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Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin

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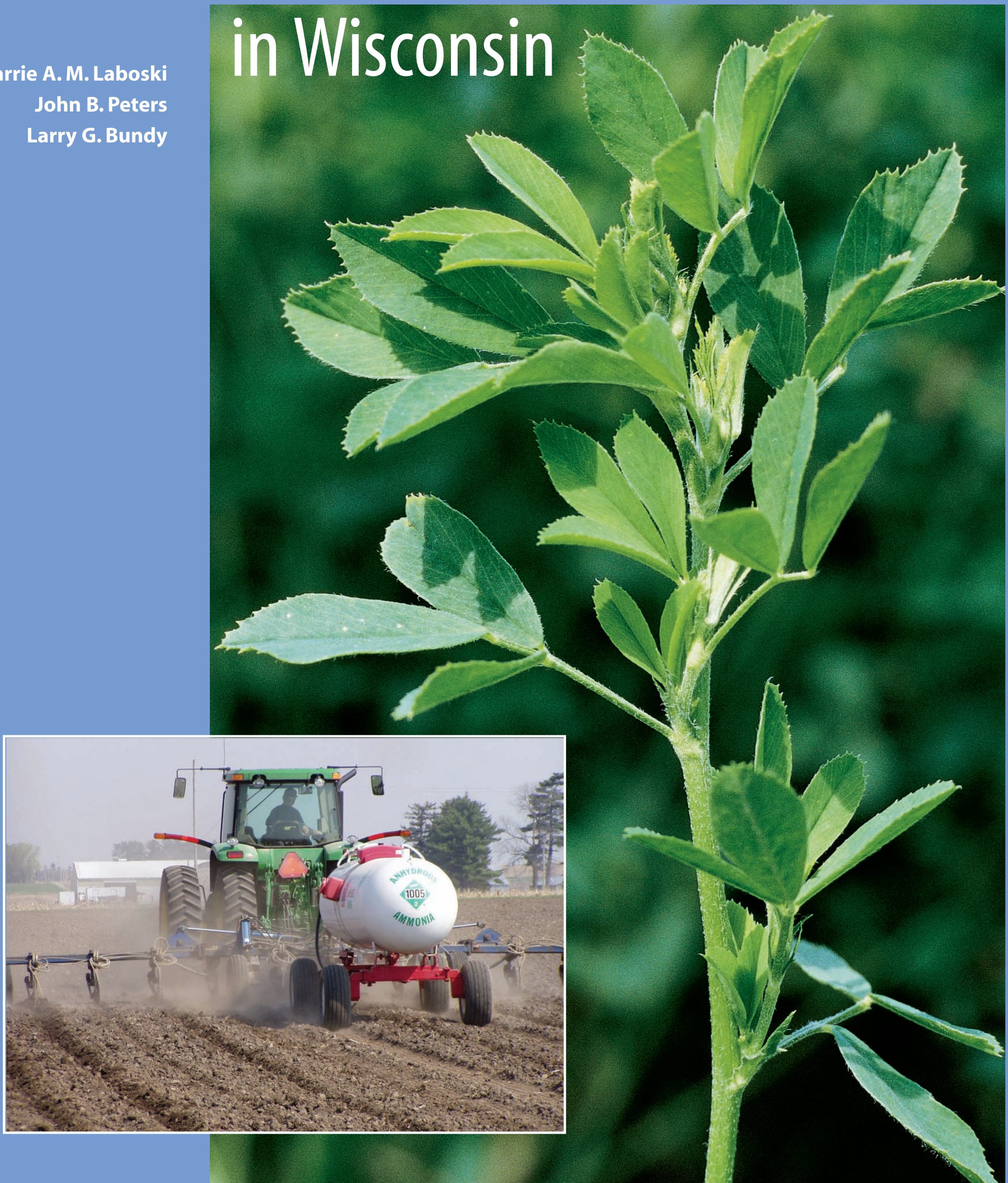

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Preface

The Wisconsin soil testing program and nutrient application guidelines were originally developed in the early 1960s. The guidelines have since been revised several times to reflect research advances, additional correlation and calibration data, and shifts in philosophical viewpoint. The latest revision incorporates additional research data, the maximum return to nitrogen (MRTN) philosophy for corn nitrogen rate guidelines, presidedress nitrate test (PSNT) and preplant nitrate test (PPNT) concepts. The Wisconsin routine farm soils (RFS) computer program, which is used by Wisconsin Department of Agriculture, Trade, and Consumer Protection certified soil testing laboratories to generate a recommendation, has been updated to reflect the changes in this document. The guidelines in this publication have been incorporated into the nutrient management planning software called SNAP-Plus (http://www.snapplus.net/).

Introduction — Chapter 1

Over 200,000 soil samples are analyzed in Wisconsin each year, and the results of these tests guide Wisconsin farmers in the use of lime and nutrient applications. The appropriate use of lime, fertilizer, manure, and other nutrient sources significantly increases Wisconsin farm income. Just as importantly, following nutrient application guidelines prevents over-application of nutrients. This, in turn, enhances profitability and reduces the potential for environmental degradation.

The importance of a good soil testing program is well recognized by most farmers. Soil testing has some limitations, but it is still the best tool available for predicting lime and fertilizer needs. With representative sampling, soil tests can accurately predict lime, phosphorus, and potassium requirements. Soil tests can also serve as a guide for nitrogen and some of the secondary nutrients and micronutrients; however, these require special testing and, in the case of nitrogen, special sampling systems.

The underlying goal for Wisconsin's recommendation program is to supply enough nutrients to the crop for optimum growth throughout the season. Because nutrient demands are not uniform throughout the season, an adequate supply must be available during the period of peak demand. The Wisconsin program defines the "critical" level as the cutoff between the "optimum" and "high" soil test levels. If the nutrient supply drops below the critical level, growers face economic losses from reduced yields or poor crop quality. If the supply exceeds the critical level, there is an increased risk of mobile nutrients moving into the ground water and surface water. In addition, there is no profit in applying nutrients that will not be used. The Wisconsin nutrient application guidelines help a grower to anticipate crop needs and monitor nutrient availability.

The goals of Wisconsin's soil testing program are to: (1) provide an accurate index of the level of available nutrients in the soil; (2) indicate the degree of nutrient deficiency that may exist for the various crops grown; (3) suggest how the deficiency might be corrected; and (4) provide the results in an understandable and meaningful way so that the farmer can make the appropriate decision as to what nutrients to add.

Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin describes how to interpret soil test results, provides nutrient application guidelines, and outlines the assumptions underlying the guidelines.

