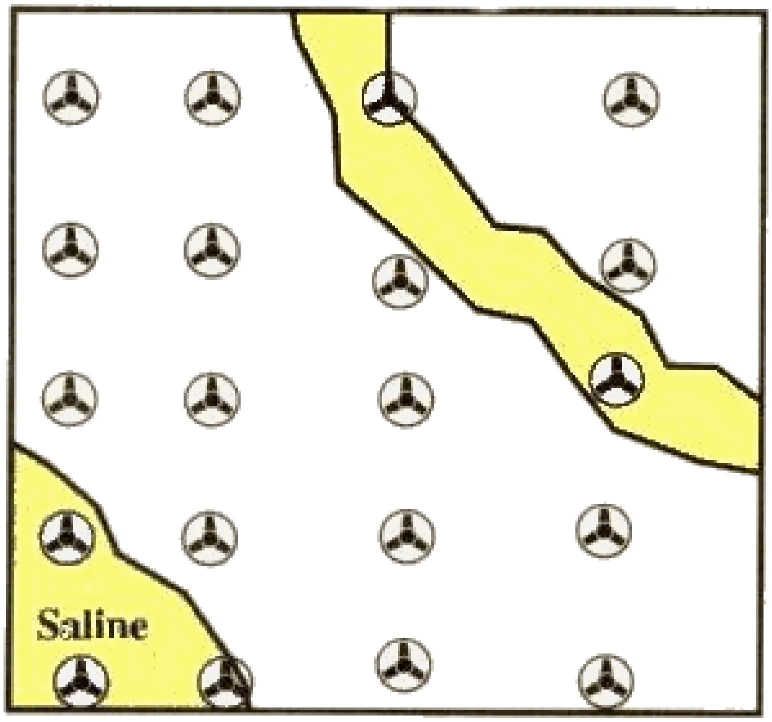
- A small ¼ acre area is selected as typifying the field or majority soil type within the field. In this benchmark area, 15-20 samples are randomly collected and mixed together.
- This technique assumes that the benchmark area is less variable than the entire field because it is smaller. This same area will be sampled year after year which should minimize sampling errors.
- Selection of the benchmark area is critical. Representative sites may be selected through close crop observation (particularly during early growth stages when fertility differences are most evident), past grower experience, yield maps, soil surveys and/or remote sensed images.



15-20 soil cores in each bench-mark area.

Grid Soil Sampling

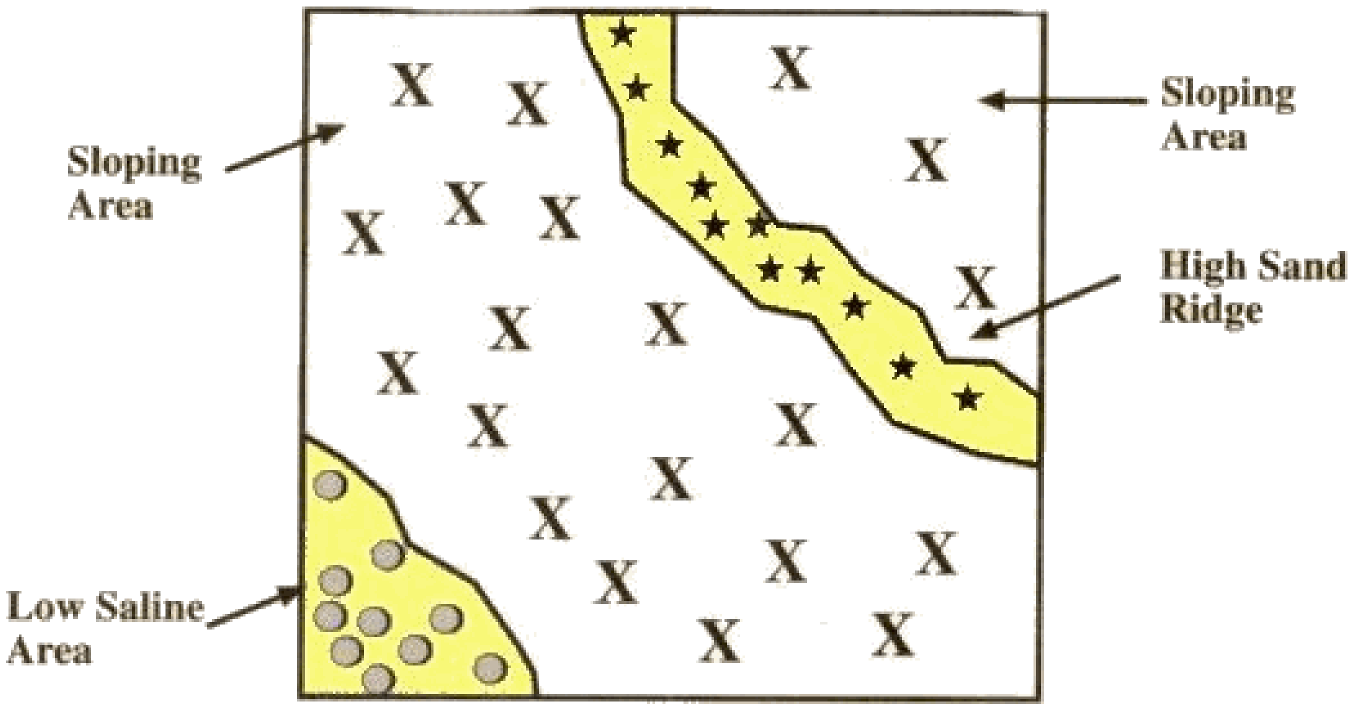
- This technique uses a systematic method to reveal fertility patterns and assumes there is no logical reason for fertility patterns to vary within a field.
- The field is divided into small areas or blocks. A sample location within the block, often at the point in the centre or grid point, is sampled 3-10 times. Modifications to the grid point sample may be done to avoid repeat sampling of regular spaced patterns within fields, such as fertilizer overlaps, tillage or tile drainage.
- Grid sampling may be costly depending on the grid size selected. U.S. experience indicates that a sampling density of one sample per acre is required to provide accurate information for variable rate fertilization. Sampling of larger areas may still provide useful information on the magnitude of field variability.



8-10 cores taken in each grid cell

Landscape Directed Soil Sampling

- This technique is used when major areas within fields have distinctly different soil properties, such as texture or landscape features. These areas should be sampled, and possibly fertilized separately.
- Fields need to be delineated into different polygons or soil management zones. These patterns may be detected by soil survey, detailed elevation mapping, aerial black and white photographs, yield maps or remote sensed images.



