University of Minnesota EXTENSION

NUTRIENT MANAGEMENT

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Fertilizing Corn in Minnesota

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In Minnesota, corn is grown on more acres than any other crop. Nationally, Minnesota ranks among the top five states in corn production. Average corn yields have improved steadily over the past several decades. While general fertilizer use contributed substantially to yield increases in the past, total fertilizer management which optimizes nutrient efficiency will be needed to increase future production and profitability.

NITROGEN GUIDELINES

Minnesota corn growers receive substantial return for money invested in nitrogen (N) fertilizers. For many situations, the most profitable yield cannot be achieved unless N fertilizers are used.

There are many management decisions involved in the use of N fertilizers. The most important, however, is the selection of a N rate that will produce maximum profit while limiting the potential for environmental degradation. The choice of an appropriate rate of fertilizer N is not easy because of the transient nature of N in soils.

STANDARD N GUIDELINES

The consideration of soil productivity, price/value ratio, and previous crop are used to arrive at the fertilizer N guidelines for corn. This represents a significant change compared to previous approaches. This process is a product of a seven-state effort, (Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, and Wisconsin) to use a similar philosophy/approach for determining N rate guidelines for corn.

Because of technology improvements in corn production practices such as weed and pest control, expected yield is not as important a factor in determining N rate as it has been in the past. Soil productivity has become a better indicator of N need. A majority of Minnesota soils are highly productive and have generally produced maximum economic corn yield with similar N rates over the last 15 years. Some soils have a reduced potential attributed to erosion, reduced water holding capacity caused by lower organic matter content, sandy soil texture, poor drainage, and restricted root growth. The fluctuation in fertilizer price affects the economic optimum N rate. To account for this change, the ratio of the price of N per pound to the value of a bushel of corn has been added to the N rate decision. An example calculation of the price/value ratio is if N fertilizer costs $0.40 per lb N or $820 per ton of anhydrous ammonia, and corn is valued at $4.00 per bushel, the ratio would be 0.40/4.00 = 0.10.

The maximum return to N value (MRTN) shown in **Table 1** is the N rate that maximizes profit to the producer based on the large number of Minnesota experiments supporting these guidelines. Once the soil productivity and price/value ratio have been determined, a producer's attitude towards risk must be factored into the process. A producer who is risk adverse and cannot tolerate risk associated with less-than-maximum yields in some years, even though economic return to N may not always be the highly profitable, may want to use the N rates near the high end of the acceptable range shown in **Table 1**. On the other hand, if corn is grown on medium or fine textured soils considered to be of low or medium productivity and/or localized N response data support lower N rates, producers may choose N rates near the low end of the acceptable range in **Table 1** if they are willing to accept the possibility of less-than-maximum yield in some years without sacrificing profit. This acceptable range gives producer flexibility in arriving at an acceptable and profitable N rate that is calculated as the rate +/- $1 from the MRTN rate.

Table 1. Guidelines for use of nitrogen fertilizer for corn grown following corn or soybean when supplemental irrigation is not used.

N price/Crop value ratio	Corn/Corn		Soybean/Corn	
	MRTN	Acceptable range	MRTN	Acceptable range
	---------- lb N/acre ----------			
0.05	180	160 to 200	140	125 to 160
0.10	155	145 to 170	120	105 to 130
0.15	150	140 to 155	105	95 to 115
0.20	140	130 to 150	95	85 to 105

The N rate guidelines in Table 1 are used if corn is grown in rotation with soybean or following corn when NOT irrigated. Corn grown on sandy soils deserves special consideration. If irrigated, the guidelines listed in **Table 2** are appropriate when corn is grown in rotation with corn. If corn is grown following soybean on irrigated sandy soils a credit of 30 lb of N per acre should be taken from the suggestions given in **Table 2**.

Table 2. Guidelines for use of N fertilizer for corn following corn when grown on irrigated sandy soils.

N price/Crop value ratio	MRTN	Acceptable range
	---------- lb N/acre ----------	
0.05	235	210 to 255
0.10	210	190 to 225
0.15	190	175 to 210
0.20	180	165 to 190

For non-irrigated corn grown on soils with a loamy fine sand texture and less than 3% organic matter, use the guidelines provided in **Table 3**.

Soils considered medium productivity in the past were given special consideration. More recent data has not shown strong support for a separate suggested application rate of N for medium productivity soils. The rate of N can be adjusted based on the acceptable range if a soil is considered to be medium productivity and has shown to be more or less responsive to fertilizer N.