Chapter 2 — Sampling soils for testing

A soil test is the only practical way of determining whether lime and fertilizer are needed for a specific crop. However, if a soil sample does not represent the general soil conditions of the field, the recommendations based on this sample may be misleading. An acre of soil to a 6-inch depth weighs about 1,000 tons, yet less than 1 ounce of soil is used for each test in the laboratory. Therefore, it is very important that the soil sample is representative of the entire field. Before collecting the soil samples the overall approach of the nutrient management program should be determined. This will affect the number of samples needed and method by which samples will be taken. Specifically, will nutrient and lime applications be made at a single uniform rate for the whole field being tested or will applications be made at variable rates to field areas that have been identified as having different soil test levels?

Goals of a soil sampling program

When sampling soils for testing and obtaining fertilizer and lime recommendations, the most common objectives are to:

1. Obtain samples that accurately represent the field from which they were taken.
2. Estimate the amount of nutrients that should be applied to provide the greatest economic return to the grower.
3. Estimate the variation that exists within the field and how the nutrients are distributed spatially.
4. Monitor the changes in nutrient status of the field over time.

Selecting a soil sampling strategy

Before selecting the sampling strategy, consider analytical costs, time and equipment available, field fertilization history, and the likelihood of response to fertilization.

Sampling fields for a single whole field (uniform) recommendation

With conventional sampling, you will receive a single set of nutrient and lime application guidelines that are based on sample averages. The sampling guidelines in Table 2.1 are based on when the field was last tested (more or less than 4 years ago) and whether the fields were responsive or non-responsive the last time they were tested. The responsive range is considered to be where either soil test phosphorus or potassium levels are in the high (H) category or lower. A non-responsive field is one where both soil test phosphorus and potassium levels are in the very high (VH) or excessively high (EH) categories.

Each sample should be made up of a minimum of 10 cores, to assure accurate representation of the nutrient needs of the field. Research has shown that taking 10–20 cores provides a more representative sample of the area than when samples are made up of fewer cores. Use a W-shaped sampling pattern (as shown in Figure 2.1) over the whole area that is represented by the sample when gathering soil cores to make a composite sample. Be sure to thoroughly mix the cores before placing approximately 2 cups in the sample bag.

For best results, submit multiple samples for all fields. When at least three samples are provided, the Wisconsin nutrient application guidelines program will remove samples that are significantly higher than the field average and recalculate an adjusted average for the field. This ensures that no part of the field is under-fertilized. Where only one or two samples are submitted for a field, no sample can be discarded, whereas one sample can be discarded if three or four samples are submitted, and up to two samples may be discarded from fields having five or more samples. It is not appropriate to vary nutrient application rates across sampling areas when using this soil sampling scheme.

Sampling fields for site-specific management

Site-specific management requires a distinct picture of the magnitude and location of soil test variability. Sampling soils for site-specific management usually involves taking many more composite samples than sampling for a single recommendation. A global positioning system (GPS) is used to record the geographical coordinates of each sample. This information is used to generate an application map by using various mathematical techniques to interpolate the nutrient application rate between sampling points. Using variable rate application technology, these fields can be managed more intensively than the conventional approach of one fertilizer and lime rate per field. A careful evaluation of the economics of this intensive of a sampling system needs to be done before proceeding.

When using a site-specific approach to soil sampling, sample handling and testing are similar to the traditional system, but recommendations may vary from one part of the field to another, and these areas must be managed separately to realize the potential advantages of intensive soil sampling.

Several sampling strategies can be used to guide variable-rate fertilizer and lime applications. Grid sampling uses a systematic approach that divides the field into squares of approximately equal size (grid cells). The sampling technique used is known as grid-point sampling. A grid-point sample

Figure 2.1. Recommended W-shaped sampling pattern for a 15-acre field. Each sample should be composed of at least 10 cores.

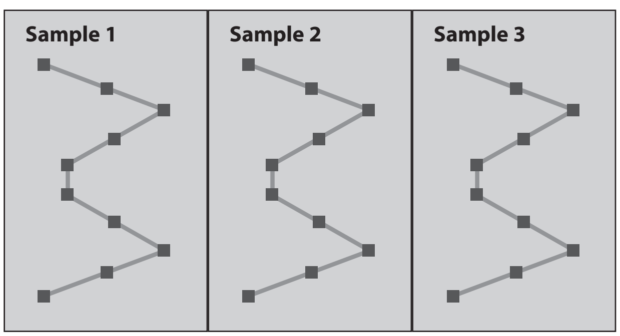


Table 2.1. Recommended sample intensity for uniform fields.

Field characteristics	Field size (acres)	Suggested number of samples [a]
Fields tested more than 4 years ago OR fields testing in the responsive range	All fields	1 sample/5 acres
Non-responsive fields tested within past 4 years	5–10	2
	11–25	3
	26–40	4
	41–60	5
	61–80	6
	81–100	7

[a] Collect a minimum of 10 cores per sample.

consists of at least 10 cores collected from a small area (10-foot radius) around a geo-referenced point. When using a grid sampling approach, Wisconsin research recommends a sampling strategy based on an unaligned systematic grid (Figure 2.2). Sampling points should be unaligned because sampling in a uniform grid arrangement may lead to biased results if aligned with row patterns. Fields that have soil test phosphorus and potassium levels in the non-responsive categories should be grid-point sampled on a 300-foot grid. This is equivalent to one soil sample for every 2 to 2.5 acres. Where there is no information about the phosphorus or potassium status of the field or where previous tests were in the responsive range, a 200-ft grid size should be used. This is equivalent to approximately one soil sample per acre. These small grid cell sizes are needed to be able to adequately characterize the variability in soil fertility and are based on Wisconsin research. A larger grid cell size (such as 5 acres) may not adequately describe the field variability and may limit the potential economic benefits of site-specific management.

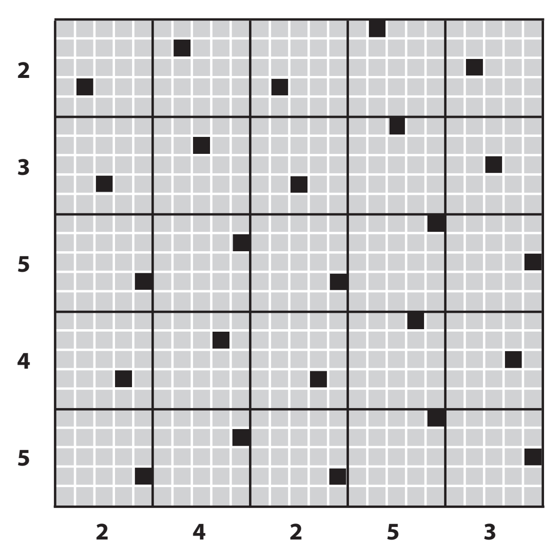
Other considerations in selecting a sampling strategy

The sampling strategy selected must also be appropriate for the field size and topography.

