# FERTILIZER GUIDELINES FOR AGRONOMIC CROPS IN MINNESOTA






UNIVERSITY OF MINNESOTA
EXTENSION
Driven to Discover℠

# Table of Contents

## UNDERSTANDING THE SOIL TEST REPORT

The concept of soil sampling and analysis of samples collected has been the basis of fertilizer recommendations used in crop production for many years. Regardless of the procedure used for the collection of the samples, the results of the laboratory analysis that reach the crop producer are frequently confusing. The units used to report the analytical results are not familiar. There are several numbers on the analysis sheet. There is a relationship between the analytical results and fertilizer and lime recommendations. Some explanation of the information which appears on the analytical report would probably be helpful.

### The Reporting Units

The numbers found on any soil test report are the result of some analytical measurement of the nutrients in the soil. Most soil testing laboratories report this measurement as parts per million abbreviated as ppm. This reporting unit is used for nutrients other than nitrogen. Some laboratories report measurements in terms of pounds per acre. There is a simple conversion factor for these two reporting systems. That conversion is: ppm x 2 = lb. per acre.

When soil pH is measured, there are no units associated with the number that is reported. The same is true for the buffer pH.

When soil samples are analyzed for nitrate-nitrogen ($NO_3^-$-N), most laboratories will report the analytical results in two ways. The concentration is reported in terms of ppm. Then, depending on the depth from which the sample was collected, the concentration is converted into pounds of $NO_3^-$-N per acre for each increment of depth that was sampled. For example, if soil was collected from depths of 0 to 8 and 8 to 24 inches, the amount of $NO_3^-$-N at each depth is reported in terms of lb. per acre. The total for the 0 to 24 in. depth is calculated as the total that is found at 0 to 8 and 8 to 24 in. The sample calculations also apply to other depths that might be sampled.

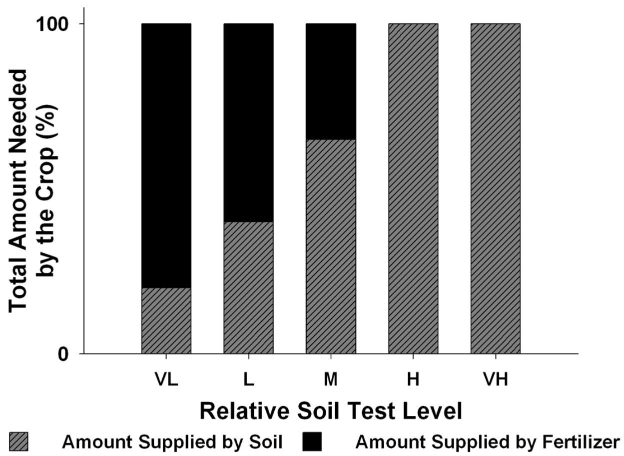
There are a variety of reporting units for soil organic matter content. Some laboratories report the organic matter in relative terms for low, medium, and high. Others report the measured percentage.

The units chosen to report the analytical results do not have any effect on fertilizer guidelines. It is important, however, to be aware of the difference between ppm and lb. per acre when reading the units associated with the numbers on the soil test report.

### The Procedures Used

There are several analytical procedures that can be used to extract plant nutrients from soils. The procedures used in testing soils are not designed to measure the total amount of any nutrient present in the soil. The analytical procedure used to measure a specific nutrient is selected because it extracts the portion of the total amount of that nutrient that is best related to plant growth. The selection of an analytical procedure is not arbitrary. The procedure selected has been developed from considerable research as the one which best predicts the amount of that nutrient in the soil that can be used by plants. The Bray and Kurtz #1 procedure (sometimes referred to as the weakBray procedure) used for measuring phosphorus in acid soils is a good example. Results of considerable research have shown that the amount of phosphorus extracted by this method is the best predictor of the need for phosphate fertilizer for acid soils. Bray and Kurtz also developed an analytical procedure that uses a stronger acid. However, the amount of phosphorus extracted by the stronger acid was not related to crop growth. Therefore, the use of this strong Bray or Bray P-2 procedure has no value for making phosphate fertilizer guidelines in Minnesota.

Analytical procedures used in soil testing are usually standardized. Currently, most soil testing laboratories that operate in the North-Central states use the same analytical procedure when analyzing for a specific nutrient. These laboratories also participate in a quality control program that produces confidence in the analytical results coming from that laboratory.




## Relative Levels

The numbers listed on most soil test reports are usually followed by a letter such as VL, L, M, H, or VH. These letters are abbreviations for very low, low, medium, high, and very high, respectively. These letters designate the relative level of the nutrient measured and provide a good indication of the probability of measuring an economic increase in yield if fertilizer supplying the nutrient in question is applied. For example, if the relative level is classified as being very low, there is a high probability that crop yields will increase if fertilizer supplying the nutrient in question is applied. By contrast, no increase in yield from the application of the nutrient would be expected if the relative level in the soil is in the very high range. The relative proportion of nutrient needed from either soil or fertilizer at the various soil test levels is illustrated in the following figure.

The relative levels of the various immobile nutrients in soils have been defined in terms of concentration (ppm) measured by the appropriate extraction procedures. These definitions, used by the University of Minnesota, South Dakota State University, and North Dakota State University, are listed in the following table.

*Description of each relative level for the phosphorus (P), potassium (K), and zinc (Zn) extracted by the appropriate analytical procedure.*

| | Phosphorus | | | |
|---|---|---|---|---|
| Relative Level | Bray and Mehlich III | Olsen | Potassium | Zinc |
| | - - - - ppm -- - - | | | |
| Very low (VL) | 0-5 | 0-3 | 0-40 | 0-0.25 |
| Low (L) | 6-11 | 4-7 | 41-80 | 0.26-0.50 |
| Medium (M) | 12-15 | 8-11 | 81-120 | 0.51-0.75 |
| High (H) | 16-20 | 12-15 | 121-160 | 0.76-1.00 |
| Very high (VH) | 21+ | 16+ | 161+ | 1.01+ |

The range of values for each relative level shown in the above table is not used by all soil testing laboratories. A soil testing laboratory can use any range of values that it chooses. A difference in the range of values for each relative level is one source of confusion that adds to the difficulty of evaluating results from more than one soil testing laboratory. The ranges in the preceding table are the end result of a considerable amount of research conducted in the field.

It is important to understand that the number associated with any nutrient on a soil test report is an index value to be associated with one of the five relative levels. It is not the amount of a nutrient that is available for crop use. It is not the total amount of a nutrient present in the soil. The number listed is an index value only and when combined with an expected yield can be used to develop a fertilizer guideline.

## Understanding the Lime Guideline

The soil test report also shows the pH of the soil sample and, if acid, provides a guideline for the amount of liming material to be used. When a soil sample is started through the analysis process, it is first mixed with water and stirred; then a pH reading is taken. This reading is the soil pH value. If this value is less than 6.0, the soil is mixed with a special buffer solution and another pH reading is taken. This second reading is known as the buffer pH. This buffer pH value is used to determine the rate of lime that is needed.

## Interesting, But Not Useful

The reports from some soil testing laboratories list the Cation Exchange Capacity (CEC) of a soil. This is a fixed soil property that varies with soil texture and organic matter content. This soil property, however, is not useful for making fertilizer guidelines.

The laboratories that measure CEC also usually report values of exchangeable potassium (K), calcium (Ca), and magnesium (Mg). This is interesting information. But, this information is of little value for making fertilizer guidelines in Minnesota.

## Don't Be Confused

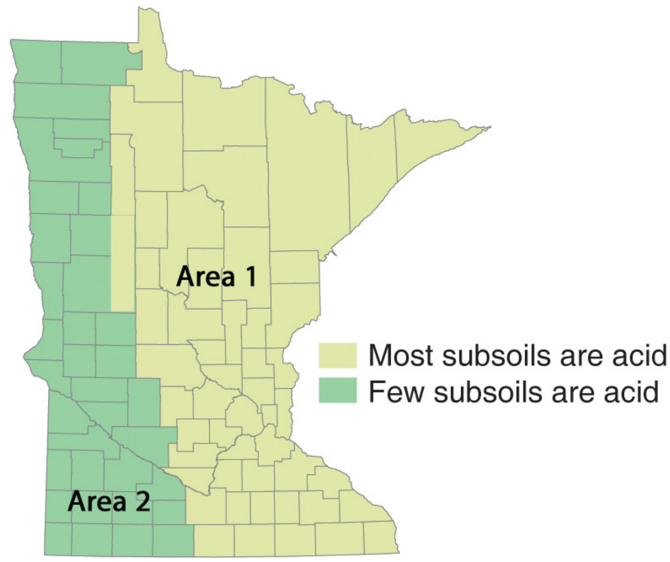
The soil test report contains a substantial amount of information. At first glance, this report can be confusing.  Hopefully, the information presented in the previous paragraphs can help to eliminate some of the confusion.

# ALFALFA

An assessment of the need for lime is usually the first consideration for alfalfa production. When soils are acid (pH less than 7.0), optimum alfalfa yields are usually associated with a soil pH in the range of 6.5 to 7.0. There are no management practices that are economic that will decrease soil pH values in excess of 7.4.   When soil pH values are calcareous (7.4 and higher), the best strategy is to concentrate on appropriate management of fertilizer.

Two pH values may be printed on a soil test report form. Soil pH is determined by suspending soil in water and taking a reading. If the soil pH is less than 6.0, the sample is placed in a buffer solution and a reading is taken. This buffer pH value determines the rate of lime to apply.

*Figure 1. Reference Map for lime guidelines.*




Liming suggestions are listed in Tables 1 and 2. Figure 1 is used to determine location of Area I and Area II. Liming materials that are quarried in Minnesota are analyzed for Effective Neutralizing Power (ENP) and the results are reported as lb. ENP per ton of material.

Suggestions listed on the soil test report forms are given as lb. of ENP per acre. Rate of application (tons per acre) can be calculated from these two pieces of information. Analysis of byproduct liming materials is not required; it is voluntary. Additional information about lime use can be found in FS-5956, *Lime Needs in Minnesota*, and FS-05957, *Liming Materials for Minnesota Soils*.

*Table 1. Lime guidelines for mineral soils when the soil pH is less than 6.0. The rates suggested should raise the pH to 6.5.*

| SMP | Area 1 | | Area 2 | |
|---|---|---|---|---|
| Buffer Index | ENP | Ag Lime * | ENP | Ag Lime * |
| | lb./acre | ton/acre | lb./acre | ton/acre |
| 6.8 | 3000 | 3.0 | 2000 | 2.0 |
| 6.7 | 3500 | 3.5 | 2000 | 2.0 |
| 6.6 | 4000 | 4.0 | 2000 | 2.0 |
| 6.5 | 4500 | 4.5 | 2000 | 2.0 |
| 6.4 | 5000 | 5.0 | 2500 | 2.5 |
| 6.3 | 5500 | 5.5 | 2500 | 2.5 |
| 6.2 | 6000 | 6.0 | 3000 | 3.0 |
| 6.1 | 6500 | 6.5 | 3000 | 3.0 |
| 6.0 | 7000 | 7.0 | 3500 | 3.5 |

** These are approximate guidelines based on the average ENP value of ag lime. An ENP of 1,000 Lb. per ton is an average value for ag lime (crushed limestone) in Minnesota.*

*Table 2. Lime guidelines for mineral soils when the BUFFER TEST IS NOT USED (Soil pH is 6.0 or higher). The rates suggested should raise the pH to 6.5.*

| | Area 1 | | Area 2 | |
|---|---|---|---|---|
| Soil Water PH | ENP | Ag Lime * | ENP | Ag Lime * |
| | lb./acre | ton/acre | lb./acre | ton/acre |
| 6.5 | 0 | 0 | 0 | 0 |
| 6.4 | 2000 | 2.0 | 0 | 0 |
| 6.3 | 2000 | 2.0 | 0 | 0 |
| 6.2 | 3000 | 3.0 | 0 | 0 |
| 6.1 | 3000 | 3.0 | 0 | 0 |
| 6.0 | 3000 | 3.0 | 2000 | 2.0 |

** These are approximate guidelines based on the average ENP value of ag lime. An ENP of 1,000 Lb. per ton is an average value for ag lime (crushed limestone) in Minnesota.*

## Nitrogen

The use of nitrogen (N) is not suggested when alfalfa is seeded in medium or fine-textured soils because a reduction in nodulation might be observed. Small amounts of N fertilizer supplying about 25 lb. N per acre may enhance establishment when alfalfa is seeded in a coarse-textured soil. A small amount of N may be applied when alfalfa is seeded with a nurse or companion crop. This is especially true when soils are sandy. The suggested N rate for this nurse or companion crop situation is 30 lb. per acre.

## Phosphate and Potash

Suggestions for the use of phosphate and potash are adjusted for expected yield and the soil test values for phosphorus (P) and potassium (K). The guidelines for phosphate and potash use are listed in Tables 3 and 4. These fertilizers can be top-dressed to established stands or broadcast and incorporated before planting. See FO-03814, Fertilizing Alfalfa in Minnesota for more detailed information about the management of phosphate and potash fertilizers.

*Table 3. Phosphate fertilizer guidelines for alfalfa production in Minnesota.*

| | Phosphorus (P) Soil Test (ppm) * | | | | | |
|---|---|---|---|---|---|---|
| Expected Yield | Bray:<br>Olsen: | 0-5<br>0-3 | 6-10<br>4-7 | 11-15<br>8-11 | 16-20<br>12-15 | 21+<br>16+ |
| ton/acre | | ----P2O5 to apply (lb./acre)---- | | | | |
| 3 or less | | 45 | 35 | 20 | 10 | 0 |
| 4 | | 65 | 45 | 25 | 10 | 0 |
| 5 | | 80 | 55 | 30 | 15 | 0 |
| 6 | | 95 | 65 | 40 | 15 | 0 |
| 7 | | 110 | 80 | 45 | 20 | 0 |
| more than 7 | | 125 | 90 | 55 | 25 | 0 |

** Use the following equations to calculate phosphate fertilizer guideline for specific expected yields and specific soil test values for P.*

$P_2O_{5rec}$ = [18.57 - (0.93) (Bray p), ppm] (Expected Yield)

$P_2O_{5rec}$ = [18.57 - (1.16) (Olsen P), ppm] (Expected Yield)

*Table 4. Potash fertilizer guidelines for alfalfa production in Minnesota.*

| | Potassium (K) Soil Test (ppm) * | | | | |
|---|---|---|---|---|---|
| Expected Yield | 0-40 | 41 -80 | 81 -120 | 121-160 | 161 + |
| tons/acre | ---- $K_2O$ to apply (lb./acre) ---- | | | | |
| 3 or less | 145 | 100 | 55 | 10 | 0 |
| 4 | 190 | 130 | 70 | 10 | 0 |
| 5 | 240 | 165 | 90 | 15 | 0 |
| 6 | 290 | 195 | 105 | 15 | 0 |
| 7 | 335 | 230 | 125 | 20 | 0 |
| more than 7 | 380 | 265 | 145 | 20 | 0 |

** Use the following equation to calculate potash fertilizer guideline for specific expected yields and specific soil test values for K.*

$K_2O_{rec}$ = [55.7 - (0.38) (K soil test), ppm] (Expected Yield)

## Other Nutrients

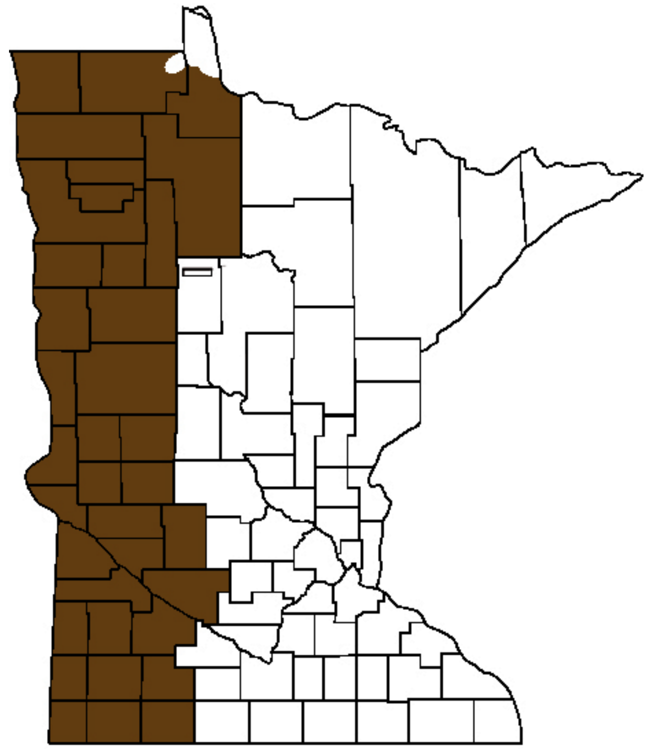
Sulfur (S) and boron (B) are two nutrients that might be needed in a fertilizer program for alfalfa. Use of sulfur will probably increase alfalfa production if soils are sandy. However, use of S on fine-textured soils will probably not increase alfalfa yield unless soil organic matter in the top 6-8 inches is 3.0% or less. The soil test for sulfur is not accurate for fine-textured soils and is not recommended. An annual application of 25 lb. S per acre is suggested for sandy soils while 15-25 lb. S per acre is suggested in fine textured soils when soil organic matter is 3.0% or less.