Table 3. Nitrogen guidelines for corn grown on non-irrigated loamy fine sands with less than 3% organic matter.

N price/Crop value ratio	Corn/Corn	Corn/Soybean
	---------- lb N/acre ----------	
0.05	100	70
0.10	90	60
0.15	80	50
0.20	70	40

NITROGEN MANAGEMENT FOR FIRST- AND SECOND-YEAR CORN FOLLOWING ALFALFA

Alfalfa, which includes pure stands of alfalfa and alfalfa-grass mixtures with at least 50% alfalfa in the stand, can eliminate or greatly reduce the need for N from fertilizer or manure during the two subsequent years if corn is grown.

Past guidelines assigned N credits to corn based on alfalfa stand density, but analyses of field trials from across Minnesota and the Midwest indicate that the frequency and level of yield response to N in first- and second-year corn following alfalfa are more closely associated with soil texture, age of alfalfa at termination, alfalfa termination timing, and weather conditions.

It is well established that first-year corn following alfalfa rarely responds to N except on sandy soils, on fine-textured soils when there are prolonged wet early-season conditions, and on medium-textured soils when following very young alfalfa stands or in some cases when following spring-terminated alfalfa. In past field trials from across Minnesota and the Midwest, yield of second-year corn following alfalfa did not respond to N in one-half of the fields.

Suggested rates of N for first- and second-year corn following alfalfa are in **Table 4.** In some cases, the optimal rate of N can vary greatly due to weather-related variability in soil N mineralization. In such cases, limit the amount of N from fertilizer and manure that is applied prior to and near corn planting, and apply additional N to corn during the growing season if necessary based on weather and crop conditions.

Table 4. Nitrogen suggestions for first- and second-year corn following alfalfa.[a]

Soil texture[b]	Irrigated or non-irrigated	Alfalfa age[c]	Alfalfa termination time	First-year corn following alfalfa	Second-year corn following alfalfa
		years		lb N/acre	lb N/acre
Coarse	Irrigated	1	Fall or spring	140-170	140-170[d]
Coarse	Irrigated	2 or more	Fall or spring	70-150	70-150
Coarse	Non-irrigated	1	Fall or spring	40-80[d]	80-120[d]
Coarse	Non-irrigated	2 or more	Fall or spring	0-20	0-80
Medium	Both	1	Fall or spring	40-80[d]	80-120[d]
Medium	Both	2 or more	Fall	0-20	0-80
Medium	Both	2 or more	Spring	0-40	0-80
Fine	Both	1	Fall or spring	40-80[d]	80-120[d]
Fine	Both	2 or more	Fall	0-20[d]	0-80[d]
Fine	Both	2 or more	Spring	0-40[d]	0-80[d]

[a] Includes pure stands of alfalfa and alfalfa-grass mixtures with at least 50% alfalfa in the stand.

[b] Coarse = sands and sandy loams; medium = loams and silt loams; fine = clays, clay loams, and silty clay loams.

[c] Alfalfa age at termination, including the establishment year if alfalfa was direct seeded without a small grain companion crop.

[d] An additional 30 to 40 lb N/acre can be applied to corn during the growing season if necessary based on the University of Minnesota supplemental N worksheet, available at: http://z.umn.edu/ncalculator

NITROGEN CREDITS FROM OTHER PREVIOUS CROPS

To arrive at a guideline following other crops, an adjustment (credit) is made to the corn following corn guidelines. The adjustments can be found in **Table 5**.

In **Table 5**, several crops are divided into Group 1 and Group 2. The crops for each group are listed in **Table 6**.

Table 5. Nitrogen credits for different previous crops for first year corn.

Previous crop	1st year N credit
	lb N/acre
Group 1 crops	75
Group 2 crops	0
Edible bean	20
Field pea	20

Table 6. Crops in Group 1 and Group 2.		
Group 1 crops	**Group 2 crops**	
alsike clover	barley	Potatoes
birdsfoot trefoil	buckwheat	Rye
grass/ legume hay	canola	sorghum-sudan
grass/ pasture	corn	sugar beet
fallow	grass hay	Sunflower
red clover	grass pasture	sweet corn
	oats	Vegetables
		Wheat

The N rates listed in **Tables 1 and 2** define the total amount of fertilizer N that should be applied. All N applied should be accounted for in the calculation including N in starter fertilizer, weed and feed program, DAP (di-ammonium phosphate) or MAP (mono-ammonium phosphate) applied late fall (fter 4" average soil temperatures stabilize at 50°F) on non-sandy soils or for all soil types in spring, and with sulfur.