Contour strips — On contour strip fields, sample each strip separately if it is approximately 5 acres or more in size, following the sampling intensity guidelines provided in Table 2.1. Cores from two or three small strips that have identical cropping and management histories may be combined following these same recommended sampling intensity guidelines. Using a grid point sampling approach on contour strips or small fields is not appropriate, regardless of grid cell size. This is because a grid technique may result in many soil samples being collected from one contour strip, but none in other strips; additionally grid point samples may be on the edge of the strips and not adequately represent the strip.

Five-acre grid point sampling — The 5-acre grid point sampling system for whole field management recommendations has recently become popular with soil samplers because it takes less time to collect cores as compared to the traditional W pattern. Another advantage of this approach is its ability to track changes in soil test levels over time, because soil samples are collected from the same geo-referenced (GPS)

Figure 2.2. An example of an unaligned grid pattern for sampling site-specific fields.



point each time the field is sampled. Five-acre grid point sampling can likely be used in some situations, but not in others. For example, in fields that were soil sampled within the past 4 years and which were in the non-responsive range, averaging the soil test results from 5-acre grid point sampling is reasonable. This is because there previously had not been a fertilizer recommendation on these fields and some variability at excessively high soil test levels does not change the fact that no fertilizer was recommended. For fields that were sampled more than 4 years ago or where past soil test results were in the responsive range, 5-acre grid point sampling may not be the best choice of sampling techniques. This is because 5-acre grid point sampling may not adequately represent the variability within a field; and a comparatively small change in soil test level of 5–10 ppm could mean a large change in the amount of nutrients recommended. For small fields and contour strips, taking a few 5-acre grid point samples in each field and averaging them likely does not provide a very representative sample of the field. Additionally, the total number of samples may be small enough that none of them can be eliminated from the field average if it appears that one is an outlier.

Smart (zone or directed) sampling — Another approach gaining support among researchers is smart sampling, also known as directed or management zone sampling. This approach uses information that has been collected using other precision agricultural technologies such as yield maps, aerial photographs of bare soil or crop canopy, or soil electrical conductivity measurements. Directed sampling evaluates the spatial distribution of several factors that may influence nutrient availability and crop productivity to help define sampling areas with similar characteristics. With previous comments in mind, either the W pattern or grid-point method can be used to collect samples within management zones. If the results of grid or management zone sampling do not warrant variable-rate application (for example, relatively little between-sample variation), average them to determine the appropriate single-rate treatment.

Procedures for taking soil samples

When to take soil samples

Take soil samples at any convenient time. Studies examining the effect of sampling time on soil test results suggest that test values for pH, phosphorus (P), and potassium (K) are typically slightly higher in early spring samples than in fall samples. To receive your recommendations early enough to enable you to apply the lime and fertilizer needed, it may be best to sample in the fall. Another benefit of fall testing is that fertilizer prices are more likely to be discounted then. Hayfields can be sampled after any cutting. Regardless of when you sample, it is best to be consistent from one year to the next.

Winter sampling, or sampling when the soil is frozen, is permissible only when it is possible to take a uniform boring or core of soil to the appropriate depth. This may require using a portable power boring tool. Using a pick or spade to remove a few chunks of frozen soil from the surface will give inaccurate results.

How to take soil samples

Certain government agency programs require nutrient management plans prepared according to the current USDA Wisconsin Natural Resources Conservation Service (NRCS) nutrient management standard (590). Soil sampling and testing procedures and nutrient application rates based on these soil tests must be consistent with the provisions of the 590 standard to be eligible for many cost-sharing programs. These provisions currently include following the soil sampling techniques just outlined and which are contained in Extension publication *Sampling Soils for Testing* (A2100), soil testing by a Wisconsin Certified Laboratory, and use of nutrient application rates consistent with the guidelines contained in this publication.

The following steps will help you take full advantage of the Wisconsin nutrient application guidelines and must be followed to be consistent with the 590 standard.

Use a sampling probe or auger to take samples. You can obtain these tools on loan from most county Extension offices or fertilizer dealers.

1. If manure or crop residues are on the surface, push them aside to keep from including them in the soil sample.
2. Insert the probe or auger into the soil to plow depth or at least 6 inches. To aid year-to-year comparisons, it is important to take repeated samplings from the same field to exactly the same depth.
3. Take at least 10 soil cores or borings for each composite sample and, preferably, at least two composite samples for every field. For non-responsive fields greater than 5 acres in size, obtain, at a minimum, the number of samples specified in Table 2.1. For responsive fields, as well as all fields that have not been sampled in the past 4 years, take one composite sample for every 5 acres.
4. Avoid sampling the following:
   - Dead furrows or back furrows.
   - Lime, sludge, or manure piles.
   - Animal droppings.
   - Near fences or roads.
   - Rows where fertilizer has been banded.
   - Eroded knolls.
   - Low spots.
   - Where stalks or large bales were stacked.
   - Headlands.
   - Areas that vary widely from the rest of the field in color, fertility, slope, texture (sandy, clayey, etc.), drainage, or productivity. If the distinctive area is large enough to receive lime or fertilizer treatments different from the rest of the field, sample it separately.
5. Thoroughly mix the sample, then place about 2 cups of soil in a sample bag.
6. Identify the bag with your name, field identification, and sample number.
7. Record the field and sample location on an aerial photo or sketch of the farm and retain for your reference. Record the GPS coordinates, if applicable.
8. Fill out the soil information sheet. A completely and carefully filled out information sheet will provide the most accurate nutrient recommendations.

Always include a soil test information sheet when submitting soil samples to a laboratory for testing. The UW Soil and Plant Analysis Lab soil test information sheet can be found online at: http://uwlab.soils.wisc.edu/madison/files/rfs_front.pdf.

Provide the soil name and field history whenever possible for more accurate recommendations. Information about legume crops previously grown on the soil and manure application history is essential for proper nutrient crediting from these sources. Include soil names from county soil survey reports or individual farm conservation plans. For assistance obtaining this information, contact your county Extension agent, Natural Resource Conservation Service (NRCS) district conservationist, or the Land Conservation Committee (LCC).