When needed, boron can be top dressed to established stands (Table 5). Because of the low rates of B needed, the B fertilizer should be blended with phosphate and/or potash fertilizers and broadcast for best results. Soils in Minnesota contain adequate amounts of copper (Cu), manganese (Mn), iron (Fe), and zinc (Zn) for optimum alfalfa production and those four micronutrients should not be needed in a fertilizer program.

*Table 5. Boron fertilizer suggestions for alfalfa in Minnesota.*

| Soil Test for Boron | Boron Suggestions |
|---|---|
| - - - - ppm - - - - | Boron to apply (lb./acre) |
| less than 1.0 | 2-4 |
| 1.1-5.0 | 0 |
| more than 5.0 | 0 |

*Figure 2. The fall soil nitrate test should be used for nitrogen recommendations in the counties that are shaded.*



Nitrogen fertilizer guidelines can be based on the results of the soil $NO_3^-$-N test or the consideration of expected yield, previous crop, and soil organic matter content. The soil $NO_3^-$-N test is suggested for use in shaded areas of western Minnesota (see accompanying map).

# BARLEY

## Nitrogen

In Minnesota, barley is either grown for malting or as a feed grain. This intended use affects the guidelines for nitrogen (N) use. Barley can replace corn in a livestock ration. It is a good alternative for corn where soils are droughty and corn yields are frequently limited by moisture stress.

Guidelines for fertilizer N are calculated as follows:

Malting Barley

$N_{rec} = (1.5)\ (EY) - STN_{(0\text{-}24\ in.)} - N_{Pc}$

Feed Grain Barley

$N_{rec} = (1.7)\ (EY) - STN_{(0\text{-}24\ in.)} - N_{Pc}$

Where:

EY = expected yield (bu./acre)

STN = nitrate-nitrogen ($NO_3^-$-N) measured to a depth of 24 in. (lb./acre)

$N_{pc}$ = amount of N supplied by the previous legume crop (lb./acre).

These N credits are summarized in Table 6.

*Table 6. Nitrogen credits for various legume crops that might precede barley in a crop rotation. Use these credits for the "Npc" factor in situations where the soil nitrate test is used.*

| Previous Crop | 1st Year Nitrogen Credit |
|---|---|
| | lb. N/acre |
| Soybean | 20 |
| Edible beans, field peas | 10 |
| Harvested sweetclover | 10 |
| Harvested alfalfa* | |
| 4 to 5 plants/ft$^2$ | 75 |
| 2 to 3 plants/ft$^2$ | 50 |
| 1 or fewer plants/ft$^2$ | 0 |
| Harvested red clover | 35 |

** Add 20 lb. N/acre to the credits listed if the 3rd or 4th cutting was not harvested.*

Use Table 7 if the soil $NO_3^-$-N test is not used. The suggestions in this table are based on a realistic expected yield, previous crop, and soil organic matter content. When using guidelines in this table, there is no distinction between malting barley and feed barley.

The N supplied by legume crops in a rotation with barley can be utilized by barley grown for the first and second year after the legume.

The nitrogen credits for a legume crop grown two years preceding the barley are listed in Table 8. These credits are suggested when the soil $NO_3^-$-N test is not used. Subtract these credits from the N recommendations listed for the crop sequence when barley is grown after crops in Group 2.

Crops in Group 1:
Alsike clover, birdsfoot trefoil, grass/legume hay, grass legume pasture, fallow, red clover.

Crops in Group 2:
Barley, buckwheat, canola, corn, grass hay, grass pasture, oat, potato, rye, sorghum-sudan, sugar beet, sunflower, sweet corn, triticale, wheat.

*Table 8. Nitrogen credits when barley is grown two years after a legume and last year's crop was not a legume.*

| Previous Legume Crop | Nitrogen Credit for 2nd Year After A Legume |
|---|---|
| | lb. N/acre |
| Alfalfa (4 + plants/ft$^2$) non-harvested sweetclover | 35 |
| Alfalfa (2 - plants/ft$^2$) | 25 |
| Alsike clover, birdsfoot trefoil, red clover | 20 |

## Phosphate and Potash

Guidelines for phosphate and potash fertilizer use are listed in Tables 9 and 10, respectively. For more details on the application of these fertilizers, see FO-03773, *Fertilizing Barley in Minnesota*. In general, lower rates of phosphate and potash can be used if placed in a band near the

*Table 7. Nitrogen guidelines for barley for situations when the soil nitrate test is not used.*

| | | Expected Yield (bu./acre) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Crop Grown Last Year | Organic Matter Level* | 50 or less | 50-59 | 60-69 | 70-79 | 80-89 | 90-99 | 100+ |
| Afalfa (4+ plants/ft$^2$) | Low | 0 | 0 | 10 | 25 | 40 | 55 | 70 |
| | Med and high | 0 | 0 | 0 | 0 | 20 | 35 | 50 |
| Afalfa (2-3 plants/ft$^2$) | Low | 0 | 0 | 15 | 30 | 45 | 60 | 75 |
| | Med and high | 0 | 0 | 0 | 10 | 25 | 40 | 55 |
| Soybeans | Low | 30 | 50 | 65 | 80 | 95 | 110 | 125 |
| Afalfa (1 or less plants/ft$^2$) | Med and high | 0 | 30 | 45 | 60 | 75 | 90 | 105 |
| Edible beans, field peas, | Low | 40 | 60 | 75 | 90 | 105 | 120 | 135 |
| | Med and high | 0 | 40 | 55 | 70 | 85 | 100 | 115 |
| Group 1 Crops | Low | 0 | 20 | 35 | 50 | 65 | 80 | 95 |
| | Med and high | 0 | 0 | 15 | 30 | 45 | 60 | 75 |
| Group 2 Crops | Low | 50 | 70 | 85 | 100 | 115 | 130 | 145 |
| | Med and high | 30 | 50 | 65 | 80 | 95 | 110 | 125 |
| Organic Soils | | 0 | 0 | 0 | 0 | 30 | 40 | 50 |

** low = less than 3.0%; medium and high = 3.0% or more*

seed. Compared to a broadcast application, rates can be reduced by 1/2 if a banded application is used.

## Other Nutrients

The use of sulfur (S) and copper (Cu) may be important for optimum barley production in limited situations. If barley is grown on sandy soils, either broadcast 25 lb. S/acre or use 10-12 lb. S/acre with the drill at planting. Sulfur will not be needed for barley grown on fine-textured soils.

The Cu suggestions are summarized in Table 11. Copper will not be needed in a fertilizer program when barley is grown on mineral soils. In Minnesota, barley has not responded to the use of zinc (Zn), iron (Fe), manganese (Mn) and boron (B) in a fertilizer program.

*Table 11. Copper suggestions for barley grown on organic (peat) soils.*

| Copper Soil Test | Broadcast | Foliar Spray |
|---|---|---|
| ppm | - - - - copper to apply (lb./acre) - - - - | |
| 0 - 2.5 (low) | 6-12 | 0.3 |
| 2.6 - 5.0 (marginal)* | 6 | 0.3 |
| 5.1 + (adequate) | 0 | 0 |

**Suggestions for marginal soil tests are based on limited trial data*

*Table 9. Phosphate fertilizer Guidelines for barley production.*

| | Phosphorus (P) Soil Test, ppm* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Expected | Bray: | 0-5 | | 6-10 | | 11-15 | | 16-20 | | 21+ |
| Yield | Olsen: | 0-3 | | 4-7 | | 8-11 | | 12-15 | | 16+ |
| | | Drill | Bdcst | Drill | Bdcst | Drill | Bdcst | Drill | Bdcst | |
| bu./acre | | - - - - $P_2O_5$ to apply (lb./acre) - - - - | | | | | | | | |
| less than 50 | | 20 | 35 | 15 | 25 | 10 | 15 | 10-15 | 0 | 0 |
| 50-59 | | 20 | 40 | 15 | 25 | 10 | 15 | 10-15 | 0 | 0 |
| 60-69 | | 25 | 45 | 15 | 30 | 15 | 20 | 10-15 | 0 | 0 |
| 70-79 | | 25 | 50 | 20 | 35 | 15 | 20 | 10-15 | 0 | 0 |
| 80-89 | | 30 | 60 | 20 | 40 | 15 | 25 | 10-15 | 0 | 0 |
| 90-99 | | 35 | 65 | 25 | 45 | 15 | 25 | 10-15 | 0 | 0 |
| 100 + | | 35 | 70 | 25 | 50 | 20 | 0 | 10-15 | 0 | 0 |

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

$P_2O_{5\ rec}$ = [0.785 – (0.039) (Bray P, ppm)] (Expected Yield)

$P_2O_{5\ rec}$ = [0.785 – (0.050) (Olsen P, ppm)] (Expected Yield)

*Table 10. Potash fertilizer quidelines for barley production.*

| | Potassium (K) Soil Test, ppm* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Expected | 0-40 | | 40-80 | | 80-120 | | 120-160 | | 160+ |
| Yield | Drill | Bdcst | Drill | Bdcst | Drill | Bdcst | Drill | Bdcst | |
| bu./acre | - - - - $K_2O$ to apply (lb./acre) - - - - | | | | | | | | |
| less than 50 | 25 | 50 | 20 | 40 | 15 | 20 | 10-15 | 0 | 0 |
| 50-59 | 30 | 60 | 25 | 45 | 15 | 25 | 10-15 | 0 | 0 |
| 60-69 | 35 | 70 | 25 | 50 | 20 | 30 | 10-15 | 0 | 0 |
| 70-79 | 40 | 85 | 30 | 60 | 25 | 35 | 10-15 | 0 | 0 |
| 80-89 | 50 | 95 | 35 | 65 | 25 | 40 | 10-15 | 0 | 0 |
| 90-99 | 55 | 105 | 40 | 75 | 30 | 45 | 10-15 | 0 | 0 |
| 100 + | 55 | 110 | 40 | 80 | 35 | 50 | 10-15 | 0 | 0 |

** Use the following equation for a potash guideline for a specific expected yield.*

$K_2O_{\ rec}$ = [1.286 – (0.0085) (K Soil Test)] (Expected Yield)

# BUCKWHEAT

## Nitrogen

Nitrogen (N) fertilization is an important management practice for optimum production of buckwheat. Nitrogen fertilizer guidelines can be based either on the results of the soil $NO_3^-$-N test or the consideration of the combination of expected yield, previous crop, and soil organic matter content. The soil $NO_3^-$-N test is appropriate for western Minnesota (see Figure 2). When the soil $NO_3^-$-N test is used, the fertilizer N guidelines are calculated as follows:

$$N_{rec} = (0.0458)\ (EY) - STN_{(0\text{-}24\ in.)} - N_{Pc}$$

Where:

EY = expected yield (lb./acre)

STN = nitrate-nitrogen ($NO_3^-$-N) measured to a depth of 24 in. (lb./acre)

$N_{pc}$ = amount of N supplied by the previous legume crop (lb./acre).

These N credits are summarized in Table 6.

The N fertilizer guidelines for production situations where the soil $NO_3^-$-N test is not used are listed in Table 12.

For most production situations, the N fertilizers should be broadcast and incorporated before planting. The N fertilizer can be applied in either dry or liquid form. There is no research to document that one form is superior to the other.

*Table 12. Nitrogen guidelines for buckwheat in situations when the soil NO3--N test is not used.*

| | | Expected Yield (lb./acre) | | | |
|---|---|---|---|---|---|
| Crop Grown Last Year | Organic Matter Level* | 1200-1450 | 1451-1700 | 1701-1950 | 1951-2200 |
| Alfalfa (4+ plants/ft$^2$) | Low | 0 | 0 | 0 | 0 |
| | Med and high | 0 | 0 | 0 | 0 |
| Soybeans | Low | 0 | 10 | 20 | 30 |
| Alfalfa (1 or less plants/ft$^2$) | Med and high | 0 | 0 | 0 | 0 |
| Edible beans, field peas, | Low | 20 | 30 | 40 | 50 |
| | Med and high | 0 | 10 | 20 | 30 |
| Group 1 Crops | Low | 0 | 0 | 0 | 0 |
| | Med and high | 0 | 0 | 0 | 0 |
| Group 2 Crops | Low | 40 | 50 | 60 | 70 |
| | Med and high | 20 | 30 | 40 | 50 |

** low = less than 3.0%; medium and high = 3.0% or more*

*Table 13. Phosphate fertilizer guidelines for buckwheat production.*

| | | Phosphorus (P) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|---|
| Expected | Bray: | 0-5 | 6-10 | 11-15 | 16-20 | 21 + |
| Yield | Olsen: | 0-3 | 4-7 | 8-11 | 12-15 | 16 + |
| lb/acre | | - - - - $P_2O_5$ to apply (lb./acre) - - - - | | | | |
| 1200- 1450 | | 35 | 20 | 15 | 0 | 0 |
| 1451 - 1700 | | 40 | 25 | 15 | 0 | 0 |
| 1701-1950 | | 45 | 30 | 20 | 0 | 0 |
| 1951 -2200 | | 50 | 35 | 20 | 0 | 0 |

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

$P_2O_{5rec}$ = [0.0275 – (0.0014) (Bray P, ppm)] (Expected Yield)

$P_2O_{5rec}$ = [0.0275 – (0.0017) (Olsen P, ppm)] (Expected Yield)

Therefore, all sources of N are equal if properly applied.

Crops in Group 1:
Alsike clover, birdsfoot trefoil, grass/legume hay, grass legume pasture, fallow, red clover.

Crops in Group 2:
Barley, buckwheat, canola, corn, grass hay, grass pasture, oat, potato, rye, sorghum-sudan, sugar beet, sunflower, sweet corn, triticale, wheat.

### Phosphate and Potash

The guidelines for the use of phosphate and potash are summarized in Tables 13 and 14.

These fertilizers, when needed, should be broadcast and incorporated before planting. Special sources of phosphate and potash are not needed for buckwheat production. All commonly sold sources for each nutrient are equal.