O = probe sites from low, saline areas
X = probe sites from sloping areas
*** = probe sites from high sand ridge**

Proper soil analysis techniques

Soil analysis techniques that provide meaningful test results should be used. For Manitoba, the following are the recommended and approved procedures for the four major nutrients:

Nitrogen (N) - Water soluble nitrate-nitrogen measured to the 24 inch depth.

Phosphorus (P) - "Olsen" (sodium bicarbonate) technique measures extractable P in the top 6 inch depth and is well-suited to alkaline soils. Some laboratories use the acetic fluoride or modified Kelowna test. Evaluations in other Prairie provinces indicate these methods perform satisfactorily in assessing P responsiveness of the soil. However, since the amount of P extracted is different than the Olsen (sodium bicarbonate) method, the Manitoba provincial recommendations in Appendix Table 12 cannot be used.

Potassium (K) - The "Ammonium Acetate Exchange" technique measures exchangeable K in the top 6 inch depth. The acetic fluoride or modified Kelowna test also contains ammonium acetate and is a suitable technique.

Sulphur (S) - Water soluble sulphate-sulphur measured to the 24 inch depth.

Copper, Zinc, Iron, Manganese – DTPA extractable in the top 6 inch depth.

Boron - Commonly extracted by commercial labs using hot water.

Note: Use of the other recommendation guidelines or application of Manitoba guidelines to different analytical techniques may not provide sound fertilizer recommendations.

Plant tissue analysis

Plant tissue analysis is a tool that can be used to fine-tune fertilizer management practices. Plant tissue analysis measures the nutrient levels in growing crops. Test values are compared with established values for inadequate, adequate and excess levels for each element and plant species. In this way, the nutritional health of the plant sample and the crop it represents can be assessed and the supply and availability of nutrients to crops during the growing season can be evaluated.

Plant tissue analysis is useful in evaluating fertilizer management programs and practices (including a soil testing program), diagnosing nutrient-related crop production problems and identifying nutrient levels in crops that may limit top yield achievement, including potential micronutrient problems.

Like soil testing, the validity and usefulness of plant tissue analysis depends on proper plant sampling and sample handling procedures. These include:

- Sampling crops from individual fields separately.
- Sampling the proper plant part at the proper growth stage. This is specific to each individual crop and lab. **Sampling guidelines should be obtained from a reliable laboratory providing the service.**
- Sampling an adequate number of representative plants from a large number of "average" locations in a field. Abnormal plants from non-representative field locations should not be included unless the "comparative sampling" approach is used. Here, samples are taken separately from both normal and abnormal areas to determine if plant nutrition is the cause of the apparent difference.
- Dry samples as soon as possible after removal at normal room temperatures that do not exceed 35°C.
- Avoiding contamination of sample with fertilizer dust, cigarette ashes, and other substances.

Like soil testing, analytical results must be assessed using standards developed specifically for crops and cropping conditions in Manitoba. Interpreting the results of plant tissue analysis often requires the assistance of a professional agronomist.

Table 11 provides the sufficiency levels of nutrients for many Manitoba crops at specific growth stages. Nutrient levels below these sufficiency levels are considered deficient.

Table 11. Crop nutrient sufficiency levels.

Crop	Plant part/ Growth stage	N %	P %	K %	Ca %	Mg %	S %	Fe ppm	Mn ppm	Cu ppm	Zn ppm	B ppm
Alfalfa	Top 6 in./ Flowering	2.5-5.0	0.25-0.7	2.0-3.5	0.5-3.0	0.3—1.0	0.25-0.5	30-250	25-100	8-30	20-70	30-80
Buckwheat	Entire top/ Flowering	1.75-3.0	0.25-0.5	1.5-3.0	0.3-2.0	0.2-1.5	0.15-0.4	20-250	10-100	5-25	15-70	5-25
Cereals - barley - wheat - oats	Entire top/ Prior to filling	2.0-3.0	0.26-0.5	1.5-3.0	0.2-2.0	0.15-0.5	0.15-0.4	20-250	15-100	- 3.7-25 4.5-25 2.5-25	15-70	5-25
Canola	Entire top/ Flowering	2.5-4.0	0.25-0.5	1.5-2.5	0.5-4.0	0.2-1.5	0.25-0.5	20-200	15-100	2.7-20	15-70	30-80
Corn	Ear leaf/ Tasselling	2.5-3.5	0.25-0.5	1.7-2.25	0.2-1.0	0.2-0.6	0.15-0.4	20-250	20-150	5-20	20-70	5-25
Flax	Entire top/ Flowering	1.75-3.0	0.25-0.5	1.5-3.0	0.2-2.0	0.2-1.5	0.15-0.4	20-250	20-100	3.5-25	15-70	5-25
Grasses	Entire top/ Prior to seed fill	2.0-3.0	0.25-0.5	1.5-3.0	0.2-0.5	0.15-0.5	0.15-0.4	20-250	15-100	5-25	15-70	5-25
Peas/beans	First fully developed leaf/ Flowering	3.0-5.5	0.25-0.5	1.5-3.0	0.35-2.0	0.2-1.5	0.2-0.4	20-250	20-100	5-20	15-70	5-25

Potatoes	3rd to 5th leaf from top/ Flowering	3.0-4.5	0.25-0.5	2.0-6.0	0.5-4.0	0.5-1.5	0.2-0.5	70-250	20-100	5-25	20-70	15-40
Soybeans	Upper trifoliate leaf/ Prior to Flowering	4.25-5.5	0.25-0.5	1.7-2.5	0.35-2.0	0.2-1.5	0.2-0.4	50-350	20-100	10-30	20-50	20-50
Criteria used by the former Manitoba Agriculture and Food Provincial Soil Testing Laboratory, 1991.												

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Manure

Manure may provide many of the nutrients required by crops - in addition to providing organic matter which helps to improve soil tilth, structure, aeration and water holding capacity.

The nutrient value of manure depends upon:

- the total amount of nutrients in manure - determined by analysis
- determining the proportion of total nutrients that are available to the current crop
- accounting for nutrient release from organic forms
- accounting for possible nutrient losses in storage and application
- the method and rate of application

Determining nutrient content

The best way to determine this is to conduct an analysis of the manure. Ideally, manure samples should be collected and analysed before application. It is important to collect a representative sample that has been thoroughly agitated; as a result many liquid manures are actually sampled during application. Several commercial laboratories offer analyses of manure samples.