How often to sample

Most fields should be retested at least every 4 years to monitor soil fertility levels so that nutrient deficiencies are prevented and excess nutrient accumulation is avoided. Crop nutrient removals over a 4-year period in most cropping systems will not change soil test levels enough to affect recommended nutrient application rates. Exceptions include the sands and loamy sands, which should be tested every 2 years. Also, depending on the initial soil test phosphorus and potassium levels, cropping systems such as high-yielding corn silage or alfalfa may require more frequent testing to adequately monitor changes in soil test levels.

What to do with soil samples

The soil samples and a completed soil information sheet can be taken to your county Extension office for forwarding to certified soil testing laboratory. Alternatively, samples can be sent directly to the soil testing laboratory or delivered in person.

To receive nutrient application rate guidelines consistent with those found in this publication, submit your soil samples to one of the Wisconsin certified laboratories. The College of Agricultural and Life Sciences, University of Wisconsin-Madison and the

University of Wisconsin-Extension, through the Department of Soil Science operates soil testing laboratories at Madison and Marshfield. Several private laboratories are also certified, and are listed at http://uwlab.soils.wisc.edu/wdatcp.htm. To become certified, laboratories must use the soil testing methods and nutrient application rate guidelines specified by the Wisconsin Department of Agriculture, Trade and Consumer Protection (WDATCP). Certified laboratories must also meet quality control standards through periodic analysis of quality control soil samples.

To have your soil tested by the university, send your samples to either of the laboratories listed below:

Soil and Plant Analysis Laboratory
8452 Mineral Point Road
Verona, WI 53593-8696
(608) 262-4364

Soil and Forage Analysis Laboratory
8396 Yellowstone Drive
Marshfield, WI 54449-8401
(715) 387-2523

Tillage system considerations when sampling

Moldboard plowing. Sample to the depth of tillage.

Chisel plowing and offset disking. Take soil samples to 3/4 of the tillage depth. When possible, take soil samples before spring or fall tillage. Sampling before tillage lets you determine the sampling depth more accurately and you can avoid fertilizer bands applied for the previous crop.

Till-plant and ridge tillage. Sample ridges to the 6-inch depth and furrows (between rows) to a depth of 4 inches. Combine equal numbers of soil cores from ridges and furrows to make up the composite sample.

No-till. Fields that have not been tilled for 5 years or more may develop an acid layer on the surface from the use of nitrogen fertilizer. This acid layer could reduce the effectiveness of triazine herbicides. Unincorporated phosphorus (P) and potassium (K) are also likely to build up in the surface soil. If an acid layer is suspected, take a separate sample to a depth of only 2 inches. When sending the soil to the lab, indicate that the sampling depth was only 2 inches. This sample will be tested for pH only, unless P and K are specifically requested. For fertilizer recommendations, take a separate sample to a depth of 6–7 inches. Fertilizer recommendations require this sampling depth because fertilizer calibration studies are based on plow-depth sampling. Sample between rows to avoid fertilizer bands.

3 Chapter — Soil test procedures

The routine soil testing program for laboratories using the Wisconsin soil test recommendation program includes soil pH, organic matter content, lime requirement (buffer pH), and extractable phosphorus and potassium. In addition, special tests may be requested for nitrate-nitrogen, calcium, magnesium, sulfur, boron, manganese, and zinc. Soil tests for copper, iron, molybdenum, and chlorine have not been calibrated to crop response in Wisconsin; these nutrients are rarely deficient in Wisconsin soils.

Several other tests can be performed on request. These tests include physical analysis for particle size distribution (% sand, % silt, % clay), exchangeable sodium, soluble salts, total nitrogen, inorganic nitrogen, total organic carbon, and heavy metals (arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, zinc).

In Wisconsin, a soil testing laboratory must be certified by the Wisconsin Department of Agriculture, Trade, and Consumer Protection (WDATCP) if results are to be used in nutrient management planning or related to any government cost sharing program. A current list of the Wisconsin Certified Laboratories can be found at http://uwlab.soils.wisc.edu/wdatcp.htm. Table 3.1 briefly describes the procedures used for each soil test performed at University of Wisconsin laboratories and other WDATCP-approved laboratories.

Table 3.1. Analytical procedures for soil tests performed at University of Wisconsin-Extension laboratories and Wisconsin DATCP-approved private laboratories.

Soil test	Procedures [a]
Soil pH	Prepare a 1:1 soil to water mixture and measure the pH with a glass electrode.
Buffer pH (BpH)	Prepare a 1:1:1 soil:water:Sikora buffer mixture and measure the pH with a glass electrode.
Phosphorus (P)	Extract with Bray 1, develop color and measure with a photoelectric colorimeter.
Potassium (K)	Extract with Bray 1, and measure with atomic absorption or flame photometer.
Organic matter (OM)	Loss of weight on ignition at 360°C for 2 hours. OM = 0.07 + 0.89 (LOI) [b]
Calcium (Ca), magnesium (Mg), sodium (Na)	Extract with neutral 1 $\underline{N}$ [c] ammonium acetate and measure with atomic absorption or flame photometer.
Estimated cation exchange capacity (CEC)	Calculate from soil test levels for Ca, Mg, K; $\text{Est CEC} = \left(\frac{\text{ppm Ca}}{200} + \frac{\text{ppm Mg}}{122} + \frac{\text{ppm K}}{391}\right) \times \frac{\text{5 grams}}{\text{wt of soil in 5-gram scoop}}$
Sulfur (S)	Extract with 500 ppm phosphorus in acetic acid, develop turbidity, and measure with a photoelectric nephelometer.
Boron (B)	Extract with hot water, develop color, and measure with a photoelectric colorimeter.
Manganese (Mn)	Extract with 0.1 $\underline{N}$ [c] phosphoric acid and measure by atomic absorption.
Zinc (Zn)	Extract with 0.1 $\underline{N}$ [c] hydrochloric acid and measure by atomic absorption.
Nitrate-nitrogen (NO_3^--N)	Extract soil with 2 $\underline{N}$ [c] KCl and analyze by flow injection.
Physical analysis (% sand, silt, clay)	Prepare 50 or 100 g soil with dispersing solution and measure with hydrometer.
Soluble salts	Prepare 1:2 soil to water mixture and measure with conductivity bridge.

[a] Detailed descriptions of the procedures can be found at: http://uwlab.soils.wisc.edu/.