There is no research which suggests that nutrients other than N, P, and K are needed in a fertilizer program for buckwheat production in Minnesota. **CAUTION! Do not apply any fertilizer in contact with buckwheat seed at planting.**

*Table 14. Potash fertilizer guidelines for buckwheat production.*

| Expected | Potassium (K) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|
| Yield | 0-40 | 40-80 | 80-120 | 120-160 | 160 + |
| lb/acre | - - - - $K_2O$ to apply (lb./acre) - - - - | | | | |
| 1200-1450 | 45 | 35 | 20 | 0 | 0 |
| 1451-1700 | 55 | 40 | 25 | 0 | 0 |
| 1701-1950 | 60 | 45 | 25 | 10 | 0 |
| 1951-2200 | 70 | 50 | 30 | 10 | 0 |

** Use the following equation if a potash guideline for a specific expected yield.*

$K_2O_{rec}$ = [0.0358 – (0.023) (Soil Test K, ppm)] (Expected Yield)

## CANOLA

In recent years, the canola crop has become an important part of the crop rotations in northern Minnesota. Yields have increased as improved management practices are adopted by growers. Improved fertilizer management is one major contributor to improved yields. The guidelines for improved canola production are described in the sections that follow.

### Nitrogen

Nitrogen (N) fertilizer guidelines can be based either on the results of the soil $NO_3^-$-N test or the consideration of expected yield, previous crop, and soil organic matter content. The soil $NO_3^-$-N test is appropriate for western Minnesota (see Figure 2). When the soil $NO_3^-$-N test is used, the N guidelines can be derived from the following equation:

$$N_{rec} = (6.5)\,(EY) - STN_{(0\text{-}24\ in.)} - N_{Pc}$$

Where:
EY = expected yield (cwt./acre)
STN = nitrate-nitrogen ($NO_3^-$-N) measured to a depth of 24 in. (lb./acre)
$N_{pc}$ = amount of N supplied by the previous legume crop (lb./acre).
These N credits are summarized in Table 6.

The fertilizer guidelines for situations where the soil test is not used are listed in Table 15.

Crops in Group 1:
Alsike clover, birdsfoot trefoil, grass/legume hay, grass legume pasture, fallow, red clover.

Crops in Group 2:
Barley, buckwheat, canola, corn, grass hay, grass pasture, oat, potato, rye, sorghum-sudan, sugar beet, sunflower, sweet corn, triticale, wheat.

### Phosphate and Potash

The guidelines for the use of phosphate fertilizer are summarized in Table 16. The suggestions for

*Table 15. Nitrogen guidelines for canola in situations when the soil $NO_3^-$-N test is not used.*

| | | Expected Yield (cwt./acre) | | | |
|---|---|---|---|---|---|
| Crop Grown Last Year | Organic Matter Level* | 10-15 | 16-20 | 21-25 | 25 + |
| Alfalfa (4+ plants/ft$^2$) | Low<br>Med and high | 0<br>0 | 0<br>0 | 0<br>0 | 0<br>0 |
| Alfalfa (2-3 plants/ft$^2$) | Low<br>Med and high | 0<br>0 | 0<br>0 | 0<br>0 | 0<br>0 |
| Soybeans<br>Alfalfa (1 or less plants/ft$^2$) | Low<br>Med and high | 0<br>0 | 10<br>0 | 20<br>0 | 30<br>0 |
| Group 1 Crops | Low<br>Med and high | 0<br>0 | 0<br>0 | 0<br>0 | 0<br>0 |
| Group 2 Crops | Low<br>Med and high | 40<br>20 | 50<br>30 | 60<br>40 | 70<br>50 |

** low = less than 3.0%; medium and high = 3.0% or more*

potash use are in Table 17. The listed rates are suggested for a broadcast application.

*Table 16. Phosphate fertilizer guidelines for canola production.*

| | | Phosphorus (P) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|---|
| Expected | Bray: | 0-5 | 6-10 | 11-15 | 16-20 | 21 + |
| Yield | Olsen: | 0-3 | 4-7 | 8-11 | 12-15 | 16 + |
| cwt/acre | | - - - - $P_2O_5$ to apply (lb./acre) - - - - | | | | |
| 10-15 | | 40 | 25 | 15 | 0 | 0 |
| 16-20 | | 55 | 40 | 25 | 0 | 0 |
| 21-25 | | 75 | 50 | 30 | 10 | 0 |
| 25 + | | 80 | 55 | 35 | 10 | 0 |

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

$P_2O_{5\ rec}$ = [3.60 – (0.17) (Bray P, ppm)] (Expected Yield)

$P_2O_{5\ rec}$ = [3.60 – (0.22) (Olsen P, ppm)] (Expected Yield)

*Table 17. Potash fertilizer guideline for canola production.*

| Expected | Potassium (K) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|
| Yield | 0-40 | 40-80 | 80-120 | 120-160 | 160 + |
| cwt/acre | - - - - $K_2O$ to apply (lb./acre) - - - - | | | | |
| 10-15 | 60 | 40 | 25 | 0 | 0 |
| 16-20 | 85 | 60 | 35 | 10 | 0 |
| 21-25 | 110 | 80 | 45 | 15 | 0 |
| 25 + | 115 | 85 | 50 | 15 | 0 |

** Use the following equation if a potash guideline for a specific soil test and a specific expected yield is desired.*

$K_2O_{\ rec}$ = [5.4 – (0.034) (Soil Test K, ppm)] (Expected Yield)

### Sulfur

The canola crop is very responsive to sulfur fertilization. When this crop is grown on heavy textured soils, a rate of 10 to 15 lb. of sulfur per acre is suggested. The suggested rate increases to 20 to 30 lb. of sulfur per acre when this crop is grown on sandy soils. Broadcast applications are appropriate for this crop.

### Other Nutrients

There is no research data to suggest that other nutrients are needed in a fertilizer program for canola production. Therefore, none are recommended. **CAUTION! Do not apply fertilizer in contact with the seed at planting.**

## Corn

In Minnesota, corn is grown on more acres than any other crop. Nationally, Minnesota ranks among the top five in 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

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.

With the volatility in energy costs, fertilizer N cost has risen dramatically. This increase does affect the economic optimum N rate. To account for this change, the ratio of the price of N per lb. 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 $0.30 per lb N or $492 per ton of anhydrous ammonia, and corn is valued at $2.00 per bushel, the ratio would be 0.30/2.00 = 0.15.

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 greatest, may want to use the N rates near the high end of the acceptable range shown in Table 18. On the other hand, if water quality concerns are an issue 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 18 if they are willing to accept the possibility of less-than- maximum yield in some years without sacrificing profit. This acceptable range gives each producer flexibility in arriving at an acceptable and profitable N rate. The maximum return to N value (MRTN) shown in Table 18 is the N rate that maximizes profit to the producer based on the large number of experiments supporting these guidelines.

The N rate guidelines in Table 18 are used if corn is grown in rotation with soybean or following corn under high productivity conditions and guidelines in Table 19 are used under medium productivity conditions. Corn grown on sandy soils deserves special consideration. If irrigated, the guidelines listed in Table 18 are appropriate. For non-irrigated corn grown on sandy soils (loamy fine sands, sandy loams, loams) with more than 3% organic matter, use the guidelines given in Table 19. 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 20.

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 21. In Table 21, several crops are divided into Group 1 and Group 2.

*Table 18. Guidelines for use of nitrogen fertilizer for corn grown on soils considered to be highly productive.*

| N Price/ Crop | Corn/Corn | | Corn/Soybeans | |
|---|---|---|---|---|
| Value Ratio | MRTN | Acceptable Range | MRTN | Acceptable Range |
| | - - - - lb N/acre - - - - | | | |
| 0.05 | 155 | 130 to 180 | 120 | 100 to 140 |
| 0.10 | 140 | 120 to 165 | 110 | 90 to 125 |
| 0.15 | 130 | 110 to 150 | 100 | 80 to 115 |
| 0.20 | 120 | 100 to 140 | 85 | 70 to 100 |

*MRTN = maximum return to nitrogen*

*Table 19. Guidelines for use of nitrogen fertilizer for corn grown on soils considered to have medium productivity potential.*

| N Price/Crop Value Ratio | Corn/Corn | Corn/Soybeans |
|---|---|---|
| | - - - - lb N/acre - - - - | |
| 0.05 | 130 | 100 |
| 0.10 | 120 | 90 |
| 0.15 | 110 | 80 |
| 0.25 | 100 | 70 |

*Table 20. Suggested 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/Soybeans |
|---|---|---|
| | - - - - lb N/acre - - - - | |
| 0.05 | 100 | 70 |
| 0.10 | 90 | 60 |
| 0.15 | 80 | 50 |
| 0.25 | 70 | 40 |

It's 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. These second year N credits are listed in Table 22. If corn is grown in the second year following alfalfa and red clover, these N credits should be subtracted from the N rates that would be used when corn follows the crops listed in Group 2.

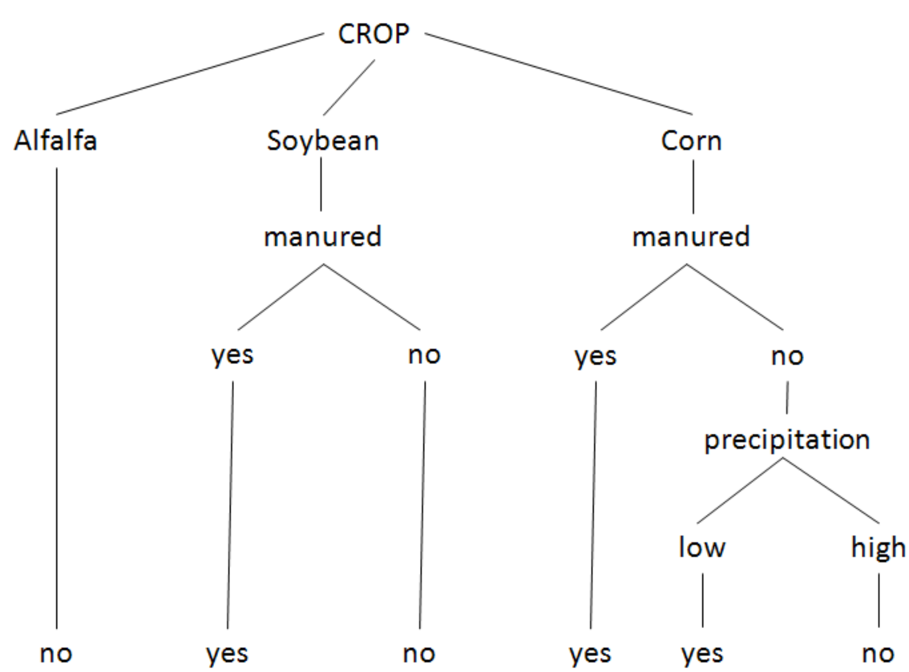
*Table 21. Nitrogen credits for different previous crops for the first year of corn.*

| Previous Crop | 1st Year Nitrogen Credit |
|---|---|
| | lb. N/acre |
| Small Grains* | 40 |
| Harvested alfalfa: | |
| 4 or more plants/$ft^2$ | 150 |
| 2 to 3 plants/$ft^2$ | 100 |
| 1 or fewer plants/$ft^2$ | 40 |
| Group 1 Crops | 75 |
| Group 2 Crops | 0 |
| Edible beans | 20 |
| Field peas | 20 |

**Use this credit if any small grain stubble in southeastern Minnesota counties was tilled after harvest; if there was no tillage, use guidelines for crops in group 2. Use guidelines for crops in group 2 if corn follows small grain in the remainder of the state.*

Crops in Group 1:
Alsike clover, birdsfoot trefoil, grass/legume hay, grass legume pasture, fallow, red clover.

*Figure 3. Flow chart decision-aid for determining the probability of having significant residual NO3--N in the soil.*



Crops in Group 2:
Barley, buckwheat, canola, corn, grass hay, grass pasture, oat, potato, rye, sorghum-sudan, sugar beet, sunflower, sweet corn, triticale, wheat.

*Table 22. Nitrogen credits for some forage legumes if corn is planted two years after the legume.*

| Legume Crop | 2nd Year Nitrogen Credit |
|---|---|
| | lb. N/acre |
| Harvested alfalfa: | |
| 4 or more plants/ft$^2$ | 75 |
| 2 to 3 plants/ft$^2$ | 50 |
| 1 or fewer plants/ft$^2$ | 0 |
| Red clover | 35 |

## Use of the Soil $NO_3^-$-N test encouraged.

### Western Minnesota

The use of the soil $NO_3^-$-N 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 2. The $NO_3^-$-N soil test is particularly useful for conditions where elevated residual nitrate-N is suspected. Figure 3 is a decision tree that indicates situations where the nitrate-N soil test would be especially useful.

For this test, soil should be collected from a depth of 6-24 inches in addition to the 0-6 inch sample. The corn grower in western Minnesota also has the option of collecting soil from 0-24 inches and analyzing the sample for $NO_3^-$-N.

When using the soil $NO_3^-$-N test, the amount of fertilizer N required is determined from the following equation:

NG = (Table 18 value for corn/corn) - (0.60 * STN(0-24 in.))

NG = Amount of fertilizer N needed, lb./acre
Table 18 value = the amount of fertilizer needed, adjusted for soil potential, value ratio, and risk.
STN(0-24) = Amount of $NO_3^-$-N measured by using the soil $NO_3^-$-N test, lb/acre.

### South-central, southeastern, east-central Minnesota

Research has led to the inclusion of a soil $NO_3^-$-N test to adjust fertilizer N guidelines in south-central, southeastern, and east-central Minnesota (non-shaded areas of Figure 2). This test, in which soil $NO_3^-$-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 $NO_3^-$-N test on coarse-textured soils derived from glacial outwash is generally not worthwhile because these soils consistently have low amounts of residual $NO_3^-$-N.

The amount of residual $NO_3^-$-N in the soil is also dependent on the rainfall received the previous year. In a year following a widespread drought, 1989 for example, a majority of fields will have significant residual $NO_3^-$-N. However, following relatively wet years, such as the early 1990s, little residual $NO_3^-$-N can be expected.

This soil $NO_3^-$-N testing option, which estimates residual $NO_3^-$-N, will not be appropriate for all conditions. Figure 3 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 $NO_3^-$-N test. The University of Minnesota's N guidelines (Table 18) are still the starting point. A five-step process is suggested when the soil $NO_3^-$-N test is considered.

1. Determine N rate guideline using Table 18 using soil productivity, price/value ratio, and previous crop for the specific field. The prescribed rate assumes that best management practices 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 $NO_3^-$-N is small and soil testing for $NO_3^-$-N is not recommended, use the N guideline derived in Step 1.
3. If conditions suggest that a soil $NO_3^-$-N test is warranted, collect a preplant, 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 $NO_3^-$-N.
4. Determine residual N credit based on the measured soil $NO_3^-$-N concentrations. Use Table 23 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 preplant and/or as a sidedress application.

This soil $NO_3^-$-N test SHOULD NOT be used when commercial fertilizer was applied in the previous fall. The variability in the degree of N conversion to $NO_3^-$-N before spring makes this test meaningless in these situations.

For more information on this soil N test option, see Extension Bulletin FO-6514, *A Soil Nitrogen Test Option for N Recommendation with Corn*.