It is generally accepted that legume crops provide N to the next crop in the rotation. Some forage legumes provide some N in the second year after the legume was grown. Red clover is the only crop other than alfalfa that may provide a second-year N credit. If red clover was grown two years before the current crop, 35 lbs of N per acre should be subtracted from the N rate when corn follows the crops listed in Group 2, **Table 5**.

USE OF THE SOIL NITRATE TEST ENCOURAGED

Western Minnesota

The use of the soil nitrate test is a key management tool for corn producers in western Minnesota. The use of this test is appropriate for the shaded counties shown in **Figure 1**. The nitrate-N soil test is particularly useful for conditions where elevated residual nitrate-N is suspected. **Figure 2** is a decision tree that indicates situations where the nitrate-N soil test would be especially useful.

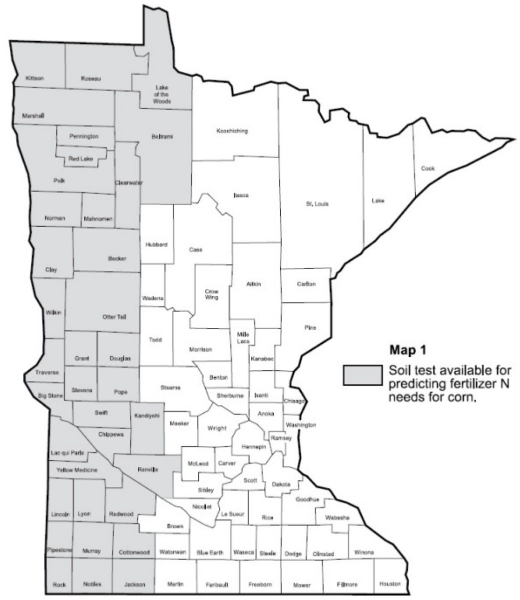

Figure 1. The fall soil nitrate test should be used for nitrogen guidelines in the counties that are shaded

For this test, soil should be collected from a depth of 6-24 inches in addition to the 0-6 inch sample that is used to test for pH, phosphorus, and potassium. The corn grower in western Minnesota also has the option of collecting soil from 0-24 inches and analyzing the sample for nitrate-nitrogen (NO_3-N). This 0-24 inch sample should not be analyzed for pH, phosphorus, and potassium because the results cannot be used to predict lime needs or rates of phosphate and potash fertilizer needed.

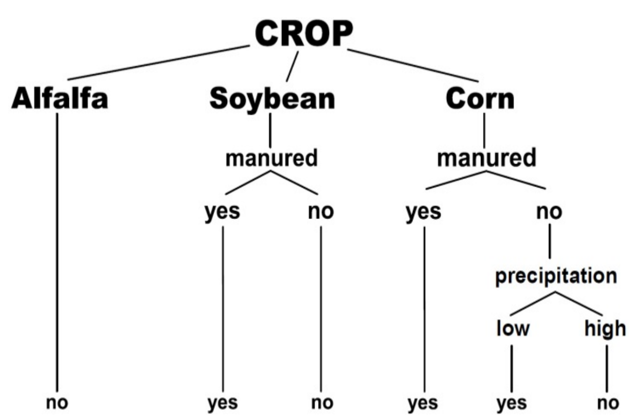

Figure 2. Flow chart decision-aid for determining probability of having significant residual nitrate-nitrogen in the soil.

When using the soil nitrate test, the amount of fertilizer N required is determined from the following equation:

- **NG =(Table 1 value for corn/corn) - (0.60 x STN(0-24in.))**
- NG = Amount of fertilizer N needed, lb/acre
- Table 1 value = the amount of fertilizer needed adjusted for soil potential, value ratio, and risk
- STN(0-24 inch) = Amount of nitrate-N measured by using the soil nitrate test, lb/acre

South-central, southeastern, east-central Minnesota

Research has led to the inclusion of a soil N test to adjust fertilizer N guidelines in south-central, southeastern, and east-central Minnesota (non-shaded areas of **Figure 1**). This test, in which soil nitrate-N is measured in the spring before planting from a two-foot sampling depth, is an option that can be used to estimate residual N. In implementing this test, the user should first evaluate whether conditions exist for residual N to accumulate. Factors such as previous crop, soil texture, manure history, and preceding rainfall can have a significant effect on accumulation of residual N.