[b] LOI = percent weight loss on ignition,

[c] $\underline{N}$ = normal solution

Soil test values for phosphorus and potassium are interpreted from very low (VL) to excessively high (EH). The category is based on the soil test value in combination with the crop demand level. The probability of a yield response to applied nutrients is much greater for the very low and low categories than for the high, very high and excessively high categories. Probability of a response to fertilizer applied at each soil test category is described in Table 3.2.

Table 3.2. Codes and descriptions of soil test interpretation categories.

——Category——			Probability of a yield increase to applied nutrients (%)
Name	Symbol	Description	
Very low	VL	Substantial quantities of nutrients are required to optimize crop yield. Buildup should occur over a 5- to 8-year period. Response to secondary or micronutrients is likely or possible for high or medium demanding crops, respectively.	>90
Low	L	Somewhat more nutrients than those removed by crop harvest are required. Response to secondary or micronutrients is possible for high demanding crops, but unlikely for medium or low demanding crops.	60–90
Optimum	Opt	This is economically and environmentally the most desirable soil test category. Yields are optimized at nutrient additions approximately equal to amounts removed in the harvested portion of the crop. Response to secondary or micronutrients is unlikely regardless of crop demand level.	30–60
High	H	Some nutrients are required, and returns are optimized at rates equal to about one-half of nutrient removal by the crop.	5–30
Very high	VH	Used only for potassium. Soil tests are above the optimum range and gradual drawdown is recommended. Approximately one-fourth of nutrient removal is recommended.	2–5
Excessively high	EH	No fertilizer is recommended for most soils since the soil test level will remain in the non-responsive range for at least two to three years. On medium- and fine-textured soils, a small amount of starter fertilizer is advised for some crops (for more detail, see Chapter 10 Starter Fertilizer).	<2

Chapter 4 — Soil and crop information

Several key components are necessary to customize a fertilizer and lime recommendation to each field's needs. The first component, a current soil test, has already been discussed in Chapter 2 Sampling Soils for Testing. Two other necessary components include specific information about the soil and crops to be grown.

Soil

Soil groups are based upon a soil's texture (percentage of sand, silt and clay), clay mineralogy, and organic matter content. Soil groups are used to help interpret phosphorus and potassium soil test levels. There are six primary soil groups in Wisconsin; five for mineral soils (A, B, C, D, and E) and one for organic soils (O). The approximate location of each soil group is shown in Figure 4.1. There is one secondary soil group which is used only for interpreting soil test phosphorus levels and encompasses mineral soils with a pH ≥ 7.5 and organic matter content ≤ 10 %; these are group X soils. Group X was developed as a means for identifying soils which are believed to contain enough free calcium carbonate that the Bray 1 soil test extractant may be neutralized and result in an under-estimation of plant available phosphorus. A soil may belong to group X for soil test phosphorus interpretation, but will belong to one of soil groups A–E for soil test potassium interpretation. The primary soil group alone indicates the soil nutrient buffer capacity.

Table 4.1 provides the soil group for each mapped soil series in Wisconsin. Also included in this table are other properties that are unique to each soil series, including subsoil sulfur code and corn and alfalfa yield potential codes. The subsoil sulfur code is a relative ranking of the amount of sulfur contained in the subsoil and is used in determining a sulfur recommendation. Corn and alfalfa yield potentials are relative rankings of a soil's ability to produce high yields of each crop. Several factors were involved in determining the yield potential of each soil series including: water holding capacity, drainage class, depth of root zone, and length of growing season.

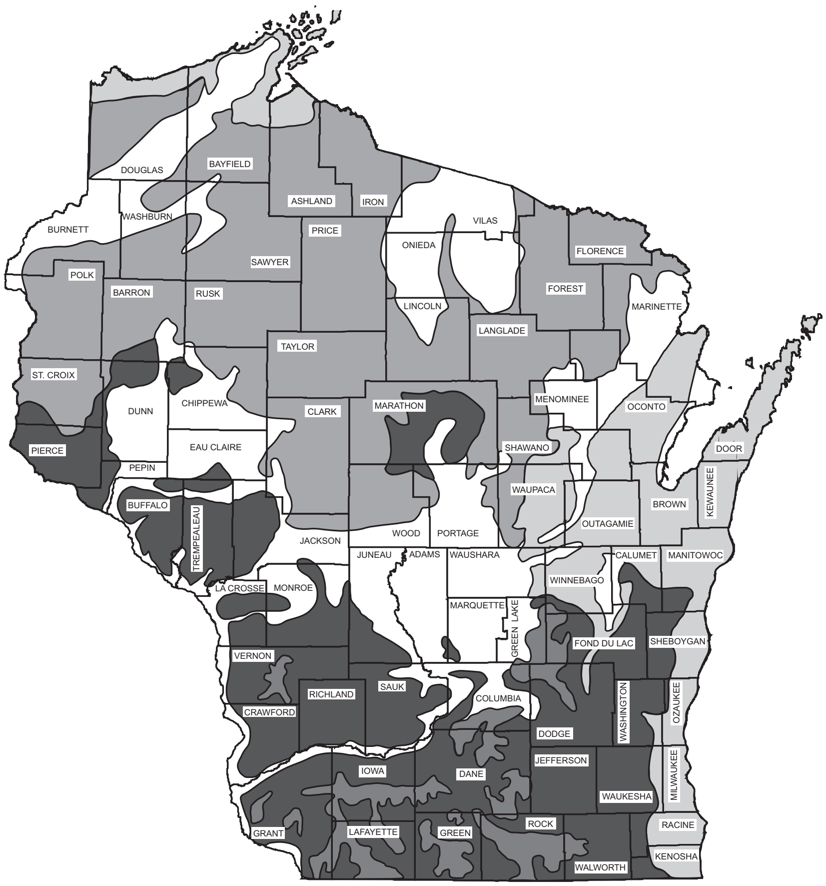
If a soil series name is not known, a more generic fertilizer and lime recommendation can be made using county-based information. A soil group can be determined using Table 4.2.

Crops

There are four key items unique to each crop which impact phosphorus and potassium fertilizer recommendations and lime requirement.