*Table 23. Residual N credit values based on the concentration of $NO_3^-$-N measured before planting in the spring from the top two feet of soil.*

| Soil $NO_3^-$-N | Residual N credit |
|---|---|
| - - - - ppm - - - - | - - - - lb N/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 |

## 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 best management practices (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 best management practices is voluntary. Corn growers should implement BMPs to optimize N use efficiency, profit, and protect against increased losses of $NO_3^-$-N 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 Suggestions

When needed, the use of phosphate and/or potash fertilizer can produce profitable increases in corn yields. The suggestions for phosphate fertilizer use are summarized in Table 24. The suggestions for potash fertilizer use are listed in Table 25.

## Rate Changes with Placement

The phosphate suggestions provided in Table 24 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 higher. There are some situations where the results of the Bray test are higher than the results of the Olsen test when soil pH values are higher than 7.4. For these cases, the amount of phosphate recommended 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 recommended in Minnesota. However, some soil testing laboratories analyze P with this analytical test. For these situations, use the recommendations appropriate for the results of the Bray procedure. The definition of categories is the same for both the Bray and Mehlich III analytical procedures.

As with phosphate, the suggested rates of potash vary with the soil test for potassium (K), expected yield, and placement (Table 25). A com-

*Table 24. Phosphate suggestions for corn production in Minnesota.**

| | | Soil test P (ppm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | v. low | | low | | medium | | high | | v. high | |
| Expected Yield | Bray: | 0-5 | | 6-10 | | 11-15 | | 16-20 | | 21+ | |
| | Olsen: | 0-3 | | 4-7 | | 8-11 | | 12-15 | | 16+ | |
| | | Bdcst | Band | Bdcst | Band | Bdcst | Band | Bdcst | Band | Bdcst | Band |
| bu/acre | | - - - - $P_2O_5$ /acre to apply (lb/acre) - - - - | | | | | | | | | |
| < 100 | | 60 | 30 | 40 | 20 | 25 | 20 | 10 | 10-15 | 0 | 10-15 |
| 100–125 | | 75 | 40 | 50 | 25 | 30 | 20 | 10 | 10-15 | 0 | 10-15 |
| 125–150 | | 85 | 45 | 60 | 30 | 35 | 25 | 10 | 10-15 | 0 | 10-15 |
| 150–175 | | 100 | 50 | 70 | 35 | 40 | 30 | 15 | 10-15 | 0 | 10-15 |
| 175–200 | | 110 | 55 | 75 | 40 | 45 | 30 | 15 | 10-15 | 0 | 10-15 |
| 200–225 | | 130 | 65 | 90 | 45 | 55 | 30 | 20 | 10-15 | 0 | 10-15 |
| 225– 250 | | 145 | 75 | 100 | 50 | 60 | 30 | 20 | 10-15 | 0 | 10-15 |
| 250 + | | 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.*

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

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

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

*Table 25. Potash suggestions for corn production in Minnesota.**

| | Soil test K (ppm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | v. low | | low | | medium | | high | | v. high | |
| Expected Yield | 0-40 | | 41-80 | | 81-120 | | 121-160 | | 160+ | |
| | Bdcst | Band | Bdcst | Band | Bdcst | Band | Bdcst | Band | Bdcst | Band |
| bu/acre | - - - - $K_2O$/acre to apply (lb/acre)- - - - | | | | | | | | | |
| < 100 | 100 | 50 | 75 | 40 | 45 | 30 | 15 | 10-15 | 0 | 10-15 |
| 100–124 | 120 | 60 | 90 | 45 | 50 | 30 | 20 | 10-15 | 0 | 10-15 |
| 125–149 | 145 | 75 | 105 | 55 | 60 | 40 | 20 | 10-15 | 0 | 10-15 |
| 150–174 | 165 | 85 | 120 | 60 | 70 | 40 | 25 | 10-15 | 0 | 10-15 |
| 175-199 | 185 | 90 | 135 | 70 | 80 | 50 | 25 | 10-15 | 0 | 10-15 |
| 200-220 | 210 | 105 | 155 | 80 | 90 | 55 | 30 | 10-15 | 0 | 10-15 |
| 220-240 | 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 the following equation if a $K_2O$ guideline for a specific soil test value and a specific expected yield is desired.*

$K_2O_{rec}$ = [1.166 - 0.0073 (Soil Test K, ppm)] (expected yield)

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

bination 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.

## 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 24 and 25 cannot be rigid across the entire state. There are some special situations where rates might be changed. See University of Minnesota Extension folder FO-03790, *Fertilizing Corn in Minnesota*, for a description of this situation. 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 decline, 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.

The rate of fertilizer that can be applied in a band below and to the side of the seed at planting varies with the nutrient used, the distance between seed and fertilizer, and soil texture. See Use of Banded Fertilizer for Corn Production (FO-74250) for more information.

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

## Sulfur Use

The addition of sulfur (S) to a fertilizer program should be a major consideration when corn is grown on sandy soils, reduced tillage systems, or in a long term continuous corn rotation.

The use of a soil test for sulfur is not a reliable predictor of the need for sulfur in a fertilizer program. Soil texture is a reliable predictor. If the soil texture is a loamy sand or sandy loam, either apply 12 to 15 lb S per acre in a banded fertilizer or broadcast and incorporate 25 lb S per acre before planting. Keep in mind that ammonium thiosulfate should not be placed in contact with the seed. This material will not harm germination or emergence if there is 1 inch of soil between seed and fertilizer.  No sulfur is suggested on fine textured soils unless organic matter content in the top 6-8 inches is less than 3.0% or fields with long term continuous corn with high amounts of residue.  In this case 10-15 lb. S per acre should be broadcast before planting.

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. Because the greatest need for S occurs early in the growing season, application of any needed S in a starter fertilizer is preferred.

## Magnesium Needs

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. 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 26.

## Micronutrient Needs

Research trials conducted throughout Minnesota indicate that zinc (Zn) is the only micronutrient that may be needed in a fertilizer program for the corn crop. This nutrient, however, is not needed on 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 27.

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

*Table 26. Suggestions for magnesium use for corn production.*

| Magnesium soil test | Relative level | Mg to apply | |
|---|---|---|---|
| | | Broadcast | Band |
| ppm | | - - - - lb/acre - - - - | |
| 0–50 | Low | 50-100 | 10-20 |
| 51–100 | Medium | 0 | Trial * |
| 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.*

*Table 27. Zinc suggestions for corn production in Minnesota.*

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

** Zinc extracted by the DTPA procedure.*

# DRY EDIBLE BEAN

This crop is important in the rotations for farm enterprises in Central, West-Central, and Northwest Minnesota. Fertilizer suggestions are adjusted for growing situations. The suggestions that are appropriate for non-irrigated fine-textured soils may not be appropriate for irrigated sandy soils. The same reasoning applies for the opposite situation. Fertilizer guidelines for Minnesota are summarized in the paragraphs and tables that follow.

## Nitrogen

Optimum yields of this crop depend on efficient use of nitrogen (N) fertilizers. Guidelines for N use can be based on the results of a soil $NO_3^-$-N test or the consideration of the combination of expected yield, previous crop, and soil organic matter content. The soil $NO_3^-$-N test is appropriate for use in Western Minnesota (See Figure 2). The soil $NO_3^-$-N is not recommended for sandy soils even though these soils may be in Western Minnesota.

$$N_{rec} = (0.05)\ (EY) - STN_{(0\text{-}24\ in.)} - N_{Pc}$$

Where:

EY = expected yield (lb./acre)

STN = nitrate-nitrogen ($NO_3^-$-N) measured to a depth of 24 in. (lb./acre)

$N_{pc}$ = amount of N supplied by the previous legume crop (lb./acre).

These N credits are summarized in Table 28.

*Table 28. Nitrogen credits for various legume crops that might precede the edible bean crop in the rotation. Use these credits when the soil nitrate test is used.*

| Legume Crop | 1st Year Nitrogen Credit |
|---|---|
| | lb. N/acre |
| Harvested alfalfa: | |
| 4 or more plants/ft$^2$ | 70 |
| 2 to 3 plants/ft$^2$ | 50 |
| 1 or fewer plants/ft$^2$ | 20 |
| Red clover | 35 |

The N fertilizer guidelines for situations where the soil $NO_3^-$-N test is not used are summarized in Table 29. These suggestions are appropriate for edible bean production on fine-textured soils. When grown on sandy soils under irrigation, a standard guideline of 120 lb. N per acre is used. If, on sandy soils, the edible beans follow alfalfa, a N credit of 70 lb. N per acre for the alfalfa crop is suggested.

Because of the high potential for diseases, if edible bean should follow soybeans, edible bean, peas, and other crops of edible bean, these crops are not considered as previous crops in the rotation.

Timing of the nitrogen application is an important consideration for edible bean production. In order to keep damage from white mold to a minimum, it's important to keep the canopy open as much as possible. The canopy may be closed at flowering if all of the N fertilizer is applied before planting. Therefore, split applications of fertilizer N are suggested. This is especially true for sandy soils. Research results show that delayed applications of fertilizer N do not reduce yields. Therefore, two applications of fertilizer N are suggested. The first application can be made approximately two weeks after planting. The second application can be made as late as is practical for field equipment. The second application should be timed so that this equipment does not damage the crop.

## Phosphate and Potash

Current phosphate guidelines are summarized in Table 30. The guideline for potash use is in Table 31. The guidelines in these tables are for both broadcast and banded applications. There is no research to suggest that one placement is more efficient than the other. Recent research suggests that these immobile nutrients, when applied in a band near the seed at planting, produce a substantial increase in yield. Banded applications are an excellent option when suggested rates are low.

*Table 30. Phosphate fertilizer guidelines for edible bean production.*

| | | Phosphorus (P) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|---|
| Expected | Bray: | 0-5 | 6-10 | 11-15 | 16-20 | 21 + |
| Yield | Olsen: | 0-3 | 4-7 | 8-11 | 12-15 | 16 + |
| lb/acre | | - - - - $P_2O_5$ to apply (lb./acre) - - - - | | | | |
| 1400-1900 | | 35 | 25 | 15 | 0 | 0 |
| 1901-2400 | | 45 | 30 | 20 | 10 | 0 |
| 2401-2900 | | 55 | 40 | 25 | 10 | 0 |
| 2901 + | | 60 | 45 | 25 | 10 | 0 |

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

$P_2O_{5\ rec}$ = [0.0231 – (0.0011) (Bray P, ppm)] (Expected Yield)

$P_2O_{5\ rec}$ = [0.0231 – (0.0014) (Olsen P, ppm)] (Expected Yield)

*Table 31. Potash fertilizer guidelines for edible bean production.*

| Expected | Potassium (K) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|
| Yield | 0-40 | 40-80 | 80-120 | 120-160 | 160 + |
| lb/acre | - - - - $K_2O$ to apply (lb./acre) - - - - | | | | |
| 1400-1900 | 45 | 15 | 0 | 0 | 0 |
| 1901-2400 | 55 | 20 | 0 | 0 | 0 |
| 2401-2900 | 65 | 25 | 0 | 0 | 0 |
| 2901 + | 75 | 30 | 0 | 0 | 0 |

** Use the following equation if a potash guideline for a specific soil test and a specific expected yield is desired.*

$K_2O_{\ rec}$ = [0.0346 – (0.00042) (Soil Test K, ppm)] (Expected Yield)

*Table 29. Nitrogen guidelines for edible bean grown on non-irrigated fine-textured soil and a soil $NO_3^-$-N test is not used.*

| | Expected Yield (lb./acre) | | | | |
|---|---|---|---|---|---|
| Crop Grown Last Year | Organic Matter Level* | 1401-1900 | 1901-2400 | 2401-2900 | 2901 + |
| Alfalfa (4+ plants/$ft^2$) | Low | 0 | 0 | 0 | 0 |
| | Med high | 0 | 0 | 0 | 0 |
| Alfalfa (2-3 plants/$ft^2$) | Low | 0 | 20 | 40 | 60 |
| | Med high | 0 | 0 | 10 | 30 |
| Group 1 Crops | Low | 0 | 0 | 25 | 45 |
| | Med high | 0 | 0 | 0 | 25 |
| Group 2 Crops | Low | 60 | 80 | 100 | 120 |
| | Med high | 30 | 50 | 70 | 90 |

** low = less than 3.0%; medium and high = 3.0% or more*

Crops in Group 1:
Alsike clover, birdsfoot trefoil, grass/legume hay, grass legume pasture, fallow, red clover.
Crops in Group 2:
Barley, buckwheat, canola, corn, grass hay, grass pasture, oat, potato, rye, sorghum-sudan, sugar beet, sunflower, sweet corn, triticale, wheat.

### Micronutrients

Past research with the edible bean crop has indicated that zinc (Zn) is the only micronutrient that may be needed in a fertilizer program. Zinc suggestions for both starter and broadcast application are listed in Table 32.

Research has shown that there are no other nutrients needed in a fertilizer program.

**CAUTION! Do not apply any fertilizer in contact with the seed at planting.**

*Table 32. Zinc suggestions for edible bean production in Minnesota.*

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

** Zinc extracted by the DTPA procedure.*

## GRASSES FOR HAY AND PASTURE

Several forage grasses and grass mixtures are adapted to Minnesota. As with other crops, adequate fertilizer programs are needed for optimum economic production. This is true for grasses grown for either hay or pasture.

### Nitrogen

The grasses and grass mixtures, whether grown for hay or pasture, are perennial crops. Therefore, previous crop is not a consideration when making fertilizer guidelines.  Nitrogen fertilizer guidelines are based on expected yield. The expected yield will vary with such factors as intended use, management intensity, and soil texture. The suggestions for each expected yield are listed in Table 33.

*Table 33. Nitrogen guidelines for grasses and grass mixtures in Minnesota.*

| Expected Yield | N to apply |
|---|---|
| ton dry matter/acre | lb./acre |
| 2 | 60 |
| 3 | 90 |
| 4 | 120 |
| 4 + | 150 |

Expected yields of 4 or more tons of dry matter per acre are reasonable for situations where soils have a good water holding capacity and intensive management practices such as the use of rotational grazing are used. Without irrigation, expected yields of 2 ton per acre are more reasonable when grasses are grown on sandy soils where moisture is usually limited. It's not possible to assign a yield expectation for every situation in Minnesota where forage crops are grown. This is a decision for the individual managing the production of forage grasses.

The time of nitrogen fertilizer application should match the growth pattern of the forage grasses. With cool season grasses, the majority of the growth takes place in late spring and early summer. Therefore, early spring application of nitrogen is suggested for these grasses. Brome-grass, orchardgrass, and reed canarygrass are three major cool season grasses grown in Minnesota.

Timing for warm season grasses should be different. These grasses thrive when temperatures are warm in mid-summer. Therefore, a late spring application of nitrogen is suggested. Switch-grass is an example of a warm season grass.

Split application of nitrogen fertilizer is an option for intensive management situations when expected yields are greater than 4 ton per acre. If the split application is an option, 3/4 of the nitrogen should be applied in early spring and 1/4 in late August.

### Phosphate and Potash

The phosphate fertilizer guidelines are listed in Table 34 while the potash fertilizer guidelines are listed in Table 35. The listed rates are for all forage grasses and grass mixtures. The needed fertilizer should be broadcast to established stands in early spring for cool season grasses, and late spring for the warm season grasses.