A crop rotation that has corn following corn generally provides the greatest potential for significant residual N accumulation. In contrast, when soybean is the previous crop, much less residual N has been measured. This test should not be used following alfalfa.

The soil N test works best on medium and fine-textured soils derived from loess or glacial till. The use of the soil N test on coarse-textured soils derived from glacial outwash is generally not worthwhile because these soils consistently have low amounts of residual nitrate-nitrogen.

The amount of residual nitrate-nitrogen in the soil is also dependent on the rainfall received the previous year. In a year following a widespread drought, 2012 for example, a majority of fields will have significant residual nitrate. However, following relatively wet years little residual nitrate can be expected.

This soil N testing option, which estimates residual nitrate-nitrogen, will not be appropriate for all conditions. **Figure 2** can be used to help decide which fields may need to be sampled. This flowchart uses such factors as previous crop, manure history, and knowledge of previous rainfall.

Nitrogen fertilizer guidelines for corn can be made with or without the soil N test. The University of Minnesota's N guidelines (**Table 1**) are still the starting point. A five-step process is suggested when the soil nitrate-nitrogen test is considered.

1. Determine N rate guideline using Table 1 using soil productivity, price/value ratio, and previous crop for the specific field. The prescribed (rate assumes that best management practices (BMPs) will be followed for the specific conditions.

2. Determine whether conditions are such that residual nitrate-nitrogen may be appreciable. **Figure 2**, which includes factors such as previous crop, manure history, and previous fall rainfall can provide insight as to the applicability of testing for nitrate- nitrogen. If conditions are such that the probability of residual nitrate is small and soil testing for nitrate is not recommended, use the N guideline derived in Step 1.

3. If conditions suggest that a soil nitrate test is warranted, collect a pre-plant, 0-2 ft. soil sample taking enough soil cores from a field so that the sample is representative of the entire field. The sample should be sent to a laboratory and analyzed for nitrate-nitrogen.

4. Determine residual N credit based on the measured soil nitrate-nitrogen concentrations. Use **Table 7** to determine this credit.

5. Calculate the final N rate by subtracting the residual N credit (Step 4) from the previously determined N guideline (Step 1). The resulting

fertilizer N rate can then be applied either pre-plant and/or as a side-dress application.

Table 7. Residual N credit values based on the concentration of nitrate-N measured before planting in the spring from the top two feet of soil.	
Soil nitrate-N	Residual N Credit
ppm	lb N per acre
0.0-6.0	0
6.1-9.0	35
9.1-12.0	65
12.1-15.0	95
15.1-18.0	125
>18.0	155

This soil nitrate-nitrogen test should not be used when commercial fertilizer was applied in the previous fall. The variability in the degree of N conversion to nitrate-N before spring makes this test meaningless in these situations.

BEST MANAGEMENT PRACTICES FOR NITROGEN

Because of the diversity of soils, climate, and crops in Minnesota, there are no uniform statewide guidelines for selection of a source of fertilizer N, placement of the N fertilizer, and use of a nitrification inhibitor. In order to accurately address this diversity, Minnesota has been divided into five regions and BMPs for N use in each region have been identified and described. The listing of these management practices for all regions is not appropriate for this publication.

Currently, the use of these BMPs is voluntary. Corn growers should implement BMPs to optimize N use efficiency, profit, and protect against increased losses of nitrate-nitrogen to groundwater aquifers and surface waters. Time of application, selection of a N source, placement of fertilizer N, and decisions regarding the use of a nitrification inhibitor are topics that are discussed in detail in other Extension publications listed at the end of this folder.

PHOSPHATE AND POTASH GUIDELINES

When needed, the use of phosphate and/or potash fertilizer can produce profitable increases in corn yields. Soil test categories represent the probability the soil will supply all the needed crop nutrients. **Table 8** shows field research data summarizing the expected percent of time where a measurable response to P fertilizer will occur and the percentage of maximum yield produced when no fertilizer is applied. The chance of a yield response to P and the increase in yield is greatest when soil P tests Very Low and decreases as soil test P increases. Corn yield may still be increased by P at High and Very High soil test, but the net return to P may not be profitable.