1. **The phosphorus and potassium demand level for the crop.** Each crop requires varying levels of available phosphorus and potassium to optimize yield. Crops are placed into one of six phosphorus and potassium demand levels based on their relative nutrient needs: (1) corn; (2) soybeans and low demand level field crops; (3) alfalfa, corn silage, irrigated field crops, and low demand level vegetable crops; (4) red clover and medium demand level field crops; (5) high demand level vegetable crops; and (6) potatoes. Table 4.3 identifies the specific demand levels for various crops.
2. **The amount of phosphate and potash removed in the harvested portion of the crop** is used to establish the amount of fertilizer to apply. Table 4.3 lists the amount of P_2O_5 and K_2O removed in pounds per unit of yield.
3. **The yield goal for each crop** is required to determine the application rate of phosphate and potash fertilizer for all crops and the nitrogen fertilizer rate for potatoes. Realistic yield goals should not be higher than 10 to 15% above the previous 3–5 year field average. Typical yield ranges and the moisture content at which yield is reported are provided in Table 4.3. If the yield level for corn or alfalfa is not known for a particular field, use the county-based corn and alfalfa yield potentials provided in Table 4.2. To assign a yield goal to a yield potential use the midpoint of the range provided in Table 4.4.
4. **Target pH** is the optimal pH for production of a particular crop. Target pH is used to determine lime requirement and other pH adjustments. Refer to Table 4.3 for target pH values for various crops.

Figure 4.1. Approximate location of predominant soil groups.



Legend	Soil group	Description	OM (%)	pH	Hues [a] (color)	Texture code	Location
	A	Southern "forested" medium- and fine-textured soils	< 3.0	< 7.5	less pink	2	southern Wisconsin
	B	Southern "prairie" medium- and fine-textured soils	3.1-10.0	< 7.5	less pink	2	southern Wisconsin
	C	Red medium- and fine-textured soils	≤ 10.0	< 7.5	more pink	4	throughout state
	D	Northern medium- and fine-textured soils	≤ 10.0	< 7.5	less pink	2	northern and central Wisconsin
	E	Sandy coarse-textured soils (sands and loamy sands)	≤ 10.0	all	–	1	throughout state
	O	Organic soils (mucks and peats)	> 10.0	all	–	3	small pockets throughout state
	X	High pH soils [b]	≤ 10.0	≥ 7.5	–	–	throughout state

[a] Hues are relative to Munsell color 7.5YR.

[b] Used only with phosphorus recommendations.

Table 4.1. Codes assigned to Wisconsin soils for soil group, subsoil sulfur, and corn and alfalfa yield potentials.

Soil name	Soil number[a]	Soil group[b]	Subsoil sulfur code[c]	Yield potential code[d]	
				Corn	Alfalfa
Abbaye	1	D	L	4	4
Absco	2	E	L	4	4
Abscota	3	E	L	4	4
Ackmore	4	A	H	1	2
Adder	5	O	H	2	4
Adolph	6	D	L	4	4
Adrian	7	O	H	2	4
Aftad	8	D	M	3	3
Ahmeek	9	D	H	4	3
Akan	10	A	M	3	3
Alango	710	C	M	4	3
Alban	11	D	M	3	3
Alcona	12	D	M	3	3
Aldo	13	E	L	4	4
Algansee	14	E	L	4	4
Allendale	15	D	M	4	4
Allouez (See Elderon)					
Almena	16	D	H	3	2
Alpena	17	E	L	4	4
Alstad	18	D	M	3	3
Altdorf	19	D	M	3	4
Altoona (See Siouxcreek)					
Amasa	711	D	M	3	3
Amery	20	D	M	3	3
Amnicon	21	C	M	4	3
Angelica	22	C	L	3	3
Anigon	23	D	M	3	2
Ankeny	24	B	L	2	2
Annalake	25	D	M	3	3
Annriver	712	D	M	4	4
Antigo	26	D	M	3	2
Anton	27	C	M	4	3
Arbutus	28	E	L	4	4
Arenzville	29	A	L	1	1
Argonne	30	D	M	4	3
Arland	31	D	M	3	3
Arnheim	32	E	L	4	4
Ashdale	33	B	H	1	1
Ashippun	34	B	L	1	2
Ashkum	35	B	M	1	3
Ashwabay	36	E	L	4	4
Atterberry	37	A	M	1	2
Au Gres	38	E	L	4	3
Auburndale	39	D	M	3	3
Augwood	40	E	L	4	4
Ausable	713	E	L	4	4
Aztalan	41	B	M	1	2
Bach	42	C	L	3	3
Badriver	43	C	M	4	3
Balmoral	714	B	M	1	1
Banat	44	D	L	4	4
Baraboo	45	A	M	2	3
Barremills	700	B	M	1	1
Barrington (See Zurich)					
Barronett	46	D	M	3	3
Barry	47	B	M	2	3
Basco	48	B	M	3	3
Batavia	49	B	M	1	1
Bearpen	50	A	M	1	2
Beartree	715	D	L	4	4
Beauprey	51	C	M	3	4
Beaverbay	716	D	L	3	3
Beavercreek	701	A	L	4	4
Beecher	52	B	M	1	2
Bellechester	53	E	L	4	4
Belleville	54	E	L	3	4
Bellevue	55	B	M	2	2
Bergland	56	C	M	4	4
Bertrand	57	A	M	1	1
Beseman	58	O	H	4	4
Bevent (See Sultz)					
Bigisland	717	E	L	4	4
Billett	59	A	M	3	3
Billyboy	60	D	M	3	3
Bilmod	61	A	M	3	3
Bilson	62	A	M	3	3
Bjorkland	63	E	L	4	4
Blackhammer	774	A	M	1	2
Blackriver	64	D	M	3	3
Blomford (See Brevort)					
Blount	65	A	M	2	2
Bluffton	66	D	M	3	3
Boaz	67	A	M	2	2
Boguscreek	68	A	M	1	1
Bohemian	69	D	M	4	3
Bonduel	70	C	M	3	3
Boone	71	E	L	4	4
Boots	72	O	H	2	4

Table 4.1. Codes assigned to Wisconsin soils for soil group, subsoil sulfur, and corn and alfalfa yield potentials *(continued)*.