*Table 34. Phosphate fertilizer guidelines for grasses and grass mixtures.*

| | | Phosphorus (P) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|---|
| Expected | Bray: | 0-5 | 6-10 | 11-15 | 16-20 | 21 + |
| Yield | Olsen: | 0-3 | 4-7 | 8-11 | 12-15 | 16 + |
| ton/acre | | - - - - $P_2O_5$ to apply (lb./acre) - - - - | | | | |
| 2 | | 40 | 30 | 20 | 10 | 0 |
| 3 | | 50 | 40 | 30 | 20 | 0 |
| 4 | | 60 | 50 | 40 | 30 | 0 |
| 4 + | | 70 | 60 | 50 | 40 | 0 |

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

$P_2O_{5\ rec}$ = [19.12 – (0.723) (Bray P, ppm)] (Expected Yield)

$P_2O_{5\ rec}$ = [19.12 – (1.012) (Olsen P, ppm)] (Expected Yield)

*Table 35. Potash fertilizer guidelines for grasses and grass mixtures.*

| Expect-ed | Potassium (K) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|
| Yield | 0-40 | 40-80 | 80-120 | 120-160 | 160 + |
| ton/acre | - - - - $K_2O$ to apply (lb./acre) - - - - | | | | |
| 2 | 90 | 60 | 30 | 0 | 0 |
| 3 | 100 | 70 | 40 | 10 | 0 |
| 4 | 110 | 80 | 50 | 20 | 0 |
| 4 + | 120 | 90 | 60 | 30 | 0 |

** Use the following equation if a potash guideline for a specific soil test and a specific expected yield is desired.*

$K_2O_{rec}$ = [40.43 – (0.286) (Soil Test K, ppm)] (Expected Yield)

### Other Nutrients

Research trials in Minnesota have shown that forage grasses and grass mixtures have not responded to the application to other nutrients in a fertilizer program. Therefore, none are suggested.

## GRASS-LEGUME MIXTURES

A wide variety of grass legume mixtures are adapted to Minnesota growing conditions. These mixtures are also a special challenge for fertilizer management which should be focused on maintaining both components (grasses, legumes) of the mixture.

### Nitrogen

Use of nitrogen fertilizer is important for maintaining the grass component of the mixture. Excessive nitrogen will stimulate the growth of grasses which will crowd the legumes out of the mixture. Minimum rates will allow the legumes to crowd out the grasses. A rate of 60 lb. of nitrogen per acre is suggested for grass-legume mixtures. This nitrogen should be top-dressed to the established stands in early spring.

### Phosphate and Potash

Fertilizers to supply phosphate and potash are necessary to maintain the legume component of the mixture. The suggestions for phosphate and potash use are listed in Tables 36 and 37. The suggested amounts should be top-dressed to established stands in early spring.

*Table 36. Phosphate guidelines for grass-legume mixtures.*

| | | Phosphorus (P) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|---|
| Ex-pected | Bray: | 0-5 | 6-10 | 11-15 | 16-20 | 21 + |
| Yield | Olsen: | 0-3 | 4-7 | 8-11 | 12-15 | 16 + |
| ton/acre | | - - - - $P_2O_5$ to apply (lb./acre) - - - - | | | | |
| 2 | | 35 | 25 | 15 | 0 | 0 |
| 3 | | 55 | 40 | 25 | 10 | 0 |
| 4 | | 70 | 50 | 30 | 10 | 0 |
| 5 | | 90 | 65 | 40 | 15 | 0 |

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

$P_2O_{5\ rec}$ = [20 – (1.0) (Bray P, ppm)] (Expected Yield)

$P_2O_{5\ rec}$ = [20 – (1.4) (Olsen P, ppm)] (Expected Yield)

*Table 37. Potash guidelines for grass-legume mixtures.*

| Expected | Potassium (K) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|
| Yield | 0-40 | 41-80 | 81-120 | 121-160 | 161 + |
| ton/acre | - - - - $K_2O$ to apply (lb./acre) - - - - | | | | |
| 2 | 95 | 65 | 40 | 15 | 0 |
| 3 | 140 | 100 | 60 | 20 | 0 |
| 4 | 185 | 135 | 80 | 25 | 0 |
| 5 | 230 | 165 | 100 | 35 | 0 |

** Use the following equation if a potash guideline for a specific soil test and a specific expected yield is desired.*

## Other Nutrients

Sulfur is an important addition to a fertilizer program if alfalfa and red clover are the legumes included in the mixture. An annual application of 25 lb. sulfur per acre is suggested if the legumes are grown on sandy soils. Use of other nutrients has not increased dry matter production of grasses and legumes used in the various mixtures. Therefore, the use of other nutrients is not suggested at this time.

## Liming Considerations

Maintaining a favorable soil pH is one key to maintaining legumes, especially alfalfa in the mixture. The suggested rate of lime should be broadcast and incorporated before the legumes are seeded. Use of lime will not maintain soil pH in the favorable range forever. When pH values drop into the acid range, alfalfa will probably disappear when it is mixed with grasses. Reseeding can be expensive and unless lime is incorporated, there is no way to reseed alfalfa to get a high yielding stand. Therefore, special attention to legumes other than alfalfa is suggested for soils where acid pH values are a problem. Some forage legumes are more tolerant than alfalfa to pH values in the acid range.

# KENTUCKY BLUEGRASS, TIMOTHY, REED CANARY GRASS, SEED PRODUCTION

The fertilizer guidelines for seed production from these grasses are listed in Tables 38, 39, and 40. Except for new seedlings, the suggested fertilizer should be top-dressed to the established stands.

*Table 38. Nitrogen guidelines for grass seed production.*

| Field status | Mineral Soils | Organic Soils |
|---|---|---|
| | - - - - N to apply (lb./acre) - - - - | |
| New seeding | 30 | 0 |
| Established stand | 100 | 40 |

*Table 39. Phosphate guidelines for grass seed production (both new seedings and established stands).*

| Phosphorus (P) Soil Test | | |
|---|---|---|
| Bray | Olsen | Phosphate to Apply |
| - - - - ppm - - - - | | - - - - lb $P_2O_5$/acre - - - - |
| 0-5 | 0-3 | 80 |
| 6-11 | 4-7 | 60 |
| 12-15 | 8-11 | 40 |
| 16-21 | 12-15 | 20 |
| 21 + | 16 + | 0 |

*Table 40. Potash guidelines for grass seed production.*

| Potassium (K) Soil Test | Potash to Apply |
|---|---|
| - - - - ppm - - - - | - - - - lb $K_2O$/acre - - - - |
| 0-40 | 120 |
| 41-80 | 90 |
| 81-120 | 60 |
| 121-160 | 30 |
| 161 + | 0 |

There is no research to indicate that other nutrients are needed in a fertilizer program for grass seed production. Therefore, use of other nutrients is not suggested for this crop at this time.

# MILLET

This crop is important in some farm enterprises in Minnesota. Fertilizer is an important production input for optimum yields. Recommendations for nitrogen, phosphate, and potash are summarized in the tables that follow.

## Nitrogen

Nitrogen (N) fertilizer guidelines can be based on the results of the soil $NO_3^-$-N test or the consideration of the combination of expected yield, previous crop, and soil organic matter content. The soil nitrate test is appropriate for western Minnesota (see Figure 2).

When the soil nitrate test is used, the fertilizer N guidelines are calculated as follows.

$$N_{rec} = (0.035)\ (EY) - STN_{(0\text{-}24\ in.)} - N_{Pc}$$

Where:

EY = expected yield (lb./acre)
STN = nitrate-nitrogen ($NO_3^-$-N) measured to a depth of 24 in. (lb./acre)
$N_{pc}$ = amount of N supplied by the previous legume crop (lb./acre).
These N credits are summarized in Table 6.

The N fertilizer guidelines for situations where the soil $NO_3^-$-N test is not used are listed in Table 41. The suggested rate of N fertilizer should be applied before planting. All sources of fertilizer should have an equal effect on yield.

Crops in Group 1:
Alsike clover, birdsfoot trefoil, grass/legume hay, grass legume pasture, fallow, red clover.

Crops in Group 2:
Barley, buckwheat, canola, corn, grass hay, grass pasture, oat, potato, rye, sorghum-sudan, sugar beet, sunflower, sweet corn, triticale, wheat.

## Phosphate and Potash

Current phosphate guidelines are summarized in Table 42. Guidelines for potash are in Table 43. The guidelines listed in these tables are intended for broadcast application. The sensitivity of this crop to banded application of fertilizers is not known.

**CAUTION! Do not apply N as urea (46-0-0) in contact with the seed at planting. Do not apply ammonium thiosulfate (12-0-0-26) or boron in contact with the seed.**

*Table 41. Nitrogen fertilizer guidelines for millet for situations where the soil $NO_3^-$-N test is not used.*

| | | Expected Yield (lb./acre) | | | | |
|---|---|---|---|---|---|---|
| Crop Grown Last Year | Organic Matter Level* | 1500-1900 | 1901-2300 | 2301-2700 | 2701-3000 | 3100 + |
| Alfalfa (4+ plants/ft$^2$) | Low | 0 | 0 | 0 | 0 | 0 |
| | Med and high | 0 | 0 | 0 | 0 | 0 |
| Alfalfa (2-3 plants/ft$^2$) | Low | 0 | 0 | 0 | 20 | 40 |
| | Med and high | 0 | 0 | 0 | 0 | 20 |
| Soybeans | Low | 0 | 10 | 20 | 40 | 60 |
| alfalfa (1 or less plants/ft$^2$) | Med and high | 0 | 0 | 0 | 20 | 40 |
| Edible beans, field peas, | Low | 20 | 30 | 40 | 60 | 80 |
| | Med and high | 0 | 10 | 20 | 40 | 60 |
| Group 1 Crops | Low | 0 | 0 | 0 | 0 | 25 |
| | Med and high | 0 | 0 | 0 | 0 | 0 |
| Group 2 Crops | Low | 40 | 50 | 60 | 80 | 100 |
| | Med and high | 20 | 30 | 40 | 60 | 80 |

** low = less than 3.0%; medium and high = 3.0% or more*

*Table 42. Phosphate guidelines for millet production.*

| | | Phosphorus (P) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|---|
| Expected | Bray: | 0-5 | 6-10 | 11-15 | 16-20 | 21 + |
| Yield | Olsen: | 0-3 | 4-7 | 8-11 | 12-15 | 16 + |
| lb/acre | | - - - - $P_2O_5$ to apply (lb./acre) - - - - | | | | |
| 1500-1900 | | 25 | 20 | 10 | 0 | 0 |
| 1901-2300 | | 30 | 25 | 15 | 0 | 0 |
| 2301-2700 | | 40 | 25 | 15 | 0 | 0 |
| 2701-3100 | | 45 | 30 | 20 | 0 | 0 |
| 3100 + | | 45 | 35 | 20 | 0 | 0 |

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

$P_2O_{5\ rec}$ = [0.0171 – (0.0085) (Bray P, ppm)] (Expected Yield)

$P_2O_{5\ rec}$ = [0.0171 – (0.00114) (Olsen P, ppm)] (Expected Yield)

*Table 43. Potash guidelines for millet production.*

| Expected | Potassium (K) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|
| Yield | 0-40 | 41-80 | 81-120 | 121-160 | 161 + |
| lb/acre | - - - - $K_2O$ to apply (lb./acre) - - - - | | | | |
| 1500-1900 | 45 | 35 | 20 | 10 | 0 |
| 1901-2300 | 55 | 40 | 25 | 10 | 0 |
| 2301-2700 | 65 | 50 | 30 | 10 | 0 |
| 2701-3100 | 75 | 55 | 35 | 15 | 0 |
| 3100 + | 80 | 60 | 40 | 15 | 0 |

** Use the following equation if a potash guideline for a specific soil test and a specific expected yield is desired.*

$K_2O_{rec}$ = [0.03 – (0.00018) (Soil Test K, ppm)] (Expected Yield)

There is no research evidence which suggests that sulfur and the micronutrients are needed for optimum production of this crop. Therefore, there is no suggestion to add these nutrients to a fertilizer program.

# OAT

In Minnesota, the oat crop is used for either grain and straw or as a nurse crop for seeding legumes. The recommendations in the tables that follow are intended for situations where the crop is grown for grain and straw.

## Nitrogen

Nitrogen (N) fertilizer guidelines can be based on the results of the soil $NO_3^-$-N test or a consideration of the combination of expected yield, previous crop, and soil organic matter content. The soil nitrate test is appropriate for western Minnesota (see Figure 2).

When the soil nitrate is used, the fertilizer N guidelines are calculated as follows:

$N_{rec} = (1.3)\ (EY) - STN_{(0\text{-}24\ in.)} - N_{Pc}$

Where:

EY = expected yield (lb./acre)

STN = nitrate-nitrogen ($NO_3^-$-N) measured to a depth of 24 in. (lb./acre)

Npc = amount of N supplied by the previous legume crop (lb./acre).

These N credits are summarized in Table 6.

The N fertilizer guidelines for situations where the soil $NO_3^-$-N test is not used are summarized in Table 44.

Crops in Group 1:
Alsike clover, birdsfoot trefoil, grass/legume hay, grass legume pasture, fallow, red clover.

Crops in Group 2:
Barley, buckwheat, canola, corn, grass hay, grass pasture, oat, potato, rye, sorghum-sudan, sugar beet, sunflower, sweet corn, triticale, wheat.

Nitrogen, when needed, can be supplied from several sources. If applied in a way to prevent loss, all sources of nitrogen have an equal effect on yield. When using either dry or liquid sources, the fertilizer N can be broadcast and incorporated before planting. If anhydrous ammonia is the preferred source, this N fertilizer can be knifed in before planting.

## Phosphate and Potash

Current phosphate guidelines are listed in Table 45. Guidelines for potash use are in Table 46. The rates listed are appropriate for both broadcast and banded (drill applied) application. There is no research evidence with this crop to suggest that the banded placement is more efficient than a broadcast application.

*Table 44. Nitrogen fertilizer recommendations for oat production for situations where the soil $NO_3^-$-N test is not used.*

| | | Expected Yield (bu./acre) | | | | |
|---|---|---|---|---|---|---|
| Crop Grown Last Year | Organic Matter Level* | 40-60 | 61-80 | 81-100 | 101-120 | 120 + |
| Alfalfa (4+ plants/$ft^2$) | Low | 0 | 0 | 0 | 0 | 0 |
| | Med and high | 0 | 0 | 0 | 0 | 0 |
| Alfalfa (2-3 plants/$ft^2$) | Low | 0 | 0 | 20 | 40 | 60 |
| | Med and high | 0 | 0 | 10 | 30 | 50 |
| Soybeans | Low | 0 | 20 | 40 | 60 | 80 |
| Alfalfa (1 or less plants/$ft^2$) | Med and high | 0 | 0 | 30 | 50 | 70 |
| Edible beans, field peas | Low | 20 | 40 | 60 | 80 | 100 |
| | Med and high | 10 | 30 | 50 | 70 | 90 |
| Group 1 Crops | Low | 0 | 0 | 0 | 25 | 45 |
| | Med and high | 0 | 0 | 0 | 15 | 35 |
| Group 2 Crops | Low | 40 | 60 | 80 | 100 | 120 |
| | Med and high | 30 | 50 | 70 | 90 | 110 |

** low = less than 3.0%; medium and high = 3.0% or more*

*Table 45. Phosphate guidelines for oat production.*

| | | Phosphorus (P) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|---|
| Expect-ed | Bray: | 0-5 | 6-10 | 11-15 | 16-20 | 21 + |
| Yield | Olsen: | 0-3 | 4-7 | 8-11 | 12-15 | 16 + |
| bu/acre | | - - - - $P_2O_5$ to apply (lb./acre) - - - - | | | | |
| 40-60 | | 30 | 20 | 10 | 0 | 0 |
| 61-80 | | 40 | 30 | 15 | 0 | 0 |
| 81-100 | | 50 | 35 | 20 | 0 | 0 |
| 101-120 | | 60 | 45 | 25 | 10 | 0 |
| 121 + | | 70 | 50 | 30 | 10 | 0 |

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

$P_2O_{5rec}$ = [0.644 – (0.032) (Bray P, ppm)] (Expected Yield)

$P_2O_{5rec}$ = [0.644 – (0.041) (Olsen P, ppm)] (Expected Yield)

*Table 46. Potash guidelines for oat production.*

| Expect-ed | Potassium (K) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|
| Yield | 0-40 | 41-80 | 81-120 | 121-160 | 161 + |
| bu/acre | - - - - $K_2O$ to apply (lb./acre) - - - - | | | | |
| 40-60 | 55 | 40 | 20 | 0 | 0 |
| 61-80 | 75 | 55 | 30 | 0 | 0 |
| 81-100 | 95 | 70 | 40 | 0 | 0 |
| 101-120 | 115 | 85 | 45 | 10 | 0 |
| 121 + | 130 | 90 | 50 | 10 | 0 |

** Use the following equation if a potash guideline for a specific soil test and a specific expected yield is desired.*

$K_2O_{rec}$ = [1.277 – (0.0086) (Soil Test K, ppm)] (Expected Yield)

**CAUTION! Do not apply more than 20 lb. N per acre as urea (46-0-0) with the drill. Do not place ammonium thiosulfate (12-0-0-26) in direct contact with the seed. Do not place fertilizers containing boron in direct contact with the seed.**

### Other Nutrients

Except for the need for sulfur (S) when this crop is grown on sandy soils, other nutrients are not needed in a fertilizer program. For production on sandy soils, either use 10-12 lb. S/acre with the drill at planting or broadcast 25 lb. S/acre and incorporate before planting.