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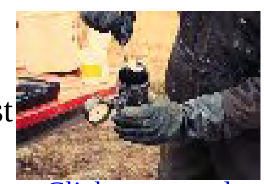
In addition to lab analyses, field test kits are available to estimate N and P content of manure. These allow nutrient estimation during manure application. When using these test kits, continue to check results with the laboratory analysis.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Nutrient availability to the current crop

- Nutrient analysis of nitrogen must indicate the ammonia-N content. This portion is readily available to the crop. The amount of total N that is in the ammonia form ranges from 50-75% for liquid manure to 10-30% for solid manure. The remaining organic portion of the N must break down in order to release usable N for the crop. It is estimated that 30% of organic N is available to the crop following application.
- Much of the P is present in the organic form. Only 50% of the total P content is considered to be available to the following crop.
- Almost all K remains in the inorganic form and is in the liquid portion of manure. It is all considered available to the following crop.
- S level of manure tends to be low and much is either present in the slowly available organic form or has been lost as sulphide gas. If S is needed for the current crop it is suggested that the sulphate form of fertilizer be applied.

Typical analyses of manures tested in Manitoba are enclosed in Table 12.

Table 12. Average nutrient analysis of manures and the amount available for crop use the year applied.

Type of manure	Number of samples	Total N (avail)*	Ammonium N	Organic N	Phosphate P_2O_5 (avail)*	Potassium K_2O	Sulphur S	Dry matter content %
LIQUID		**Lb./1000 gallons**						
Hog	36	23 (18)	16	7	15 (7.5)	13	1.4	2
Dairy	7	26 (18)	14	12	13 (6.5)	29	2.4	6
SOLID		**Lb./ton**						
Hog	3	14 (6)	2	12	15 (7.5)	16	2.5	35
Poultry	2	34 (12)	2.3	32	30 (15)	28	6.5	57
Beef	33	9 (3)	0.3	9	4 (2)	11	1.4	30

Manitoba Agriculture and Food.
*** amount available for following crop use; for nitrogen = ammonium-N + 30% of organic-N, for phosphorus = 50% of total phosphate.**

Manure can be valued by a number of ways.

1. Value to the present crop = 100% ammonium-N (less volatilization losses)
   + 30% organic N
   + 50% total P
   + 100% K (but only if potassium is a required nutrient).
2. Longer-term value - should include benefits from residual organic N and P, S and the organic matter (for which no monetary value is normally assigned).

Nutrient losses in storage and application

Much of the K content of solid manure can be lost if the liquid portion is not retained.

Ammonia losses through volatilization from surface applied manure can be very high if incorporation is delayed or if substantial rainfall (0.4 inches or 10 mm) is not received soon after application (Table 13).

surface applied manure without incorporation risks losing much of the available N and making P and K positionally unavailable for annual crops. Water runoff may carry surface broadcast nutrients off sloping fields

Table 13. The portion of ammonia-N lost % with different manure application techniques and weather.

Application Methods	Cool wet	Cool dry	Warm wet	Warm dry
Incorporated within 1 day	10	15	25	50
Incorporated within 2 days	13	19	31	57
Incorporated within 3 days	15	22	38	65
Incorporated within 4 days	17	26	44	72
Incorporated within 5 days	20	30	50	80
Not Incorporated	40	50	75	100

Irrigation	Above factors + 10%	Above factors + 10%	Above factors + 10%	Above factors + 10%
Injected	0	0	0	0
Applied to cover crop	25	25	40	50
From MARC 98 Manure Management program, Manitoba Agriculture and Food.				

Rate of application and spreader calibration

The rate of manure application is usually based on meeting the nitrogen needs of the crop. Knowing the crop needs (through soil testing), manure nutrient content (through sampling) and estimating N efficiency based on application method and timing will allow simple calculation of application rates.

Application rates of manure spreaders can be determined a number of ways:


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Liquid tankers surface spreading

1. Determine tank volume (V), the length (L) driven to empty the tank and the effective spreading width (W). Then simply divide the number of gallons (V) by the area covered (L x W) to determine rate.

2. Bury straight walled pails in the field, across the spreading pattern. Spread the manure, then measure the depth of manure in the pail and find the application rate in Table 14. Using several pails across the spreading width will identify if spreading pattern is uniform. This method can also be used for irrigation guns.


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Table 14. Calibrating liquid manure applicators

Depth of manure in Straight walled pail.		Application rate
Inches	**mm**	**Gal/acre**
1/10	2.5	2,265
1/8	3.1	2,825
1/4	6.3	5,650
3/8	9.4	8,500
1/2	12.5	11,325
5/8	15.6	14,150
3/4	18.8	17,000
1	25	22,650


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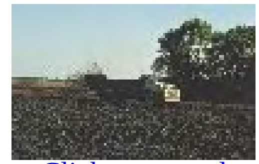
Pipeline injection

1. Identify pumping rate and travel speed of injector unit.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Solid manure spreaders

1. Determine weight of manure (M) in full spreader (so you will need to weigh spreader both full and empty), the length (L) driven to empty the spreader and the effective spreading width (W). Then simply divide the weight of manure (M) by the area covered (L x W) to determine rate.
2. Spread a 40 in. by 40 in. (1 m x 1 m) or a 10 ft. by 10 ft. plastic sheet in the field and spread manure over the top. Use table 15 to determine spreading rate. Repeat this procedure 3 times to determine the representative rate.


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Table 15. Solid manure spreader calibration.

Weight of manure/sheet (lbs.)		Application rate	
40 inch x 40 inch (1m x 1m) sheet	10 foot x 10 foot sheet	tonne/acre	Tons/acre
1	9	1.8	2.0
2	18	3.6	3.9
3	27	5.4	5.9
4	36	7.1	7.8
5	45	8.9	9.8
7	63	12.5	13.7
10	90	17.8	19.6
15	135	26.7	29.4

Application costs

Typical application costs for liquid manure are listed in Table 16. These costs will vary from operation to operation, depending on volumes, method of application and distance from barn to field to be fertilized.

Table 16. Custom application costs for manure (1998 values).

Application method	Custom applied
Liquid Manure Pipeline injection Tanker injection Irrigation	 $6.50-8/1,000 gal $8-10/1,000 gal $4-5/1,000 gal
Solid manure Truck mounted spreaders	 $1.80-3.10/t
Application costs are based on 1998 prevailing custom rates.	

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Nitrogen Fixation

Rhizobium bacteria have a symbiotic relationship with legumes to convert atmospheric nitrogen (N_2) to a plant-available form. This process is called nitrogen fixation.