Soil name	Soil number[a]	Soil group[b]	Subsoil sulfur code[c]	Yield potential code[d]	
				Corn	Alfalfa
Boplain	73	E	L	4	4
Borea	74	C	M	4	3
Borth	75	C	M	3	2
Bowstring	718	O	H	4	4
Boyer	76	A	M	3	4
Braham	719	E	L	4	3
Brander	77	D	M	3	2
Branstad	78	D	M	3	2
Brems	79	E	L	4	4
Brennyville	702	D	M	4	3
Brevort	80	E	L	3	3
Brice	81	E	L	4	4
Brickton	82	D	M	3	3
Briggsville	83	A	M	2	1
Brill	84	D	M	3	2
Brimley	85	D	M	4	3
Brinkman	703	A	M	1	1
Brodale	86	B	L	3	3
Brokaw (See Santiago)					
Brookston	87	B	M	1	3
Brophy (See Greenwood)					
Brownchurch	720	A	M	1	1
Brownstone	88	E	L	4	4
Bruce	89	D	M	4	4
Burkhardt	90	E	M	4	4
Bushville	91	D	M	4	3
Cable	92	D	M	4	4
Cadiz	93	A	M	2	1
Calamine	94	B	H	2	4
Campia	95	D	M	2	2
Capitola	96	D	M	4	4
Carbondale	97	O	H	3	4
Carlisle	98	O	H	1	4
Carlos (See Rondeau)					
Caron (See Muskego)					
Caryville	99	B	L	4	4
Casco	100	A	L	3	3
Cathro	101	O	H	3	4
Cebana	721	D	M	4	4
Ceresco	102	B	L	2	2
Chabeneau	722	D	M	3	3
Champion	103	D	M	4	3
Channahon	104	B	M	4	4
Channing	723	D	M	4	3
Charlevoix	105	D	M	3	4
Chaseburg	106	A	L	1	1
Chelmo	107	D	M	4	4
Chelsea	108	E	L	4	4
Chequamegon	724	D	M	3	3
Chetek	109	E	L	4	4
Chickney	110	D	M	4	3
Chicog	725	E	L	4	4
Chinwhisker	726	E	L	4	4
Chippeny	111	O	H	4	4
Churchtown	112	A	M	1	1
Citypoint	113	O	H	4	4
Clemens	727	D	L	4	4
Clifford (See Magnor)					
Cloquet (See Keweenaw)					
Clyde	114	B	M	1	3
Coffeen	115	B	L	1	2
Coffton	116	B	L	1	2
Coloma	117	E	L	4	4
Colwood	118	B	M	2	3
Comstock	119	D	M	3	3
Conover	120	A	M	1	2
Cormant	121	E	L	4	4
Cornucopia	122	C	M	4	3
Cosad	123	C	L	4	3
Council	124	A	L	1	1
Cress	125	D	L	4	4
Crex	126	E	L	4	4
Cromwell	127	D	L	4	4
Crossett	128	C	M	3	3
Croswell	129	E	L	4	4
Croswood	130	E	L	4	4
Crystal Lake	131	D	M	3	2
Cublake	132	E	L	4	3
Cunard	133	D	M	3	3
Curran	134	A	M	1	2
Cushing	135	D	M	3	2
Cutaway	728	E	L	3	3
Cuttre	136	C	M	4	3
Dagwagi	137	C	M	4	4

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[b] Description of soil groups are given in Figure 4.1.

[c] Subsoil sulfur codes are defined in Table 8.1.

[d] Corn and alfalfa yield potential: 1 = very high; 2 = high; 3 = medium; 4 = low. For yield ranges associated with these categories, see Table 4.4.

Table 4.1. Codes assigned to Wisconsin soils for soil group, subsoil sulfur, and corn and alfalfa yield potentials *(continued)*.

Soil name	Soil number[a]	Soil group[b]	Subsoil sulfur code[c]	Yield potential code[d]	
				Corn	Alfalfa
Dairyland	729	E	L	4	4
Dakota	138	B	M	2	3
Dalbo (See Taylor)					
Dancy	139	E	M	4	4
Darroch	140	B	M	1	2
Dawsil	141	O	H	4	4
Dawson	142	O	H	4	4
Dechamps	143	E	L	4	4
Deerton	144	E	L	4	4
Deford	145	E	L	4	4
Del Rey	146	A	M	1	2
Dells	147	A	M	2	3
Delton	148	E	L	3	3
Demontreville	149	E	L	4	3
Denomie	150	C	M	4	3
Denrock	151	B	M	2	2
Derinda	152	A	M	3	3
Detour (See Solona)					
Dickinson	153	B	M	3	3
Dickman	154	B	M	4	4
Dillon (See Newton)					
Dobie	155	D	M	3	3
Docklake	156	D	M	3	3
Dodge	157	A	M	2	2
Dodgeville	158	B	M	2	2
Dody	159	E	M	4	4
Dolph	160	D	M	3	3
Dora	730	O	H	4	4
Dorchester	161	A	M	1	2
Dorerton	162	A	M	3	3
Doritty	163	A	M	3	2
Downs	164	A	M	1	1
Drammen	165	E	L	4	4
Dresden	166	A	L	2	2
Drummer	167	B	M	1	3
Dryburg	168	C	M	4	2
Drylanding	731	E	L	4	4
Dubuque	169	A	M	3	2
Duel	170	E	L	4	4
Duelm	171	E	L	4	4
Duluth (See Amery)					
Dunbarton	172	A	H	4	4
Dunnbot	173	A	M	2	2
Dunnville	174	B	L	3	3
Durand	175	B	M	1	1
Dusler (See Oesterle)					
Eaglebay	176	C	M	4	3
East Lake (See Vilas)					
Eauclaire	177	E	L	4	3
Eaupleine (See Freeon)					
Edmund	178	B	M	3	3
Edwards	179	O	H	3	4
Elbaville	180	A	M	2	1
Elburn	181	B	M	1	2
Elderon	182	E	L	4	4
Eleroy	183	A	M	2	2
Eleva	184	A	M	3	2
Elevasil	185	A	M	4	3
Elkmound	186	E	M	4	4
Ella	187	A	M	1	1
Elliott	188	B	M	1	2
Ellwood	189	C	M	3	3
Elm Lake	190	E	M	4	4
Elvers	191	A	M	2	3
Emmert	192	E	L	4	4
Emmet	193	C	L	3	2
Ensign (See Bonduel)					
Ensley	194	C	L	3	3
Etter (See Military)					
Ettrick	195	B	L	1	3
Evart	196	E	L	4	4
Fabius	197	B	L	3	3
Fairchild	198	E	L	4	4
Fairport	199	C	L	3	2
Fallcreek	200	D	M	3	3
Farrington	201	E	L	4	4
Fayette	202	A	M	1	1
Fenander	732	E	L	4	4
Fence	203	D	M	4	2
Fenwood	204	D	H	3	2
Festina	704	A	M	1	1
Fifield (See Worcester)					
Finchford	205	E	L	4	4
Fisk	206	E	L	3	3
Fivepoints	733	A	H	3	2
Flagg	207	A	M	1	1
Flagriver	208	C	M	4	3
Flambeau	209	D	M	3	2

Table 4.1. Codes assigned to Wisconsin soils for soil group, subsoil sulfur, and corn and alfalfa yield potentials *(continued)*.