Table 8. Corn grain yield response to applied P fertilizer based on soil test category.		
BRAY-P1 OR OLSEN SOIL TEST P CATEGORY	EXPECTED TIME P FERTILIZER WILL INCREASE CORN GRAIN YIELD	EXPECTED YIELD WITHOUT P FERTILIZER
	-----------------%-----------------	
Very Low	87	87
Low	83	90
Medium	27	98
High	13	99
Very High	7	99

Guidelines for phosphate fertilizer use are summarized in **Table 9**. The guidelines for potash fertilizer use are listed in **Table 10**.

RATE CHANGES WITH PLACEMENT

The phosphate guidelines provided in **Table 9** change with soil test level for phosphorus (P), expected yield, and placement. In general, the results of the Olsen test should be used if the soil pH is 7.4 or greater. There are some situations where the results of the Bray test are greater than the results of the Olsen test when soil pH values are greater than 7.4. For these cases, the amount of phosphate suggested should be based on the soil test value that is the higher of the two.

Measurement of P by the Mehlich III procedure is not suggested for use in Minnesota. However, some soil testing laboratories analyze P with this analytical test. For these situations, use the guidelines appropriate for the results of the Bray procedure. The definition of categories is the same for both the Bray and Mehlich III analytical procedures when P is determined colorimetrically. If the soil pH is greater than 7.4 use of the Mehlich III test is not suggested as the results may not correlate to the Olsen P test.

A combination of band and broadcast applications is suggested if the soil test for P is very low (0-5 ppm for Bray; 0-3 ppm for Olsen). For fields with these very low values, plan on using the suggested band rate in a band at planting, subtract this amount from the suggested broadcast rate, then broadcast and incorporate the remainder before planting. Phosphate fertilizer can be applied as either a broadcast application or in a band fertilizer if the soil test value for P is in the low (6-10 ppm for Bray; 4-7 ppm for Olsen) or medium (11-15 ppm for Bray; 8-11 ppm for Olsen) ranges. For any banded application, use the rates suggested for band use.

Table 9. Broadcast (Bdcst) and band phosphate guidelines for corn production in Minnesota.*

		Soil test P (ppm)									
		Very Low		Low		Medium		High		Very High	
Expected	Bray:	0-5		6-10		11-15		16-20		21+	
Yield	Olsen:	0-3		4-7		8-11		12-15		16+	
		Bdcst	Band	Bdcst	Band	Bdcst	Band	Bdcst	Band	Bdcst	Band
bu/acre		---- P_2O_5 per acre to apply (lb. per acre) ----									
175 – 199		110	55	75	40	45	30	15	10-15	0	10-15
200 – 219		130	65	90	45	55	30	20	10-15	0	10-15
220 – 239		145	75	100	50	60	30	20	10-15	0	10-15
240 +		160	80	115	60	70	35	25	10-15	0	10-15

** Use one of the following equations if a P_2O_5 guideline for a specific soil test value and a specific expected yield is desired.*

$P_2O_{5 suggestions}$ = [0.700 - .035 (Bray P ppm)] (expected yield)

$P_2O_{5 suggestions}$ = [0.700 - (.044 (Olsen P ppm)] (expected yield)

No phosphate fertilizer is suggested if the soil test for P is greater than 25 ppm (Bray) or 20 ppm (Olsen).

Table 10. Broadcast (Bdcst) and band potash guidelines for corn production in Minnesota.*

	Soil test K (ppm)									
	Very Low		Low		Medium		High		Very High	
Expected	0-40		41-80		81-120		121-160		160+	
Yield	Bdcst	Band	Bdcst	Band	Bdcst	Band	Bdcst	Band	Bdcst	Band
bu/acre	---- K_2O per acre to apply (lb. per acre) ----									
175 - 199	185	90	135	70	80	50	25	10-15	0	10-15
200 - 219	210	105	155	80	90	55	30	10-15	0	10-15
220 -239	235	120	165	85	100	60	30	10-15	0	10-15
240 +	255	130	180	90	110	65	35	15-20	0	10-15

** Use one of the following equations if a K_2O guideline for a specific soil test value and a specific expected yield is desired.*

$K_2O_{suggested}$ = [1.166 - .0073 (Soil Test K, ppm)] (expected yield)

No potash fertilizer is suggested if the soil test for K is 175 ppm or greater.