Sufficient numbers of effective rhizobium bacteria must be present to ensure that plants are well nodulated and able to meet the crop's N needs. Since many soils do not contain sufficient numbers of rhizobium bacteria, inoculation is recommended to assure early formation of functioning nodules.

Inoculation

The most common forms of inoculant formulations are: powdered peat, granular, liquid and frozen concentrates and pre-inoculated seed. All but granular inoculants are applied by coating the seed with a prepared culture of the required strain of rhizobium bacteria. Granular inoculants are designed for application in the furrow with the seed. Compared with peat-based and liquid inoculant, the granular form is more convenient to use and seems to be more effective in dry soils. However, granular inoculants are more expensive and may require special modifications to seeding equipment to ensure placement in the seed zone.


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Pre-inoculation of seed has proven effective for nodulation of alfalfa and other forage legumes but has not yet proved satisfactory for large seeded legumes.


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Each legume or group of legumes requires a unique species of rhizobium to form nodules and fix N. Commercial inoculants are prepared for specific groups of legumes as follows:

- alfalfa group - for alfalfa and sweet clover
- birdsfoot trefoil - for birdsfoot trefoil
- clover group - for red, white and alsike clover
- fababean group - for fababeans including broad, horse and tick beans
- field bean group - for field, garden, navy, pinto and other coloured beans
- pea and lentil group - for field, garden, and flat peas and lentils

- soybean group - for soybeans only

Labels will contain information on proper storage, handling and application of inoculant. Improper storage, which allows drying or heating, will reduce bacteria viability.

Most legumes are very efficient and derive almost all their N needs through N fixation, so no additional N fertilizer is required. However, N fixation may be reduced by acidic soil conditions, toxic seed treatments, desiccation in dry seedbeds and high soil nitrate levels or fertilizer application which inhibit nodulation.

Field beans are rather inefficient at fixing N and obtain less than half of their requirements through fixation. At low soil nitrate levels, supplemental N is warranted (20-40 lb. N/ac). Ongoing research in Manitoba indicates that applications up to 100 lb. N/ac may increase bean yields; however, these rates may cause an increase in foliage growth and disease severity (particularly white mold), delayed maturity and reduce the effectiveness of rhizobium.

Nodulation success on soybeans in Manitoba has been sporadic in the past. Inoculation is recommended, but if nodules are not present and soybeans are yellowing at flowering, producers should consider a broadcast application of nitrogen. Apply 50 lb. N/acre as broadcast ammonium nitrate.

For more information on inoculation and the proper methods of application to seed, refer to the Manitoba Agriculture and Food factsheet *Legume Inoculation* (120-33).

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Soil pH and Salinity

Soil pH

Most Manitoba soils have a neutral (pH=7.0) to alkaline pH (pH>7.0). Soil pH influences the availability of nutrients, particularly phosphorus and micronutrients, and biological activity.

Soil pH conditions result from the original soil parent material, the type of vegetation, the climate (particularly the amount of rainfall) and the age of the soils. Most agricultural soils in Manitoba are geologically young (<12,000 years), are derived from calcareous rock and developed under moderate rainfall and grassland or deciduous forest. These conditions have contributed to generally neutral to alkaline soils. The exceptions are sandy soils which have been leached or have developed under coniferous forest and peat soils.

Under low pH:

- rhizobium bacteria which provide N fixation are inhibited
- herbicides in the imidazolinone family, such as Pursuit, break down slowly in acidic soil

Under high pH:

- availability of phosphorus and most micronutrients is reduced, making placement more important
- urea losses to volatilization are greater
- risk of injury from seed-placed urea is increased
- herbicides in the sulfonyl urea family, such as Ally and Glean, and triazines (atrazine) break down slowly

Many of these fertility concerns on high pH soils are managed through timing and placement of fertilizer applications.

Management may also affect soil pH. Liming effectively raises the pH of acidic soils. Acidification of soils may occur through repeated nitrogen and sulphur application; however, on alkaline Manitoba soils this effect is negligible. Attempts to acidify Manitoba soils are usually unsuccessful since the high calcium carbonate content effectively neutralizes acidity from added sulphur or nitrogen fertilizers.

Efforts should be made to manage factors that increase soil pH. High pH soils may result from erosion, tillage or land leveling which removes or dilutes surface soil with more calcareous subsoil and from salt movement or salinity in the soil.

Salinity

Soil salinity is a soil condition where water soluble salts in the crop rooting zone impede crop growth. The severity of the effects and strategies to address the problem depend upon soil testing to identify the amount and type of salts present.

High salt content increases the osmotic potential of the soil solution and prevents crop uptake of water. Crops are generally most sensitive to salinity during germination and emergence. Some plants are more sensitive to salinity than others, depending on growth habit, root system, etc.

To assess the type of salinity problem, both affected and non-affected areas of the field should be sampled. Analyses should be done for electrical conductivity (E.C.), pH, cation base saturation, and content of calcium, magnesium, sodium and organic matter. Electrical conductivity of a soil-water extract is an index of the concentration of dissolved salts in the soil. As salt content increases, so does the E.C. (Table 17).

Table 17. The effect of salinity on crop growth.

E.C. (dS/m or mS/cm)*	Degree of salinity	Hazard for crop growth	Plant Response	Relative tolerance of crops**
0-2	Non-saline	Very low	Negligible	
2-4	Slightly saline	Low	Restricted yield of sensitive crops	Beans, peas, corn, soybean, sunflowers, clovers, timothy
4-8	Moderately saline	Medium	Restricted yield of many crops	canola, flax, oats, wheat, rye, barley, bromegrass, alfalfa, sweet clover, trefoil
8-16	Severely saline	High	Only a few tolerant crops yield satisfactorily	Slender and tall wheatgrass, Russian and Altai wildrye
>16	Very severely saline	Very high	Only a few salt tolerant forage grasses grow satisfactorily	

*** as determined by the saturated paste method.**
**** this is the range of salinity values at which crops can be expected to yield at least 50% of normal yield.**

Another type of soil problem occurs when sodium levels are high in relation to calcium and magnesium in the soil. These soils are very sticky and slippery when wet, and very hard, cloddy and prone to crusting when dry. The sodium adsorption ratio (SAR) should be determined by the soil test lab. The SAR is the ratio of sodium to the beneficial soil structural cations, calcium and magnesium. When the SAR value exceeds 13, the soil is "sodic." If the SAR exceeds 13 and the E.C. is greater than 4, it is considered a "saline-sodic" soil.

Consult other publications for management of saline and saline-sodic soils.