## RED CLOVER, ALSIKE CLOVER, BIRDSFOOT TREFOIL

These legume crops, if properly inoculated, can take needed nitrogen from the atmosphere and fertilizer N will not be needed after the crop is established. A small amount (less than 25 lb. N/acre) may aid in getting successful establishment on sandy soils. Fertilizer N will not be needed for establishment on soils that are not sandy.

The phosphate suggestions for these crops are summarized in Table 47. The potash guidelines are in Table 48. Phosphate and/or potash fertilizers can be topdressed to established stands on an annual basis. The suggested rates of these two nutrients can also be broadcast and incorporated before seeding. This management practice may help in achieving a satisfactory stand.

*Table 47. Phosphate guidelines for red clover, alsike clover, and birdsfoot trefoil.*

| | | Phosphorus (P) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|---|
| Expected | Bray: | 0-5 | 6-10 | 11-15 | 16-20 | 21 + |
| Yield | Olsen: | 0-3 | 4-7 | 8-11 | 12-15 | 16 + |
| ton/acre | | - - - - $P_2O_5$ to apply (lb./acre) - - - - | | | | |
| 2 | | 35 | 25 | 15 | 0 | 0 |
| 3 | | 55 | 40 | 25 | 10 | 0 |
| 4 | | 70 | 50 | 30 | 10 | 0 |
| 5 | | 90 | 65 | 40 | 15 | 0 |

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

$P_2O_{5rec}$ = [20 – (1.0) (Bray P, ppm)] (Expected Yield)

$P_2O_{5rec}$ = [20 – (1.4) (Olsen P, ppm)] (Expected Yield)

*Table 48. Potash guidelines for red clover, alsike clover, and birdsfoot trefoil.*

| Expected | Potassium (K) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|
| Yield | 0-40 | 41-80 | 81-120 | 121-160 | 161 + |
| ton/acre | - - - - $K_2O$ to apply (lb./acre) - - - - | | | | |
| 2 | 95 | 65 | 40 | 15 | 0 |
| 3 | 140 | 100 | 60 | 20 | 0 |
| 4 | 185 | 135 | 80 | 25 | 0 |
| 5 | 230 | 165 | 100 | 35 | 0 |

** Use the following equation if a potash guideline for a specific soil test and a specific expected yield is desired.*

$K_2O_{rec}$ = [53.28 – (0.333) (Soil Test K, ppm)] (Expected Yield)

These legumes will respond to the application of lime if the soil pH is less than 6.0. Lime suggestions for these crops have not been well defined. An application of 3,000 lb. ENP per acre is suggested for these legumes grown on acid soils. The lime should be broadcast and incorporated before seeding.

Except for the need for sulfur (S) when these crops are grown on sandy soils, other nutrients are not needed in a fertilizer program. Use an annual broadcast application of 25 lb. S per acre when these crops are grown on sandy soils.

# RYE

Although the number of acres planted to this crop is not large, it remains a major component of some farm enterprises in Minnesota. This is a favorite crop used in rotation for those who farm sandy soils that are not irrigated. Fertilizer use is a major factor in attaining profitable yields.

## Nitrogen

The majority of this crop is grown on sandy soils. Since the soil test for $NO_3^-$-N is **NOT** suggested for use on sandy soils, guidelines for nitrogen use are based on a consideration of expected yield, previous crop, and soil organic matter content. Those guidelines are summarized in Table 49.

Crops in Group 1:
Alsike clover, birdsfoot trefoil, grass/legume hay, grass legume pasture, fallow, red clover.

Crops in Group 2:
Barley, buckwheat, canola, corn, grass hay, grass pasture, oat, potato, rye, sorghum-sudan, sugar beet, sunflower, sweet corn, triticale, wheat.

The topdress application to established stands in early spring is suggested. There is no need for the use of split applications.

## Phosphate and Potash

The guidelines for phosphate use are listed in Table 50. Suggestions for potash use are in Table 51. The suggested rates of phosphate and potash should be broadcast and incorporated before planting.

*Table 50. Phosphate guidelines for rye production.*

| | | Phosphorus (P) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|---|
| Expect-ed | Bray: | 0-5 | 6-10 | 11-15 | 16-20 | 21 + |
| Yield | Olsen: | 0-3 | 4-7 | 8-11 | 12-15 | 16 + |
| bu./acre | | - - - - $P_2O_5$ to apply (lb./acre) - - - - | | | | |
| 40-49 | | 40 | 30 | 15 | 0 | 0 |
| 50-59 | | 50 | 35 | 20 | 0 | 0 |
| 60-69 | | 60 | 45 | 20 | 0 | 0 |
| 70-79 | | 70 | 50 | 25 | 0 | 0 |
| 80 + | | 80 | 55 | 25 | 0 | 0 |

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

$P_2O_{5\ rec}$ = [1.071 – (0.054) (Bray P, ppm)] (Expected Yield)

$P_2O_{5\ rec}$ = [1.071 – (0.067) (Olsen P, ppm)] (Expected Yield)

*Table 51. Potash guidelines for rye production.*

| Expect-ed | Potassium (K) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|
| Yield | 0-40 | 41-80 | 81-120 | 121-160 | 161 + |
| bu./acre | - - - - $K_2O$ to apply (lb./acre) - - - - | | | | |
| 40-49 | 100 | 75 | 45 | 0 | 0 |
| 50-59 | 130 | 95 | 55 | 0 | 0 |
| 60-69 | 155 | 110 | 65 | 0 | 0 |
| 70-79 | 180 | 125 | 75 | 0 | 0 |
| 80 + | 190 | 135 | 80 | 0 | 0 |

** Use the following equation if a potash guideline for a specific soil test and a specific expected yield is desired.*

$K_2O_{\ rec}$ = [2.710 – (0.017) (Soil Test K, ppm)] (Expected Yield)

## Other Nutrients

Use of other nutrients in a fertilizer program has not increased rye yields in Minnesota. Therefore, use of other nutrients is not suggested at this time.

# SOYBEAN

Soybean is an important crop in Minnesota and provides a significant return in many farm enterprises. Yields will be reduced when essential nutrients are deficient. Therefore, profitable fertilizer programs must be developed to maximize yields.

## Nitrogen

The soybean is a legume and if properly inoculated, can use the nitrogen in the atmosphere ($N_2$) for plant growth. Therefore, nitrogen fertilizer is not needed for soybean production in most situations.

Nitrogen fertilizer use for soybean production in the Red River Valley deserves special consideration. Research in the region has shown that the use of fertilizer N may increase yields when

*Table 49. Nitrogen fertilizer guidelines for rye production.*

| | | Expected Yield (bu./acre) | | | | |
|---|---|---|---|---|---|---|
| Crop Grown Last Year | Organic Matter Level* | 40-49 | 50-59 | 60-69 | 70-79 | 80 + |
| Alfalfa (4+ plants/ft$^2$) | Low<br>Med and high | 0<br>0 | 0<br>0 | 35<br>0 | 60<br>40 | 95<br>75 |
| Alfalfa (2-3 plants/ft$^2$) | Low<br>Med and high | 0<br>0 | 0<br>0 | 40<br>20 | 65<br>45 | 90<br>70 |
| Soybeans<br>Alfalfa (1 or less plants/ft$^2$) | Low<br>Med and high | 40<br>20 | 65<br>45 | 90<br>70 | 115<br>95 | 140<br>120 |
| Edible beans, field peas | Low<br>Med and high | 50<br>30 | 75<br>55 | 100<br>80 | 125<br>105 | 150<br>130 |
| Group 1 Crops | Low<br>Med and high | 0<br>0 | 35<br>0 | 60<br>40 | 85<br>65 | 110<br>90 |
| Group 2 Crops | Low<br>Med and high | 60<br>40 | 85<br>65 | 110<br>90 | 135<br>115 | 160<br>140 |

** low = less than 3.0%; medium and high = 3.0% or more*

producers have experienced problems in getting good nodulation and the amount of $NO_3^-$-N to a depth of 24 inches is less than 75 lb./ acre. For these situations, use of some N (50 to 75 lb./acre) in a fertilizer program may be beneficial. The amount of $NO_3^-$-N to a depth of 24 inches should be measured before nitrogen fertilizer is applied.

## Phosphate and Potash

Phosphate fertilizer guidelines for soybean production are listed in Table 52. The suggestions for potash use are provided in Table 53. The suggested rates of phosphate and/or potash are not adjusted for placement. A summary of research from Minnesota and neighboring states leads to the conclusion that neither banded nor broadcast placement is consistently superior if adequate rates of phosphate and/or potash are used. Soybean seeds are very sensitive to fertilizer placed on or near the seed row so fertilizer should not be banded with the seed as a "pop-up" fertilizer application at the time of planting.

Timing of the phosphate application is an important consideration when fertilizing soybeans, especially when the soil pH is 7.4 or higher. The phosphate should be applied in the spring before planting to reduce the time interval for contact between soil and fertilizer.

*Table 52. Phosphate fertilizer suggestions for soybean production in Minnesota.*

| | | Phosphorus (P) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|---|
| Expected | Bray: | 0-5 | 6-10 | 11-15 | 16-20 | 21 + |
| Yield | Olsen: | 0-3 | 4-7 | 8-11 | 12-15 | 16 + |
| bu./acre | | - - - - $P_2O_5$ to apply (lb./acre) - - - - | | | | |
| Less than 30 | | 50 | 30 | 0 | 0 | 0 |
| 30-39 | | 60 | 40 | 0 | 0 | 0 |
| 40-49 | | 70 | 50 | 0 | 0 | 0 |
| 50-59 | | 80 | 60 | 0 | 0 | 0 |
| 60 + | | 90 | 70 | 0 | 0 | 0 |

** Use one of the following equations if a phosphate suggestion for a specific soil test and a specific expected yield is desired.*

$P_2O_{5\,rec}$ = [1.752 – (0.0836) (Bray P, ppm)] (Expected Yield)
$P_2O_{5\,rec}$ = [1.752 – (0.1114) (Olsen P, ppm)] (Expected Yield)

*Table 53. Potash fertilizer suggestions for soybean production in Minnesota.*

| Expected | Potassium (K) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|
| Yield | 0-40 | 41-80 | 81-120 | 121-160 | 161 + |
| bu./acre | - - - - $K_2O$ to apply (lb./acre) - - - - | | | | |
| Less than 30 | 55 | 30 | 15 | 0 | 0 |
| 30-39 | 65 | 40 | 20 | 0 | 0 |
| 40-49 | 80 | 50 | 20 | 0 | 0 |
| 50-59 | 100 | 60 | 30 | 0 | 0 |
| 60 + | 110 | 70 | 30 | 0 | 0 |

** Use the following equation if a potash suggestion for a specific soil test and a specific expected yield is desired.*

$K_2O_{\,rec}$ = [2.2 – (0.0183) (Soil Test K, ppm)] (Expected Yield)

## Other Nutrients

Research in Minnesota has shown that soybeans do not respond to the application of other nutrients in a fertilizer program. Manganese deficiency has been reported in glyphosate resistant soybeans in areas of the Eastern Corn Belt in areas traditionally responses to the nutrient, but research conducted in Minnesota has not shown a benefit to soil or foliar applied manganese on soybean.

Iron deficiency chlorosis (IDC) is a serious concern in western Minnesota. In these situations, there is an ample supply of iron in the soil. However, for reasons that are not completely understood, the soybean plant is not able to take up the iron needed for optimum growth. Research has shown a significant greening effect on soybeans and sometimes a yield increase when a 6% ortho-ortho EDDHA iron product is placed with the seed at rates of 1-3 lb. of product per acre. For best results apply EDDHA chelate must be placed in contact with the seed at planting. Planting an oats companion crop has also been shown to decrease the severity of IDC seeding at a rate of 1.5 bu./acre prior to planting soybeans. However, the oats must be left to grow to and sprayed with a herbicide by the time they are 10 inches tall to prevent over competition with soybean.

# SUGAR BEET

Optimum sugar beet production in Minnesota and North Dakota is built on a sound fertility program. There is a financial reward for delivering a high quality product to the factories. The quality of the harvested sugar beet is affected by the fertilizer that is supplied.

## Nitrogen

Nitrogen is the most important nutrient when planning a fertilizer program for sugar beet production.  Nitrogen fertilization promotes vigorous early-season growth thereby reducing the number of days to canopy closure. Early closure allows the sugar beet to make better use of sunlight and more sugar is produced. Excess nitrogen at or near the end of the growing season reduces sugar beet quality by reducing sucrose concentration. The highest quality sugar beet is produced when nitrogen deficiency occurs late in the growing season (about 6 weeks prior to harvest).

The amount of nitrogen fertilizer suggested should be adjusted for the amount of $NO_3^-$-N measured in the soil profile to a depth of 4 ft. The nitrogen fertilizer guideline will depend on the location that the sugarbeet is grown.  For the Minn-Dak and American Crystal growing areas, a total of 130 lbs per acre as soil test $NO_3^-$-N in the surface 4 ft. plus fertilizer N is needed.  If a grower is unable to get a soil sample to 4 ft and if there are small amounts of $NO_3^-$-N at a depth of 2 to 4 feet are suspected, a soil test to a depth of 2 ft. can be used.  The total N would be 110 lb per acre soil test $NO_3^-$-N plus fertilizer N.  In the Southern Minnesota Beet Sugar Cooperative growing area, the amount of $NO_3^-$-N for a 4 ft soil test and fertilizer should be 100 lbs per acre and for a 2 ft. soil test, the total should be 80 lbs per acre.

Results of various field research projects have shown that all nitrogen fertilizers will have an equal effect on production if applied in a way that loss of any nitrogen is minimized. Fall application of liquid nitrogen (28-0-0) and ammonium nitrate (33-0-0) is discouraged.

Split applications of nitrogen may be wise for sugar beets grown on sandy soils. The applications should be scheduled so that the last application takes place before July 1. For soils that are not sandy, the split applications have not been superior to a single pre-plant application and have caused a decrease in the quality of the crop.

## Phosphate

Phosphate fertilizer, when needed, has increased production without a significant effect on quality. The guidelines for phosphate use are summarized in Table 54. The suggested rates are for a broadcast application. Minnesota research has shown that banded applications on the seed are very efficient. If this seed placement is used, the suggested rate is 15 lb $P_2O_5$ per acre.  This can be supplied as 3 gallons ammonium polyphosphate (10-34-0).