Broadcast applications of phosphate fertilizer have a low probability of increasing corn yields when the soil test for P is in the high range (16-20 ppm for Bray; 12-15 ppm for Olsen). The use of phosphate in a banded fertilizer is suggested for these situations. No phosphate fertilizer is suggested for either broadcast or banded application if the soil test is greater than 25 ppm (Bray), or 20 ppm (Olsen), and conventional tillage systems are used.

As with phosphate, the suggested rates of potash vary with the soil test for potassium (K), expected yield, and placement (**Table 10**). A combination of broadcast and band applications is suggested when the soil test for K is in the range of 0-40 ppm. For fields with these values, plan on using the suggested rate in the band at planting, subtract this amount from the suggested broadcast rate, then broadcast and incorporate the remainder needed before planting. The grower has the choice of either broadcast or band placement if the soil test for K is in the low (41-80 ppm) or medium (81-120 ppm) range. The application of potash in a band is emphasized if the soil test for K is in the high range (121-160 ppm).

There is a low probability of response to broadcast applications of potash if the soil test for K is greater than 160 ppm. No potash will be needed in either broadcast or a band application if the soil test for K is 200 ppm or greater, and conventional tillage systems are used.

SPECIAL CONSIDERATIONS

Because of the diversity in Minnesota's soils and climate, rental and lease arrangements for land, and goals of individual growers, the phosphate and potash suggestions listed in **Tables 8 and 9** cannot be rigid across the entire state. There are some special situations where rates might be changed. Some, but not all, of these situations are described in the following paragraphs.

East Central Minnesota Soils: In this region of the state usually have high native levels of soil test P and strict interpretation of the guidelines suggests that no phosphate is needed in a fertilizer program. Yet, many have observed responses to phosphate when applied in a band at planting. Soils in this region are frequently cool and wet in the spring and these conditions can lead to a requirement for phosphate fertilizer early in the growing season. Therefore, a rate of 15-20 lb phosphate per acre is suggested for use in a banded fertilizer placed close to the seed at planting for corn production in these situations, regardless of soil test level for P.

Broadcasting Low Rates: Some of the suggested rates for phosphate and potash listed in **Tables 8 and 9** are small and fertilizer spreaders cannot be adjusted to apply these low rates. The suggested broadcast rate of phosphate can be blended with the suggested broadcast rate of potash and the mixture could then be applied with available equipment. In other situations, broadcast applications of low rates of only phosphate or potash may be suggested. For these fields, it may be more practical to double the suggested broadcast rate and apply on alternate years.

Table 11. Expected removal of phosphate and potash in harvested corn grain at 15.5% moisture.

	Median	Range
	-----lb per bushel-----	
Phosphate (P_2O_5)	0.28	0.25 to 0.33
Potash (K_2O)	0.19	0.18 to 0.22

Changes in Soil Test Values: Many growers would prefer to maintain soil test values for P and K in the medium to high range to reduce the risk of yield loss due to insufficient P or K. This is especially true if they own, rather than rent, the land. There is justified concern that soil test levels for either P or K will drop substantially if low rates of phosphate or potash fertilizers are applied year after year and soils are not tested frequently enough to make adjustments for decreasing soil test values. In these circumstances application of P and K based on crop removal may be warranted. Average removal of P and K for corn is listed in **Table 11**. High rates of P or K applied for maintenance will typically result in a less return in crop value per pound of nutrient applied. The most economical use of P and K fertilizer is to only apply what is needed year to year as it has not been shown that the build and maintain method is superior to the sufficiency approach for P and K management.

Strict crop removal of P and K may not provide sufficient nutrients for soils that test Very Low or Low for either nutrient. Extra P can be applied to build some soils to the Medium or High soil test category. A general rule is that 16-18 lbs P_2O_5 and 7-10 lbs K_2O are required to increase the Bray-P1 or ammonium acetate K tests by 1 ppm, respectively. The amount of P or K needed to build the soil test greatly depends on soil chemical properties. Due to uncertainty of exact build values, rates in excess of guidelines for Very Low and Low P and K categories are not suggested when attempting to build soil test values. For soils in Western Minnesota where the Olsen P test is used, aggressively building soil test P values will not be cost effective due to the reaction of ortho-phosphate with calcium. Under these circumstances applying only what the crop needs to maximize yield potential is suggested.