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Manitoba Fertilizer Recommendation Guidelines Based on Soil Tests

This section contains tables of fertilizer recommendations for most Manitoba field crops based on soil tests. These recommendations are based on field research conducted in Manitoba and have been approved for use in Manitoba by the Manitoba Soil Fertility Advisory Committee. Following are some brief points in using the attached recommendation tables:

1. Recommendations are based on soil analysis performed according to the soil analysis section.
2. Soil analysis results may be reported by soil test laboratories as lb./ac or ppm. Values in ppm can be converted to lb./ac by multiplying by a factor of 2 for each 6 inch increment of depth for the sample (e.g. multiply by 2 for 6 inch samples and by 6 for 18 inch samples). Ratings for soil test levels are given as very low (VL), low (L), medium (M), high (H), very high (VH, VH+).
3. Soil nitrate-nitrogen values used in these recommendations are based on fall soil sampling. Manitoba research has shown that 8 lb./ac nitrate-N may mineralize between late fall sampling and spring seeding. If samples are taken in the spring, deduct 8 lb./ac from the analytical values before using the tables.
4. Nitrogen rates are based on a spring broadcast application for all but row crops, where rates are based on a spring band application. Relative efficiency of nitrogen varies by method and time of application, so rates should be adjusted according to table 4.

Table 4. Nitrogen Efficiency Based on Application Time and Placement.

Time and Method	Relative Values
Spring broadcast	100%
Spring banded	120%
Fall broadcast	80%
Fall banded	100%

Adjust nitrogen recommendations from tables according to method and time of application according to this formula.

Rate of N to Apply = (Rate from chart) X (Relative Value of Spring Broadcast) / (Relative Value of Method Used)

5. Nitrogen recommendations for cereals, canola, flax, corn and sunflowers are based on TARGET YIELDS. The TARGET YIELD is the yield that a crop might be expected to produce based upon the amount of spring soil moisture and expected growing season precipitation based on the grower's experience. The TARGET YIELD FERTILIZER RECOMMENDATIONS indicate the fertilizer rate required to meet that yield expectation. Target yield recommendations are not intended as yield

predictions; nor do they imply guaranteed yield attainment. Achieving such target yields depend upon good management and cooperation of uncontrollable factors such as weather.

6. Nitrogen recommendations for cereals are further refined based upon soil moisture supply. Moisture supply is dependent upon seasonal precipitation and soil properties such as texture and drainage which affect moisture retention. Based on these criteria, soils within the province have been assigned a moisture category of MOIST or DRY. Soils of the MOIST category have a high water holding capacity or are in the cooler areas which may experience periodic dry conditions. Examples are the clay soils of the Red River Valley and the Grey Wooded soils.

   Soils of the DRY category are intermediate in water holding capacity and experience dry weather conditions.

   The IDEAL moisture category would occur under irrigation or when yield is not resstricted by lack of rainfall.

   A full listing of Manitoba soils and their moisture category are available from your Manitoba Agriculture and Food office.

7. No nitrogen is recommended for production of perennial legumes and most annual pulse crops (the exception is dry beans). All legumes should be properly inoculated at seeding to ensure nitrogen fixation.
8. In dry years, deep-rooted crop such as sunflowers will extract nitrogen below the 24 inch sampling depth. Consider sampling at the 2-4 foot depth for this crop.
9. High nitrogen rates are recommended for cereals and flax with high target yields and low soil N. Severe lodging may occur, so growers should temper rates based on their experiences.
10. Several of the phosphorus and potassium recommendations are based upon specific placement techniques. Crops vary in their tolerance of seed placed fertilizer and this influences recommendations (refer to Table 3 and Table 6).
11. For more detailed fertilizer recommendations, a "Fertilizer Selection Expert System" computer program has been developed by the University of Manitoba. This program takes into account many production factors, including soil test results, before making a customized recommendation that includes the optimum source of fertilizer, rate, method and time of application. The recommendations are based upon Manitoba soil test guidelines. The program is available from:

    Solomon Sinclair Farm Management Institute
    Room 403,
    Agriculture Building,
    University of Manitoba
    Winnipeg, Manitoba R3T 2N2
    Phone: (204) 474-9436
    Fax: (204) 261-7251.

    The cost is $50 and the program runs on DOS.

Example 1. A fall soil sample analysis is received with the following results:

Nutrient	Nitrate-N (0-24 in)	Phosphorus	Potassium	Sulphate-S (0-24 in)
Result	30 lb./ac	15 ppm	240 ppm	20 lb./ac

- The crop to be grown is feed barley and the projected yield is 85 bu/ac. The land is located on clay soils and is classified as a "moist" moisture category.
- Nitrogen fertilizer will be spring banded and phosphorus and potassium will be seed placed.
- From Appendix Table 3, 75 lb. N/ac are required "if spring broadcast". Use Table 4 to determine rate of spring banded N = 75 X 100/120 = 63 lb. N/ac.
- From Appendix Table 12, and 15 ppm soil P, one determines that 15 lb. P_2O_5/ac is required.
- From Appendix Table 13, and 240 ppm soil K, one determines that no K_2O is required.
- From Appendix Table 14, and 20 lb./ac soil sulphate-S, one determines that 15 lb. S/ac is required.

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Field Crops: Phosphorus | Potassium | Sulphur Micronutrient test strip rates

Appendix Table 1. Nitrogen recommendations for hard red spring wheat (based on spring broadcast application).

		Nitrogen Recommendation (lb/ac)								
SOIL MOISTURE CATEGORY		IDEAL			MOIST			DRY		
TARGET YIELD bu/ac Fall Soil NO_3-N		50	45	40	45	40	35	40	35	30
lb/ac in 0-24 in	Rating									
20	VL	120	90	65	110	70	45	100	55	30
30	L	100	70	45	85	45	25	80	30	10
40	M	80	50	25	65	30	5	60	10	0
50	M	60	30	5	50	10	0	40		0
60	H	40	10	0	25	0	0	20	0	0
70	H	20	0	0	0	0	0	0	0	0
90	VH	0	0	0	0	0	0	0	0	0
90	VH	0	0	0	0	0	0	0	0	0
100	VH+	0	0	0	0	0	0	0	0	0

Appendix Table 2. Nitrogen recommendations for CPS and feed wheat (based on spring broadcast application).