*Table 54. Phosphate guidelines for sugar beet production.*

| Phosphorus (P) Soil Test | | |
|---|---|---|
| Bray | Olsen | Phosphate to Apply |
| - - - - ppm - - - - | | - lb $P_2O_5$/acre - |
| 0-5 | 0-3 | 80 |
| 6-11 | 4-7 | 55 |
| 12-15 | 8-11 | 35 |
| 16-21 | 12-15 | 10 |
| 21 + | 16 + | 0 |

## Potash

Suggestions for potash use are based on the results of a soil test and are summarized in Table 55. This nutrient is not a major concern in sugar beet production because a large majority of the soils supporting this crop are natively high in potassium. Potash fertilizer can have a negative effect on germination if placed on or too close to the seed. Therefore, broadcast applications of potash are suggested.

*Table 55. Potash guidelines for sugar beet production.*

| Potassium (K) Soil Test | Potash to Apply |
|---|---|
| - - - - ppm - - - - | - - - - lb $K_2O$/acre - - - - |
| 0-40 | 110 |
| 41-80 | 80 |
| 81-120 | 50 |
| 121-160 | 15 |
| 161 + | 0 |

### Other Nutrients

In Minnesota and North Dakota growing areas, the use of sulfur, zinc, magnesium, calcium, boron, iron, copper, and manganese has had no effect on either the yield or the quality of the sugar beet crop. Therefore, the use of these nutrients is not needed.

### Cautions

Those who choose to place fertilizer with the seed should use caution. Applying more than 5 lb. per acre of N + $K_2O$ in contact with the seed can reduce emergence and subsequent stands. The use of 10-34-0 at rates less than 4 gallons per acre in 22 inch rows has not been harmful. The potential for reduced stand resulting from fertilizer placed with the seed increases as the moisture content of the soil decreases.

## SUNFLOWER

Sunflower will respond to fertilization. Nitrogen, phosphate, and potash are important. The appropriate recommendations are listed in the tables that follow.

### Nitrogen

Nitrogen (N) fertilizer guidelines can be based on the results of a soil $NO_3^-$-N test or the consideration of expected yield, previous crop, and soil organic matter content. The soil $NO_3^-$-N test is appropriate for western Minnesota (see Figure 2). When the soil nitrate test is used, the fertilizer N guidelines are calculated as follows:

$N_{rec} = (0.05)\ (EY) - STN_{(0\text{-}24\ in.)} - N_{Pc}$

Where:

EY = expected yield (lb./acre)

STN = nitrate-nitrogen ($NO_3^-$-N) measured to a depth of 24 in. (lb./acre)

$N_{pc}$ = amount of N supplied by the previous legume crop (lb./acre).

These N credits are summarized in Table 6.

The N fertilizer guidelines for situations where the soil $NO_3^-$-N test is not used are summarized in Table 56.

Crops in Group 1:
Alsike clover, birdsfoot trefoil, grass/legume hay, grass legume pasture, fallow, red clover.

Crops in Group 2:
Barley, buckwheat, canola, corn, grass hay, grass pasture, oat, potato, rye, sorghum-sudan, sugar beet, sunflower, sweet corn, triticale, wheat.

### Phosphate and Potash

Current phosphate recommendations are summarized in Table 57. Recommendations for potash use are in Table 58.

**CAUTION! Do not apply more than 10 lb N + K2O per acre in contact with the seed. Do not place ammonium thiosulfate (12-0-0-26) in direct contact with the seed. Do not place fertilizers containing boron in direct contact with the seed.**

*Table 56. Nitrogen fertilizer guidelines for sunflower production for situations where the soil $NO_3^-$-N test is not used.*

| | | Expected Yield (lb./acre) | | | | |
|---|---|---|---|---|---|---|
| Crop Grown Last Year | Organic Matter Level* | 1400-1900 | 1901-2400 | 2401-2900 | 2901-3300 | 3300 + |
| Alfalfa (4+ plants/ft$^2$) | Low | 0 | 0 | 0 | 0 | 0 |
| | Med and high | 0 | 0 | 0 | 0 | 0 |
| Alfalfa (2-3 plants/ft$^2$) | Low | 0 | 20 | 40 | 60 | 80 |
| | Med and high | 0 | 0 | 10 | 30 | 50 |
| Soybeans | Low | 30 | 50 | 70 | 90 | 110 |
| Alfalfa (1 or less plants/ft$^2$) | Med and high | 0 | 20 | 40 | 60 | 80 |
| Group 1 Crops | Low | 0 | 15 | 25 | 45 | 65 |
| | Med and high | 0 | 0 | 0 | 25 | 45 |
| Group 2 Crops | Low | 70 | 90 | 110 | 130 | 150 |
| | Med and high | 40 | 60 | 80 | 100 | 120 |

** low = less than 3.0%; medium and high = 3.0% or more*

*Table 57. Phosphate fertilizer suggestions for sunflower production in Minnesota.*

| | | Phosphorus (P) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|---|
| Expected | Bray: | 0-5 | 6-10 | 11-15 | 16-20 | 21 + |
| Yield | Olsen: | 0-3 | 4-7 | 8-11 | 12-15 | 16 + |
| lb./acre | | - - - - $P_2O_5$ to apply (lb./acre) - - - - | | | | |
| 1400-1900 | | 55 | 35 | 15 | 0 | 0 |
| 1901-2400 | | 65 | 45 | 20 | 0 | 0 |
| 2401-2900 | | 75 | 55 | 25 | 0 | 0 |
| 2901-3300 | | 85 | 65 | 25 | 10 | 0 |
| 3300 + | | 90 | 70 | 30 | 10 | 0 |

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

$P_2O_{5\,rec}$ = [0.0225 – (0.0011) (Bray P, ppm)] (Expected Yield)

$P_2O_{5\,rec}$ = [0.0225 – (0.0014) (Olsen P, ppm)] (Expected Yield)

*Table 58. Potash fertilizer suggestions for sunflower production in Minnesota.*

| Expected | Potassium (K) Soil Test, ppm * | | | | |
|---|---|---|---|---|---|
| Yield | 0-40 | 41-80 | 81-120 | 121-160 | 161 + |
| lb./acre | - - - - $K_2O$ to apply (lb./acre) - - - - | | | | |
| 1400-1900 | 55 | 40 | 20 | 15 | 0 |
| 1901-2400 | 75 | 50 | 30 | 15 | 0 |
| 2401-2900 | 90 | 65 | 35 | 20 | 0 |
| 2901-3300 | 110 | 75 | 40 | 25 | 0 |
| 3300 + | 115 | 80 | 45 | 25 | 0 |

** Use the following equation if a potash guideline for a specific soil test and a specific expected yield is desired.*

$K2O_{rec}$ = [0.0410 – (0.00027) (Soil Test K, ppm)] (Expected Yield)

## Other Nutrients

Research trials conducted in Minnesota have shown that other nutrients are not needed in a fertilizer program for sunflower production.

# WHEAT

With 1 to 2 million acres planted annually, wheat is a major crop in Minnesota's agriculture. When diseases and other crop pests are not limiting, average yields continue to increase slowly with time. Adequate and efficient use of fertilizer has been a major contributor to this increase.

## Nitrogen Suggestions

The modern wheat grower receives more return for money spent on nitrogen (N) than any other nutrient. It is important to focus on using this nutrient as efficiently as possible.

Two strategies are used for making suggestions for the amount of fertilizer N to use for wheat production in Minnesota. For the western portion of the state where most of the wheat is grown, the soil $NO_3^-$-N test (soil samples collected to 2 feet) is the best and most accurate management tool for predicting the amount of fertilizer N to use. This soil test is suggested if wheat is grown in the shaded area of the state shown in Figure 2.

If the soil nitrate test is used, the amount of fertilizer N required to meet the yield goal is calculated from the following equation:

$N_{rec} = (2.5)\ (EY) - STN_{(0\text{-}24\ in.)} - N_{Pc}$

Where:

EY = expected yield (bu./acre)

STN = nitrate-nitrogen ($NO_3^-$-N) measured to a depth of 24 in. (lb./acre)

$N_{pc}$ = amount of N supplied by the previous legume crop (lb./acre).

These N credits are summarized in Table 59.

*Table 59. Nitrogen credits for various crops that might precede wheat in a crop rotation. Use these credits when the soil nitrate test is used.*

| Previous Crop | 1st Year Nitrogen Credit |
|---|---|
| | lb. N/acre |
| Soybeans | 20 |
| Edible Beans, Field Peas | 10 |
| Harvested alfalfa[1/]: | |
| 4-5 or more plants/ft$^2$ | 75 |
| 2-3 or more plants/ft$^2$ | 50 |
| 1-2 plants/ft$^2$ | 25 |
| 1 or fewer plants/ft$^2$ | 0 |
| Harvested Red Clover | 35 |
| Sugar Beet | |
| Yellow Leaves | 0 |
| Yellow-green Leaves | 15 to 20 |
| Dark-green Leaves | 60 to 70 |

[1/] *If 3rd or 4th cutting was not harvested, add 20lb. N per acre to the N credits listed.*

If wheat is grown in the second year following any of the crops in Table 59, use the N credit listed in Table 60.

*Table 60. Nitrogen credits for some forage legumes if wheat is planted two years after the legume.*

| Legume Crop | 2nd Year Nitrogen Credit |
|---|---|
| | lb. N/acre |
| Harvested alfalfa: | |
| 4 or more plants/ft$^2$ | 35 |
| 2 to 3 plants/ft$^2$, Birdsfoot Trefoil | 25 |
| Red clover | 20 |

For situations where the soil $NO_3^-$-N test is not used, suggestions for fertilizer N are based on a consideration of previous crop, expected yield, and soil organic matter content. The soil $NO_3^-$-N test is not used for making nitrogen fertilizer guidelines for wheat grown in eastern and southern Minnesota (the area which is not shaded in Figure 2). Nitrogen fertilizer guidelines for these situations are summarized in Table 61. Use the fertilizer N guidelines for soils having a high organic matter content when wheat is grown is southeast Minnesota. This statement applies in Goodhue, Wabasha, Olmsted, Winona, Fillmore, and Houston Counties.

The nitrogen supplied by legume crops can also be utilized by the wheat crop if it is planted 2 years after the legume. The nitrogen credits for these situations are summarized in Table 60. Subtract these values from the N guidelines that are listed for crops in Group 2 (Table 61) when wheat is planted 2 years after a legume crop.

Nitrogen from the decomposing tops of a previous crop of sugar beet can be used by the wheat crop when it follows in a rotation. These N credits are based on the overall color of the sugar beet tops at harvest and are listed in Table 59. If the soil $NO_3^-$-N test is used for nitrogen guidelines, the value for the appropriate color should be used as the nitrogen credit from the previous crop (N pc) in the N guideline equation. If the N recommendations are taken from Table 61, subtract the value for the appropriate color from the appropriate N guideline listed in the table.

Crops in Group 1:
Alsike clover, birdsfoot trefoil, grass/legume hay, grass legume pasture, fallow, red clover.

Crops in Group 2:
Barley, buckwheat, canola, corn, grass hay, grass pasture, oat, potato, rye, sorghum-sudan, sugar beet, sunflower, sweet corn, triticale, wheat.

In-season applications of liquid urea ammonium nitrate solutions (28 or 32%) from 2 to 5 days after anthesis has been shown to increase grain protein. In years where expected yields are greater than the grain yield used, a foliar application of N can be used to increase protein. Research has shown that protein can be raised by 0.5 to 1.0% by an application of 30 lbs N per acre. Some leaf burning can be expected but generally will not result in lower yields.

**CAUTION – DO NOT TANK MIX 28 OR 32% UAN SOLUTIONS WITH FUNGICIDES**

Nitrogen guidelines, whether calculated from the equation or obtained from Table 61, should also be used for winter wheat production. For this crop, 15 to 30 lb. N per acre should be applied in the fall either before or at the time of seeding. The remainder of the amount of fertilizer N needed should be topdressed early in the following spring.

## Phosphate Suggestions

Suggestions for phosphate use are summarized in Table 62. The phosphorus (P) status of Minnesota soils is determined by using either the Bray or the Olsen analytical procedure. In general, the Olsen test provides more accurate recommendations if the soil pH is 7.4 or higher.

## Potash Suggestions

Suggestions for potash use are summarized in Table 63. As with phosphate, application rates vary with placement and soil test level for K. No broadcast potash will be needed when the soil test for K is 121 ppm or higher. No potash fertilizer (either drilled or broadcast) is suggested when the soil test for K is 161 ppm or higher.

It may not be practical to broadcast some of the low rates of suggested phosphate and potash. When low rates are suggested for a broadcast application, it may be more practical to double the suggested broadcast rate and apply in alternate years if the grain drill is not equipped to apply fertilizer with the seed.

## Fertilizer in Contact with the Seed

Since most of the wheat acreage in Minnesota is usually planted in early spring when soil conditions are cold and wet, the application of some fertilizer with the drill should be a routine management practice.

**CAUTION! Do not place ammonium thiosulfate (12-0-0-26) in direct contact with the seed. Do not place boron fertilizers in direct contact with the seed.**

Damage from urea (46-0-0) placed in contact with the seed is dependent on the moisture content of the soil at planting. Damage can be substantial if soils are dry at planting. If soils are dry at the time of planting, keep the amount of N as urea in contact with the seed to 10 lb. per acre or less. Higher rates can be used if the soil is wet at planting. The suggested rates for this use, however, are not well defined.
High rates of potash in contact with the seed can cause problems if soils are dry at planting. Under typical moisture conditions, rates of $K_2O$ up to 60 lb. per acre in contact with the seed should not cause problems with emergence.

Phosphate has no negative effect on seed germination and seedling growth. Therefore, ample amounts of phosphate can be applied in contact with the seed.

## Fertilizer Applied with Air Seeders

The use of air seeders has increased in popularity in recent years. Many seeders are equipped to apply a mixture of seed and dry fertilizer at the time of planting. There are, however, no firm guidelines for the amount of fertilizer that can be applied with the seed with this planting equipment.

The amount of urea that can be used with the air seeder is related to soil moisture content at planting. Recent trials showed that N rates in excess of 25 lb. per acre as urea can reduce germination if applied with the wheat using an air seeder when soils are dry. By contrast, 75 lb. N per acre as urea caused no emergence problems when soils were moist. Further research is being conducted to determine the amount of N as urea that can safely be mixed with wheat using an air seeder.

Recent trials have shown that rates of phosphate of 92 lb. $P_2O_5$ per acre or less have not hindered germination if mixed with wheat seed planted with an air seeder. The amount of $K_2O$ that can be applied in contact with the seed using an air seeder is not known at this time.

## Other Nutrients Needed

Major emphasis in wheat production should be directed to efficient and effective management of nitrogen, phosphate, and potash fertilizers. Sulfur (S) and copper (Cu) can be important in limited situations. These special cases are described in the paragraphs that follow.

## Sulfur

Sulfur fertilization can increase wheat yields when the crop is grown on sandy soils. Research trials have shown that there is no need to add S to a fertilizer program when wheat is grown on fine-textured soils in Minnesota.

The broadcast application of 25 lb. S per acre in the sulfate form will be adequate for growing wheat on sandy soils. For more efficient applications, use 10 to 15 lb. S per acre with the drill at planting.

## Copper

Copper (Cu) may be required in a fertilizer program when wheat is grown on organic soils.