Yield data collected from combines equipped with yield monitors makes it easy to calculate nutrient removal by the crop on a yearly basis. Using the previous years' yield map to generate a P or K application map is not recommended due to potential high cost of fertilizer P or K, low probability of a profitable return on investment in Medium and High P testing soils, and a general uncertainty as to the exact removal of nutrients per bushel of corn produced. A long-term average yield should be used in these circumstances. Recent long-term research data has shown that P and K will build over time in the top six inches of soil when exact removal of the nutrients was applied.

Research in Minnesota has shown that soil test levels for these two nutrients do not change rapidly with time. Yearly decreases have been small for situations where no phosphate or potash fertilizer has been applied.

A small decrease in soil test levels for P and K can be expected when phosphate and potash are used repeatedly in a banded fertilizer. Likewise, some reduction can be expected when low rates of phosphate and potash are used year after year. When soil test values drop, broadcast applications of higher rates of phosphate and/or potash fertilizers are justified if profitability and cash flow is favorable and the grower wants to maintain soil test values in the medium or high range.

Unless long-term leases or rental arrangements are in place, the use of a banded placement for phosphate and/or potash may be the most profitable management system for rented land. It is difficult to economically justify the use of high rates of phosphate and/or potash to build soil test levels on rented acres.

ADJUSTING FOR MANURE USE

The plant nutrients used in a fertilizer program for corn should be reduced if manure is used. The nutrient value of manure, however, varies with type of livestock, handling system, and method of application. Old rules are no longer appropriate when calculating the nutrient value of manure. Manure nutrient credits should be subtracted from the fertilizer guideline. Extension resources that describe in detail the use of manure are listed at the end of this publication.

USING A BANDED FERTILIZER

The use of a banded fertilizer at planting is an excellent management tool for corn production in Minnesota especially when soil conditions are cold and wet at planting. Yield increases are not always guaranteed with the use of a starter when soil test values are in the very high range or when recommended rates of broadcast P or K is applied. All nutrients applied in starter fertilizer should be accounted for in the total fertilize program.

The rate of fertilizer that can be applied in a band with the side of the seed at planting varies by fertilizer source and soil texture. A summary of appropriate rates for banding fertilizer on the corn seed can be found in the publication “Banding fertilizer on the corn seed”. Application of fertilizer two inches beside and below the seed row presents a very low risk for reduced germination.

CAUTION! Do not apply urea, ammonium thiosulfate (12-0-0-26), potassium thiosulfate, or fertilizer containing boron in contact with the seed.

SULFUR GUIDELINES

The addition of sulfur (S) to a fertilizer program should be a major consideration when corn is grown on sandy soils or on medium to fine textures soils when soil organic matter concentration in the top six inches is 4.0% or less. Application rate of sulfur should be adjusted based on crop rotation and for the concentration of organic matter in the top six inches (**Table 12**).

Table 12. Broadcast Sulfate-Sulfur guidelines for corn grown in Minnesota			
	0-6" Soil Organic Matter Concentration		
Crop Rotation	0-2%	2-4%	4%+
	lb S/acre as SO_4-S		
Soybean/Corn	**10-25**	**10-15**	**0***
Corn/Corn	**10-25**	**10-15**	**5-10****
Sandy Soils	**25**	**25-25**	**15-25**

*Research data suggest that a rate of 10 lbs of sulfate S may be warranted when corn follows soybean on poorly drained calcareous soils
**A low rate of S is suggested when corn follows corn and SOM is 4% or greater. A rate of 10-15 lbs of S is suggested for corn following corn on reduced tillage in the presence of high levels of surface residue

Plant available sulfur in the sulfate form is an anion and is susceptible to leaching loss. Recent data suggests that sulfate can carry over from one year to the next. Total corn uptake of S can range from 20-25 lbs of S per year. Application in excess of this amount will not result in increased grain yield but S not used by the current corn crop may be carried over to the next year reducing the need for S application for the following crop.

Banding sulfur fertilizer can increase the effectiveness and reduce the required application rate by as much as one half. Keep in mind that ammonium or potassium thiosulfate should not be placed in contact with the seed. Thiosulfate will not harm germination or emergence if there is 1 inch of soil between seed and fertilizer.