		Nitrogen Recommendation (lb/ac)								
SOIL MOISTURE CATEGORY		IDEAL			MOIST			DRY		
TARGET YIELD bu/ac Fall Soil NO_3-N		70	65	60	60	55	50	55	50	45
lb/ac in 0-24 in	Rating									
20	VL	140	110	90	110	70	55	130	70	45
30	L	120	90	70	85	55	35	110	50	25
40	M	100	70	50	65	35	15	90	30	5
50	M	80	50	30	50	15	0	70	10	0
60	H	60	30	10	25	0	0	50	0	0
70	H	40	10	0	0	0	0	30	0	0
90	VH	20	0	0	0	0	0	10	0	0
90	VH	0	0	0	0	0	0	0	0	0
100	VH+	0	0	0	0	0	0	0	0	0

Appendix Table 3. Nitrogen recommendations for feed barley (based on spring broadcast application).

		Nitrogen Recommendation (lb/ac)								
SOIL MOISTURE CATEGORY		IDEAL			MOIST			DRY		
TARGET YIELD bu/ac Fall Soil NO_3-N		105	95	85	90	80	80	70	65	60
lb/ac in 0-24 in	Rating									
20	VL	180	130	95	120	95	75	100	70	45
30	L	160	110	75	100	75	55	80	50	25

40	M	140	90	55	80	55	35	60	30	5
50	M	120	70	35	60	35	15	40	10	0
60	H	100	50	15	40	15	0	20	0	0
70	H	80	30	0	20	0	0	0	0	0
90	VH	60	10	0	0	0	0	0	0	0
90	VH	40	0	0	0	0	0	0	0	0
100	VH+	20	0	0	0	0	0	0	0	0

Appendix Table 4. Nitrogen recommendations for malting barley (based on spring broadcast application).

		Nitrogen Recommendation (lb/ac)								
SOIL MOISTURE CATEGORY		**IDEAL**			**MOIST**			**DRY**		
TARGET YIELD bu/ac **Fall Soil NO_3-N**		**85**	**80**	**75**	**75**	**70**	**65**	**65**	**60**	**55**
lb/ac in 0-24 in	Rating									
20	VL	180	150	95	125	105	80	130	80	50
30	L	160	130	75	105	80	60	105	60	30
40	M	140	110	55	85	60	40	85	40	10
50	M	120	90	35	65	45	20	65	20	0
60	H	100	70	15	45	25	0	45	0	0
70	H	80	50	0	25	5	0	25	0	0
90	VH	60	30	0	5	0	0	5	0	0
90	VH	40	10	0	0	0	0	0	0	0
100	VH+	20	0	0	0	0	0	0	0	0

Appendix Table 5. Nitrogen recommendations for oats (based on spring broadcast application).

		Nitrogen Recommendation (lb/ac)								
SOIL MOISTURE CATEGORY		IDEAL			MOIST			DRY		
TARGET YIELD bu/ac Fall Soil NO_3-N		105	95	85	95	90	85	85	80	75
lb/ac in 0-24 in	Rating									
20	VL	165	120	80	150	110	80	155	105	75
30	L	145	100	65	130	85	65	135	85	55
40	M	125	80	45	110	70	45	115	65	35
50	M	105	60	25	90	50	25	95	45	15
60	H	85	40	10	70	30	10	75	25	0
70	H	65	20	0	50	5	0	55	5	0
90	VH	45	0	0	30	0	0	35	0	0
90	VH	25	0	0	10	0	0	15	0	0
100	VH+	5	0	0	0	0	0	0	0	0

Appendix Table 6. Nitrogen recommendations for canola (based on spring broadcast application).

		NITROGEN RECOMMENDATION (lb/ac)			
TARGET YIELD bu/ac		45	40	35	30
Fall Soil NO_3-N					
lb/ac in 0-24 in	Rating				

20	VL	165	135	105	75
30	L	145	115	85	55
40	M	125	95	70	40
50	M	110	80	55	25
60	H	90	70	40	15
70	H	85	60	35	5
80	VH	85	55	30	0
90	VH	85	55	25	0
100	VH+	85	55	25	0

Appendix Table 7. Nitrogen recommendations for flax (based on spring broadcast application).

		NITROGEN RECOMMENDATION (lb/ac)			
TARGET YIELD bu/ac		40	35	30	25
Fall Soil NO_3-N					
lb/ac in 0-24 in	Rating				
20	VL	215	160	110	60
30	L	180	130	75	30
40	M	150	100	50	0
50	M	125	75	25	0
60	H	105	55	5	0
70	H	95	40	0	0
80	VH	85	35	0	0
90	VH	80	30	0	0
100	VH+	80	30	0	0

Appendix Table 8. Nitrogen recommendations for corn (based on a spring band application).

		NITROGEN RECOMMENDATION (lb/ac)			
TARGET YIELD bu/ac		130	115	100	85
SILAGE YIELD t/ac		19.4	17.1	14.9	12.6
Fall Soil NO_3-N					
lb/ac in 0-24 in	Rating				
20	VL	260	205	150	95
30	L	225	170	115	60
40	M	200	145	90	35
50	M	170	115	60	5
60	H	140	85	30	0
70	H	110	55	0	0
80	VH	80	25	0	0
90	VH	55	0	0	0
100	VH+	25	0	0	0

Appendix Table 9. Nitrogen recommendations for sunflowers (based on spring band application).

		NITROGEN RECOMMENDATION (lb/ac)			
TARGET YIELD lb/ac		2,500	2,250	2,000	1,750
Fall Soil NO_3-N					
lb/ac in 0-24 in	Rating				
20	VL	200	150	100	50
30	L	170	120	70	15
40	M	140	90	40	0
50	M	115	65	10	0
60	H	85	35	0	0
70	H	55	5	0	0
80	VH	25	0	0	0
90	VH	0	0	0	0
100	VH+	0	0	0	0

Appendix Table 10. Nitrogen recommendations for buckwheat (based on spring broadcast application).

Fall Soil NO_3-N		NITROGEN
lb/ac in 0-24 in	Rating	RECOMMENDATION (lb/ac)
20	VL	60
30	L	40
40	M	20
50	M	20
60	H	0
70	H	0
80	VH	0
90	VH	0
100	VH+	0

Appendix Table 11. Nitrogen recommendations for forage grasses (based on spring broadcast application).

Fall Soil NO_3-N		NITROGEN
lb/ac in 0-24 in	Rating	RECOMMENDATION (lb/ac)
20	VL	100
30	L	85
40	M	70
50	M	50
60	H	30
70	H	15
80	VH	0
90	VH	0
100	VH+	0

Appendix Table 12. Phosphorus recommendations for field crops based on soil test levels and placement.