*Table 61. Nitrogen fertilizer guidelines for wheat where the soil $NO_3^-$-N test is not used.*

| | | Expected Yield (bu./acre) | | | | |
|---|---|---|---|---|---|---|
| Crop Grown Last Year | Organic Matter Level* | 40-49 | 50-59 | 60-69 | 70-79 | 80 + |
| Alfalfa (4+ plants/ft$^2$) | Low | 0 | 30 | 55 | 80 | 95 |
| | Med and High | 0 | 0 | 35 | 60 | 75 |
| Alfalfa (2-3 plants/ft$^2$) | Low | 10 | 35 | 60 | 85 | 100 |
| | Med and High | 0 | 15 | 40 | 65 | 80 |
| soybeans | Low | 60 | 85 | 110 | 135 | 150 |
| alfalfa (1 or less plants/ft$^2$) | Med and High | 40 | 65 | 90 | 115 | 130 |
| Edible beans, field peas | Low | 70 | 95 | 120 | 145 | 160 |
| | Med and High | 50 | 75 | 100 | 125 | 140 |
| Group 1 Crops | Low | 30 | 55 | 80 | 105 | 10 |
| | Med and High | 0 | 35 | 60 | 85 | 100 |
| Group 2 Crops | Low | 80 | 105 | 130 | 155 | 170 |
| | Med and High | 60 | 85 | 110 | 135 | 150 |
| Organic Soils | | 0 | 0 | 0 | 30 | 35 |

** low = less than 3.0%; medium and high = 3.0% or more*

*Table 62. Phosphate fertilizer suggestions for wheat production in Minnesota.*

| | | Phosphorus (P) Soil Test, ppm* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Expected | Bray: | 0-5 | | 6-10 | | 11-15 | | 16-20 | | 21+ |
| Yield | Olsen: | 0-3 | | 4-7 | | 8-11 | | 12-15 | | 16+ |
| | | Drill | Bdcst | Drill | Bdcst | Drill | Bdcst | Drill | Bdcst | |
| bu./acre | | - - - - $P_2O_5$ to apply (lb./acre) - - - - | | | | | | | | |
| 40-49 | | 40 | 20 | 30 | 15 | 15 | 10 | 0 | 10-15 | 0 |
| 50-59 | | 50 | 25 | 35 | 20 | 20 | 15 | 0 | 10-15 | 0 |
| 60-69 | | 60 | 30 | 45 | 25 | 20 | 15 | 0 | 10-15 | 0 |
| 70-79 | | 70 | 35 | 50 | 25 | 25 | 20 | 0 | 10-15 | 0 |
| 80 or more | | 80 | 40 | 55 | 30 | 25 | 20 | 0 | 10-15 | 0 |

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

$P_2O_{5\ rec}$ = [1.071 – (0.054) (Bray P, ppm)] (Expected Yield)

$P_2O_{5\ rec}$ = [1.071 – (0.067) (Olsen P, ppm)] (Expected Yield)

*Table 63. Potash fertilizer guidelines for wheat production in Minnesota.*

| | Potassium (K) Soil Test, ppm* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Expected | 0-40 | | 40-80 | | 80-120 | | 120-160 | | 160+ |
| Yield | Drill | Bdcst | Drill | Bdcst | Drill | Bdcst | Drill | Bdcst | |
| bu./acre | - - - - $K_2O$ to apply (lb./acre) - - - - | | | | | | | | |
| 40-49 | 105 | 55 | 75 | 40 | 45 | 25 | 0 | 15-20 | 0 |
| 50-59 | 130 | 65 | 95 | 50 | 55 | 30 | 0 | 15-20 | 0 |
| 60-69 | 155 | 80 | 110 | 55 | 65 | 35 | 0 | 15-20 | 0 |
| 70-79 | 180 | 90 | 125 | 65 | 75 | 40 | 0 | 15-20 | 0 |
| 80 or more | 190 | 95 | 135 | 70 | 80 | 40 | 0 | 15-20 | 0 |

** Use the following equation if a potash guideline for a specific expected yield and a specific P soil test is desired.*

$K_2O_{\ rec}$ = [2.710 – (0.017) (K Soil Test)] (Expected Yield)

Suggestions for Cu use are summarized in Table 64.

The suggestions in Table 64 are for organic (peat) soils only. The use of Cu in a fertilizer program is not currently suggested when wheat is grown on mineral soils.

*Table 64. Suggestions for use of copper for wheat grown on an organic soil.*

| Copper | Broadcast | | Foliar Spray | |
|---|---|---|---|---|
| Soil Test* | Copper | Copper Sulfate | Copper | Copper Sulfate |
| | - - - - lb. Cu/acre to apply - - - - | | | |
| 0-2.5 (Low) | 6-12 | 24-28 | 0.3 | 1.2 |
| 2.6-5.0(Marginal) | 6 | 24 | 0.3 | 1.2 |
| > 5.0 (Adequate) | 0 | 0 | 0 | 0 |

** Copper is extracted by the DTPA procedure.*

## Chloride

Research in South Dakota has shown that spring wheat and winter wheat can respond to chloride fertilization. Collection of soil from a depth of 0 to 24 inches is required for a chloride recommendation. The established levels for chloride are listed below.

| Chloride Soil Test | Relative Level |
|---|---|
| lb./acre 2 ft soil test | |
| 0-30 | Low |
| 31-60 | Medium |
| 61 + | High |

The chloride guideline is calculated by subtracting the amount of chloride measurement at a depth of 0 to 2 feet from 60. Any chloride should be broadcast and incorporated before seeding. Seed placement of chloride is not superior to broadcast application. Chloride is most economically applied by using muriate of potash (0-0-60).

### Other Micronutrients

Research from throughout Minnesota has shown that magnesium, calcium, iron, boron, zinc, and manganese are not needed in fertilizer programs. Most soils are able to supply ample amounts of these nutrients to a high-yielding wheat crop.

## WILDLIFE FOOD PLOTS

### Soil pH and Liming

Maintaining an optimum soil pH can be critical for the growth and development of many crops. Legumes such as alfalfa and alsike clover require higher soil pH levels than other crops. Liming guidelines are given in Tables 1 and 2. Many soils where food plots are established have a history of forest vegetation. These soils tend to have low soil pH levels. In these cases, a soil test will typically indicate a need for lime application. Since liming a soil requires 2 to 3 tons of material per acre, consideration must be given to determine whether it is feasible to haul and apply lime to areas where food plots are established. Grasses and red clover will typically grow well when soil pH is less than 6.0. Selecting tolerant plant species is critical. Since most crops for wildlife food plots are not grown for maximum yield, liming rates could be reduced or eliminated. If equipment is available for lime application, lime should be applied prior to establishment when it can be incorporated. If lime can be applied, it is suggested that enough should be broadcasted to raise the pH of the soil to 6.0.

*Table 65. Lime guidelines for mineral soils when the soil pH is less than 6.0. The rates suggested should raise the pH to 6.0.*

| SMP | Area 1 | | Area 2 | |
|---|---|---|---|---|
| Buffer Index | ENP | Ag Lime * | ENP | Ag Lime * |
| | lb./acre | ton/acre | lb./acre | ton/acre |
| 6.8 | 2000 | 2.0 | 0 | 0 |
| 6.7 | 2000 | 2.0 | 0 | 0 |
| 6.6 | 2000 | 2.0 | 0 | 0 |
| 6.5 | 2500 | 2.5 | 0 | 0 |
| 6.4 | 3000 | 3.0 | 2000 | 2.0 |
| 6.3 | 3500 | 3.5 | 2000 | 2.0 |
| 6.2 | 4000 | 4.0 | 2000 | 2.0 |
| 6.1 | 4500 | 4.5 | 2000 | 2.0 |
| 6.0 | 5000 | 5.0 | 2500 | 2.5 |

** These are approximate guidelines based on the average ENP value of ag lime. An ENP of 1,000 Lb. per ton is an average value for ag lime (crushed limestone) in Minnesota.*

### Nitrogen Management

Optimum nitrogen management is critical not only to increase plant growth but also to maintain plant establishment on a year to year basis. Legumes, such as well nodulated alfalfa and clover, can produce enough nitrogen to satisfy the plants requirements. Plants such as grasses do not produce their own nitrogen, so fertilizer nitrogen should be applied under these circumstances. Nitrogen can be applied in a single surface application at or prior to rapid plant growth periods. The full recommended nitrogen rate may not be needed. The amount will depend on the time of planting and amount growth desired from the plants. For late plantings, nitrogen rates can be cut back considerably. A minimum rate of 30 lbs of N is suggested for maintaining stand with a maximum application of no more than 60 lbs of N.

### Phosphorus and Potassium

Current phosphate guidelines are listed in Table 66 for separate food plot plant mixtures. Guidelines for potash use are in Table 67. The rates listed are appropriate for broadcast application. Current research on P and K management in food plots is limited. However, if a crop is not harvested, P and K taken up by the plants will be recycled for the next season's use and therefore not lost through the removal of crop material. Current guidelines for individual crops consider maximum economic yield. For wildlife food plots, it is suggested that rates be reduced for individual crops since economic yield is not a consideration.

*Table 66. Phosphate fertilizer suggestions for wildlife food plots in Minnesota.*

| | | Phosphorus (P) Soil Test, ppm | | | | |
|---|---|---|---|---|---|---|
| Crop Mixture | Bray: | 0-5 | 6-10 | 11-15 | 16-20 | 21 + |
| | Olsen: | 0-3 | 4-7 | 8-11 | 12-15 | 16 + |
| | | - - - - $P_2O_5$ to apply (lb./acre) - - - - | | | | |
| Corn/Forage Brassicas | | 25 | 20 | 15 | 0 | 0 |
| Grass | | 25 | 20 | 15 | 0 | 0 |
| Legume/Grass | | 35 | 25 | 15 | 0 | 0 |
| Oat/wheat/rye | | 35 | 25 | 15 | 0 | 0 |
| Soybean | | 30 | 15 | 0 | 0 | 0 |
| Sugar beet/turnip | | 35 | 25 | 15 | 0 | 0 |

*Table 67. Potash fertilizer suggestions for wildlife food plots in Minnesota.*

| | Potassium (K) Soil Test, ppm | | | | |
|---|---|---|---|---|---|
| Crop Mixture | 0-40 | 41-80 | 81-120 | 121-160 | 161 + |
| | - - - - $K_2O$ to apply (lb./acre) - - - - | | | | |
| Corn/Forage Brassicas | 60 | 40 | 25 | 0 | 0 |
| Grass | 40 | 30 | 20 | 0 | 0 |
| Legume/Grass | 40 | 30 | 20 | 0 | 0 |
| Oat/wheat/rye | 40 | 30 | 20 | 0 | 0 |
| Soybean | 60 | 40 | 25 | 0 | 0 |
| Sugar beet/turnip | 40 | 30 | 20 | 0 | 0 |

### Secondary and Micronutrients

For most crops grown in wildlife food plots secondary or micronutrients should not be needed for optimal growth. In sandy soils a small amount of sulfur may be needed for legume and grass mixtures. In these cases 10-15 lbs sulfur per acre should be applied with the nitrogen application. Some nitrogen can be substituted with ammonium sulfate (21% N and 24% S) to provide sulfur for the plants. Gypsum can be surface applied to supply needed sulfur however gypsum DOES NOT have a liming effect on the soil.

## WILD RICE

### Nitrogen

As with most grains, N management is very important in obtaining high yields. Nitrogen deficiency is a common problem.

Wild rice paddies are very different from upland fields. Nitrate-N build up in groundwater caused by over fertilization is not a problem. Most N losses occur by the process of denitrification that produces $N_2$, which makes up 78% of the atmosphere. Dry urea, liquid ammonium fertilizers, or anhydrous ammonia are appropriate sources of N. Nitrate fertilizers are ineffective because of denitrification upon flooding.

Basal N is often applied in the fall. To maximize carryover of N to the following spring, application of basal N should be followed by flooding within 2 or 3 days. Fall flooding prevents oxidation of the ammonium forms of N to nitrate and the subsequent losses caused by denitrification when flooding occurs. When fall application is desired, but flooding is not possible, application should be made when soil temperatures are well below 50°F, preferably as close to freezing as possible.

Basal N can also be applied in the spring immediately before flooding. Both spring and fall N should be incorporated to minimize losses by the nitrification/dentrification process in the surface soil that can result in N losses. See Table 68 for N rates.

A minimum of one topdress application of 30 - 40 lb/ac of N as urea, applied by aircraft, is necessary for high yields. A second topdress is typically needed to maximize yields. A third application may be needed if no basal N was applied or basal N was lost by nitrification folowwed by denitrification. Drainage of paddy water should not occur for about 5 days after N application.

Field testing in mid June for soil ammonium N can be used to guide topdressing decisions. The SPAD chlorophyll meter or a color chart are also a useful aids in determining the timing and number topdress applications.

## Phosphorus

Phosphorus is an important nutrient for plant growth. In well-fertilized paddies, P accumulates over many seasons and P deficiency is now uncommon.

Phosphorus is the nutrient most limiting for nutrient for algal production in fresh waters, and hence, is of great concern in surface water quality. Phosphorus in paddies can move into surface waters both in the soluble form and as part of soil particles (by soil erosion). When phosphorus is surface applied, it can dissolve in paddy waters causing algal blooms. Incorporation of P fertilizer is very highly recommended and erosion from ditches, etc. should be minimized to prevent phosphorus from entering drainage waters.

Phosphorus can be applied in the fall or spring. It must be incorporated by plow down or injection. The rate of application should be determined by soil testing. When the Bray P 1 test exceeds 16 ppm, do not apply P. See Table 65.

If it is not possible to incorporate P it is best not to add any phosphorus fertilizer. The reserve P in the soil will normally be sufficient for good plant growth.

## Potassium

Potassium is required by wild rice both for high yield potential as well as helping in protection against some diseases.

Potassium at the levels applied to wild rice paddies is not an environmental concern.

Potassium can be applied in the fall or spring. Usually it is applied with the phosphorus, but, unlike phoshorus, incorporation of K is a necessity. See Table 65 for rates. Application of potassium with the topdress N is possible. This increases the late season uptake of K and might help prevent some diseases.

*Table 68. Guidelines for fertilization of wild rice.*

| Nutrient | Criteria | Organic Soils | Mineral Soils |
|---|---|---|---|
| | | Amount to apply (lb/ac-N) | |
| Nitrogen | | 25-40 | 70-100 |
| | Soil Test, Bray P-1 (ppm) | Amount to apply (lb/ac – $P_2O_5$) | |
| Phosphorus | 0-7 | 40-50 | 40-50 |
| | 8-15 | 20-30 | 20-30 |
| | 16+ | 0 | 0 |
| | Soil Test, K (ppm) | Amount to apply (lb/ac – $K_2O$) | |
| Potassium | 0-50 | 120 | 80 |
| | 51-100 | 90 | 50 |
| | 101-150 | 40 | 30 |
| | 151 + | 0 | 0 |

## Water Drainage Before Harvest

Nitrogen in the water can be detected in wild rice fields for 3 to 5 days after fertilization but at drainage time most nutrients in the water have been consumed the plants. However, to avoid erosion of drainage ditches, the water should be released slowly during a one to two week period before harvest. The soil particles from erosion can carry phosphorus, in addition to the any soluble P, into surface waters. Drainage ditches should be stabilized with grasses if possible.

**AUTHORS**
Daniel E. Kaiser, Extension Soil Scientist
John A. Lamb, Extension Soil Scientist
Roger Eliason, Director, University of Minnesota Soil Testing Laboratory

**For more information, visit us online:**
**www.extension.umn.edu/nutrient-management/**

BU-06240-S
Revised 2011



UNIVERSITY OF MINNESOTA
EXTENSION
Driven to Discover℠