There are several materials that can be used to supply S. Any fertilizer that supplies S in the sulfate (SO_4^{2-}S) form is preferred. Fertilizer sources containing elemental sulfur are commonly sold in Minnesota. Elemental sulfur must be oxidized to sulfate sulfur before it can be taken up by the plant. Oxidation of elemental sulfur requires higher temperatures and will not occur early in the growing season. If elemental S is used, sulfate S should be applied to ensure adequate availability of S early in the growing season. Liquid S is commonly sold as thiosulfate products. The thiosulfate ion contains half of the S in sulfate and half in the elemental S form.

Visual sulfur deficiency symptoms early in the growing season are common in Minnesota due to limited mineralization and uptake of S early in the growing season. Some of these symptoms may be temporary and will go away as the soil warms. If a deficiency of S is suspected, recent data have shown that fertilizer S can be applied when corn is 12 inches tall or less without a reduction in yield potential.

MAGNESIUM GUIDELINES

Most Minnesota soils are well supplied with magnesium (Mg) and this nutrient is not usually needed in a fertilizer program. There are some exceptions. The very acid soils of east-central Minnesota might need Mg.

Table 13. Guidelines for magnesium use for corn production.			
Magnesium soil test	Relative level	Mg to apply	
		Row	Broadcast
Ppm		----- lb per acre -----	
0 – 50	**Low**	**10 - 20**	**50 - 100**
51 – 100	**Medium**	**Trial***	**0**
101 +	**Adequate**	**0**	**0**

*Apply 10 -20 lb. Mg per acre in a band only if a Mg deficiency is suspected or if a deficiency has been confirmed by plant analysis.

Most Minnesota soils are well supplied with magnesium (Mg) and this nutrient is not usually needed in a fertilizer program. There are some exceptions. The very acid soils of east-central Minnesota might need Mg.

There should be no need for the addition of Mg if dolomitic limestone has been applied for legume crops in the rotation or when soils are irrigated and the water source used contains a high concentration of Mg. There is a soil test that can be used to predict the need for this nutrient. The suggestions for using Mg in a fertilizer program are summarized in **Table 13**.

MICRONUTRIENT NEEDS

Research trials conducted throughout Minnesota indicate that zinc (Zn) is the only micronutrient that may be needed in a fertilizer program for corn. This nutrient, however, is not needed in all fields. The soil test for Zn is very reliable and will accurately predict the needs for this essential nutrient. The suggestions for Zn are summarized in **Table 14**.

Table14. Zinc guidelines for corn production in Minnesota.

	Zinc to apply	
Zinc soil test*	Band	Broadcast
- ppm -	----------- lb per acre -----------	
0.0 – 0.25	2	10
0.26 – 0.50	2	10
0.50 – 0.75	1	5
0.76 – 1.00	0	0
1.01 +	0	0

* Zinc extracted by the DTPA procedure.

Because corn is the only agronomic crop that will consistently respond to Zn fertilization, the use of Zn in a banded fertilizer suggested. However, carryover to succeeding years will be better with broadcast applications. There are several fertilizer products that can be used to supply Zn. Except for large particles of zinc oxide, all are equally effective. Cost should be a major consideration in product selection.

Chelated zinc is commonly used when liquid starter fertilizer is applied directly on the corn seed. Chelated Zn can increase the availability of Zn by preventing the precipitation of low solubility Zn compounds but products typically cost more per lb of Zn applied. Utilization of chelated Zn does not increase the potential for a yield response for soils testing 0.75 ppm or greater in soil test Zn and should be targeted to soils where a response to Zn is expected.

The use of iron (Fe), copper (Cu), manganese (Mn), and boron (B) is not suggested for corn fertilizer programs in Minnesota.

For more information on nutrient management for corn please refer to: www.extension.umn.edu/agriculture/nutrient-management/

Additional Information on rotating from alfalfa to corn is based on work by Yost, M.A., J.A. Coulter, and M.P. Russelle. (2015) is included in the publication Managing the rotation from alfalfa to corn - http://z.umn.edu/rotation

The corn supplemental N rate calculator can be found at:

Print version: http://z.umn.edu/supplementaln

Web calculator: http://z.umn.edu/ncalculator

The regional corn N rate calculator can be found at: http://cnrc.agron.iastate.edu

Information regarding manure management can be found at: http://www.extension.umn.edu/agriculture/manure-management-and-air-quality/

Information on banding fertilizer on the corn seed can be found in the publication "Banding fertilizer with the corn seed" (AG-NM-1502)