			FERTILIZER PHOSPHATE (P_2O_5) RECOMMENDED lb/ac													
Soil phosphorus (sodium bicarbonate P test)			Cereal	Corn Sunflower	Canola Mustard		Buckwheat Faba beans		Flax		Peas Field beans Lentils		Legume forages		Perennial grass forages	
ppm	lb/ac	Rating	S[1]	Sb[2]	B[3]	S[1]	B[3]	S[1]	B[3]	S[1]	B[3]	S[1]	seeding PPI[4]	Est stand BT[5]	seeding PPI[4]	Est stand BT[5]
0	0	VL	40	40	40	20	40	20	40	0	40	20	75	55	45	30
	5	VL	40	40	40	20	40	20	40	0	40	20	75	55	45	30
5	10	L	40	40	40	20	40	20	40	0	40	15	75	55	45	30
	15	L	35	35	35	20	35	20	35	0	35	15	65	50	35	25
10	20	M	30	30	30	20	30	20	30	0	30	10	60	40	30	20
	25	M	20	20	20	20	20	20	20	0	20	10	50	35	20	15
15	30	H	15	15	15	0	15	20	15	0	15	0	45	30	15	10
	35	H	10	10	10	0	10	20	10	0	10	0	35	25	5	5
20	40	VH	10	10	10	0	10	20	10	0	10	0	30	20	0	0
20+	40+	VH+	10	10	10	0	10	20	10	0	10	0	25	20	0	0

S[1] – seed placed rates
Sb[2] – side banded rates for row crops
B[3] – banded away from the seed
PPI[4] – for forages phosphorus is applied most effectively by banding 1 inch to the side and below the seed. If phosphate cannot be banded, then broadcast and preplant incorporate.
BT[5] – broadcast for established stands of forages
Est stand = established stands of forages

Appendix Table 13. Potassium recommendations for field crops based on soil test level and placement.

FERTILIZER POTASH (K_2O) RECOMMENDED lb/ac													
Soil potassium (ammonium acetate K test)			Cereals		Corn		Sunflowers		Canola Mustard Flax Peas Field beans Faba beans Lentils Buckwheat	Legume forages		Perennial grass forages	
ppm	lb/ac	Rating	S[1]	PPI[3]	Sb[2]	PPI[3]	Sb[2]	PPI[3]	PPI[3]	Seeding PPI[3]	Est stand BT[4]	seeding PPI[3]	Est stand BT[4]

0	0	VL	30	60	100	200	30	60	60	150	100	90	65
25	50	VL	30	60	90	180	30	60	60	150	100	90	65
50	100	L	15	30	80	160	15	30	30	100	70	45	30
75	150	L	15	30	75	150	15	30	30	50	35	45	30
100	200	M	0	0	65	130	0	0	0	35	25	45	30
125	250	M	0	0	55	110	0	0	0	0	0	0	0
150	300	H	0	0	50	100	0	0	0	0	0	0	0
175	350	H	0	0	40	80	0	0	0	0	0	0	0
200	400	VH	0	0	30	60	0	0	0	0	0	0	0
200+	400+	VH+	0	0	0	0	0	0	0	0	0	0	0

S[1] – seed placed rates
Sb[2] – side banded rates for row crops
PPI[3] –broadcast and preplant incorporated.
BT[4] – broadcast for established stands of forages
Est stand = established stands of forages

Appendix Table 14. Sulphur recommendations for field crops based on soil test level.

Soil Sulphate-Sulphur in 0-24 in.		FERTILIZER SULPHUR (S) RECOMMENDED lb./ac		
		Cereals Flax Buckwheat Forage grasses	Canola Corn Sunflower Field peas Field beans Faba beans	Forage legumes
lb./ac	Rating			
0	VL	15	20	30
5	VL	15	20	30
10	VL	15	20	30
15	L	15	20	30
20	L	15	20	30
25	M	0	20	30
30	M	0	20	30
35	H	0	0	0
40	VH	0	0	0
40+	VH+	0	0	0

Appendix Table 15. Soil test criteria for micronutrient fertilizer test strip rates for field crops.

Micronutrient	Extractant	Critical level	Marginal range	Suggested field strip fertilizer rates.
Copper (Cu)	DTPA	0.2 ppm 5.0 ppm for peat soil	0.2 to 0.4 ppm	preplant incorporate 5-10 lb./ac copper as copper sulphate or 1-2 lb./ac copper as EDTA copper chelate. On peat, incorporate 5-15 lb./ac copper as copper sulphate or 1-3 lb./ac copper as EDTA copper chelate
Iron (Fe)	DTPA	4.5 ppm		No field crop recommendation.
Manganese (Mn)	DTPA	1.0 ppm		On peat soils, band 5-10 lb./ac manganese sulphate with cereal seed or preplant incorporate before seeding oilseeds, pulses and forages.
Zinc (Zn)	DTPA	1.0 ppm		Preplant incorporate 10-15 lb./ac zinc as zinc sulphate or 2-3 lb./ac zinc as zinc EDTA chelate.

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General Fertilizer Recommendations Without a Soil Test

The following are general fertilizer guidelines to be used in the absence of a soil test.

The suggested rates are based on long-term average soil test values across the province and are not as accurate as a soil test recommendation for a specific field and year.

Table of Contents:

Cereals | Oilseeds | Special Crops | Pulse Crops | Forage Crops

Crops	Nitrogen (N) (lb./acre)		Phosphate P_2O_5 (lb./acre)	Potash** K_2O (lb./acre)	Sulphate *** Sulphur (S) (lb./acre)	Comments
	Fallow or Legume* Breaking	Stubble				
Cereals						
Wheat - Hard Red Spring - Prairie Spring - Durum - Winter	 0-30 0-30 0-30 0-30	 55-90 60-100 55-90 80-110	 30-40 30-40 30-40 30-40	 15-30 15-30 15-30 15-30	 15 15 15 15	**Spring-seeded cereals** - For most efficient use, place phosphate, potash and nitrogen in the seed row when possible. Refer to Table 3 and Table 6 for safe rates. **Fall-seeded cereals** - Between 20 and 30 lb./ac of nitrogen can be applied with the seed to encourage early growth if soils are very low in nitrogen. The required phosphorus and potassium should be placed in the seed row in the fall for optimum efficiency and promotion of winter survival. Total seed placed fertilizer should not exceed (175 lb.acre). High rates of nitrogen in the fall may decrease winter survival of the stand. Preplant

Barley - feed (1) - malt (2)	 0-30 0-30	 55-90 55-90	 30-40 30-40	 15-30 15-30	 15 15	banding may also lead to seed bed damage, reduce seedling establishment, and reduce the amount of snow trapping which may reduce winter survival. Additional nitrogen may be more safely applied as a broadcast application in the spring. **Barley -** Depending on soil moisture conditions feed barley cultivars will yield up to 24% more than malt barley cultivars at equivalent nitrogen supply.
Rye Oats Triticale	0-20 0-30 0-20	40-65 55-90 40-65	30-40 30-40 30-40	15-30 15-30 15-30	15 15 15	

Oilseeds

Crops	Nitrogen (N) (lb./acre)		Phosphate P_2O_5 (lb./acre)	Potash** K_2O (lb./acre)	Sulphate *** Sulphur (S) (lb./acre)	Comments
	Fallow or Legume* Breaking	Stubble				
Canola/rapeseed Mustard Flax Sunflowers	0-30 0-30 0 0-30	70-90 70-90 40-65 55-90	30-40 30-40 30-40 30-40	30-60 30-60 30-60 15-30	20 20 15 20	**Canola/rapeseed and mustard -** refer to Table 3 and Table 6 for safe see placed rates. **Flax -** All fertilizer material should be placed away from the seed to avoid seed injury. **Sunflowers -** Germinating sunflower seeds are sensitive to fertilizer placed with the seed. Row equipment - when sunflowers are seed with row equipment, all phosphate and potash should be sidebanded 2 in. beside and below the seed at time of seeding. Some or all of the nitrogen may also be sidebanded. The total amount of fertilizer material side-banded should not exceed 300 lb./acre. Discer Seeder - When sunflowers are solid-seeded with a discer seeder in 12-24 in. row spacing, up to 25 lb./acre. P_2O_5 can be applied provided all fertilizer runs are left operating. If all phosphate must be placed with seed, the amount of phosphate should not exceed 15 lb./acre P_2O_5 for 12 in.

						row spacing, 10 lb./acre P_2O_5 for 18 in. row spacing and 5 lb./acre P_2O_5 for 24 in. row spacing. Nitrogen requirements not side-banded should be placed away from the seed as a band or broadcast application.
Special Crops						
Crops	**Nitrogen (N) (lb./acre)**		**Phosphate P_2O_5 (lb./acre)**	**Potash** K_2O (lb./acre)**	**Sulphate *** Sulphur (S) (lb./acre)**	**Comments**
	Fallow or Legume* Breaking	**Stubble**				
Buckwheat Corn	0-20 0-30	40-65 65-135	30-40 30-40	30-60 30-100	15 20	**Buckwheat** - Any nitrogen in excess of 6 lb./acre, phosphate in excess of 20 lb./acre P_2O_5 and all potash and sulphur should be placed away from the seed to avoid injury. **Corn -** When possible, phosphate, potash and nitrogen should be banded 2 in. beside and below the seed at time of seeding. The total amount of fertilizer mater side-banded should not exceed 300 lb./acre. Nitrogen requirements not side-banded at time of seeding should be side-dressed before the corn is 6 in. high. Excessive nutrient levels may occur when high rates of fertilizer are used on continuous corn. Soil testing to a depth of 24 in. is strongly recommended to monitor nutrient levels and avoid over-fertilization.
Potatoes	30-45	60-90	45-55	45-80	20	**Potatoes** - Side-banding 2 in. beside and below the seed at time of seeding is the most efficient use of fertilizer. Leaching loss of N can be reduced by a split applications. In-season N may be top-dressed prior to hilling, side-dressed or fertigated.
Canary Seed	General fertilizer recommendations for rye or triticale may be used.					
Pulse Crops						
Crops	**Nitrogen (N) (lb./acre)**		**Phosphate P_2O_5 (lb./acre)**	**Potash** K_2O (lb./acre)**	**Sulphate *** Sulphur (S) (lb./acre)**	**Comments**
	Fallow or Legume* Breaking	**Stubble**				

Fababeans Lentils Soybeans Field Peas	Inoculate seed Inoculate seed Inoculate seed Inoculate seed		30-40 30-40 30-40 30-40	30-60 30-60 30-60 30-60	20 20 20 20	**Pulse Crops** - Nitrogen is not recommended for most crops. Add proper inoculum to seed so that nodules will fix nitrogen requirements. Field beans may require 20-40 lbs nitrogen/acre, or up to 100 lb./acre in some cases. All phosphate in excess of 20 lb./acre P_2O_5 and all potash and sulphur should be placed away from the seed to prevent seed injury. Where field beans or soybeans are seeded in wide rows, all fertilizer should be placed away from the seed. Applying seed placed fertilizer to beans and soybeans in wide rows may cause stand reductions.
Field beans	0	20-40	30-40	30-60	20	
Forage Crops						
Crops	**Nitrogen (N) (lb./acre)**		**Phosphate P_2O_5 (lb./acre)**	**Potash** K_2O (lb./acre)**	**Sulphate *** Sulphur (S) (lb./acre)**	**Comments**
	Fallow or Legume* Breaking	**Stubble**				
(A) Grasses - New stands -Established stands	 0-20 *see* 1.	 40-60 *see* 1.	 30-40 20-30	 45-90 30-60	 15 15	Phosphorus fertilizer can be applied most effectively by banding the materials 1 in. to the side and below the seed. If phosphorus cannot be banded, incorporate it and all other fertilizer materials into the soil before seeding. 1. An economic return to the application of nitrogen fertilizer on established grass stands is questionable when the selling price of hay is low and the yield potential is low due to dry soil moisture conditions. When the prices are high and soil is moist, apply 70-110 lb./acre of nitrogen. (refer to Figure 2) Response of grasses to applied

						nitrogen depends on the type of nitrogen fertilizer, time of application, amount applied, species of grass, age of stand, number of cuts and climatic conditions. Annual broadcast applications of phosphorus, potassium and sulphur fertilizer on established grass crops may be in late fall or early spring. Do not apply fertilizer to frozen soils subject to water run off.
(B) Legumes - New stands - Established stands	Inoculate Seed Nitrogen is not recommended		55-75 40-55	60-150 40-100	30 30	Phosphorus fertilizer can be applied most effectively by banding the materials 1 in. to the side and below the seed. If phosphorus cannot be banded, incorporate it and all other fertilizer materials into the soil before seeding. Annual applications of fertilizer on established legume crops may be done in the fall or early spring. Do not apply fertilizer to frozen soils subject to water run off.
(C) Grass-legume mixtures						If the mixed stand contains more than 25% legume, fertilize as for a pure legume stand. If there is less than 25% legume in the stand, use the recommendations for pure grass stands.

***Refers to breaking after first cut of forage**
****On sandy-textured or organic soils apply this rate of K_2O**
*****When sulphur is required, apply this rate of sulphate sulphur**