Soil name	Soil number[a]	Soil group[b]	Subsoil sulfur code[c]	Yield potential code[d]	
				Corn	Alfalfa
Flink	210	E	L	4	4
Floyd	211	B	M	1	2
Forada	212	B	M	3	3
Fordum	213	D	M	3	4
Forkhorn	214	A	M	3	3
Fox	215	A	M	2	2
Foxpaw	734	D	M	4	4
Frechette	216	C	M	3	3
Freeon	217	D	M	3	2
Freer	218	D	M	3	2
Fremstadt	735	E	L	4	4
Freya	219	E	L	4	4
Friendship	220	E	L	4	4
Friesland	221	B	M	1	1
Froberg	223	C	M	4	3
Frogbay	222	C	M	4	3
Frogcreek	736	D	M	3	3
Gaastra	224	D	M	4	3
Gale	225	A	M	3	2
Gander	226	E	L	4	4
Gaphill	227	A	L	3	3
Gardenvale	228	A	M	3	2
Garne	229	E	L	4	4
Garwin	230	B	M	1	3
Gastrow	231	D	M	4	3
Gay (See Capitola)					
Gichigami	232	C	M	4	3
Giese	737	D	M	4	4
Gilford	233	A	M	2	3
Gillingham	738	A	M	4	3
Glendenning	234	D	M	3	3
Glendora	235	E	L	4	4
Glenflora	739	D	H	3	3
Gogebic	236	D	M	4	3
Goodman	237	D	M	3	2
Goodwit	238	D	M	3	2
Gosil	239	E	L	4	4
Gotham	240	E	L	4	4
Granby	241	E	L	4	4
Grassylake	242	D	M	3	3
Graycalm	243	E	L	4	4
Grayling	244	E	L	4	4
Grays	245	A	M	1	1
Greenridge	705	A	M	1	1
Greenwood	246	O	H	4	4
Grellton	247	A	M	1	1
Grettum	248	E	L	4	4
Griswold	249	B	L	2	2
Guenther	250	E	M	4	3
Halder	251	D	M	3	3
Happyhollow	706	C	M	4	4
Hatley	252	D	M	3	3
Haugen	253	D	M	3	3
Haustrup	740	D	L	4	4
Hayfield	254	A	M	2	2
Hayriver	255	D	M	4	3
Hebron	256	A	M	1	2
Hegge	257	C	M	4	4
Hemlock	258	E	L	4	4
Hennepin	259	A	L	4	3
Herbster	260	C	M	4	3
Hersey	261	A	M	1	1
Hesch	262	B	L	3	3
Hessel (See Alstad)					
Hibbing	263	C	M	4	3
Highbridge	264	C	M	4	3
Hiles	265	D	H	3	3
Hillcrest (See Downs)					
Hitt (See Dodgeville)					
Hixton	266	A	M	3	3
Hochheim	267	B	L	2	2
Hoop	268	B	L	3	3
Hoopeston	269	B	L	3	3
Hortonville	270	C	M	2	1
Houghton	271	O	H	1	4
Hubbard	272	E	L	4	4
Humbird	273	D	L	4	4
Huntsville	274	B	M	1	1
Icehouse	741	D	M	4	4
Impact	275	E	M	4	4
Indus	742	C	M	3	2
Ingalls	276	E	L	4	4
Ionia	277	A	M	1	2
Iosco	278	E	L	4	3

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[b] Description of soil groups are given in Figure 4.1.

[c] Subsoil sulfur codes are defined in Table 8.1.

[d] Corn and alfalfa yield potential: 1 = very high; 2 = high; 3 = medium; 4 = low. For yield ranges associated with these categories, see Table 4.4.

Table 4.1. Codes assigned to Wisconsin soils for soil group, subsoil sulfur, and corn and alfalfa yield potentials *(continued)*.

Soil name	Soil number[a]	Soil group[b]	Subsoil sulfur code[c]	Yield potential code[d]	
				Corn	Alfalfa
Iron River (See Wabeno)					
Ironrun	279	E	L	4	4
Isan (See Newson)					
Isanti (See Newson)					
Ishpeming	280	E	L	4	4
Jackson	281	A	M	1	1
Jasper	282	B	M	2	2
Jewett	283	B	M	3	2
Joy	284	B	M	1	2
Juda	285	B	M	1	1
Judson	286	B	L	1	1
Juneau	287	A	M	1	1
Kakagon	288	C	M	4	4
Kalamazoo (See Fox)					
Kalkaska (See Vilas)					
Kalmarville	289	A	M	4	4
Kane	290	B	M	2	2
Karlin	291	E	L	4	4
Karlsborg	292	E	L	4	3
Kato	293	B	M	1	3
Kaukauna	294	C	M	2	1
Kegonsa	295	B	L	2	2
Kellogg	296	E	L	4	3
Keltner	297	B	M	2	2
Kendall	298	A	M	1	2
Kennan	299	D	M	4	2
Keowns	300	B	H	2	3
Kert	301	D	M	3	3
Keshena	302	C	M	3	3
Kevilar	303	A	M	4	3
Kewaunee	304	C	M	2	1
Keweenaw	305	E	L	4	4
Keyesville	743	A	L	4	4
Kibbie	306	B	M	2	2
Kickapoo	307	A	L	3	3
Kidder	308	A	L	2	2
Kingsville	310	E	M	3	3
Kinross	311	E	M	4	4
Kiva	312	E	L	4	4
Knowles	313	A	L	3	2
Kolberg	314	C	M	3	2
Komro	315	E	L	4	4
Korobago	316	C	L	3	3
Kost	317	E	L	4	4
Kranski	318	E	L	4	3
La Farge	319	A	M	2	2
Lablatz	707	C	L	3	3
Lafont (See Sarona)					
Lamartine	321	A	M	1	2
Lambeau	708	A	M	1	1
Lamont	322	E	M	3	4
Langlade	323	D	H	3	2
Laona	324	D	M	4	3
Lapeer	325	A	M	3	3
Lapoin	326	C	M	4	3
Lara	327	E	L	4	4
Lawler	328	B	M	2	2
Lawson	329	B	M	1	2
Leelanau (See Menominee)					
Lena (See Houghton)					
Lenawee (See Montgomery)					
Lenroot	744	E	L	4	4
Leola	330	E	L	4	4
Lerch	331	C	M	4	4
Leroy	332	A	L	3	2
Lindquist	745	E	L	4	4
Lindstrom	333	B	M	1	1
Lino	334	E	M	4	4
Linwood (See Palms)					
Littleton (See Lawson)					
Lobo	335	O	H	4	4
Locke	336	B	M	3	3
Lomira	337	A	M	2	2
Longrie	338	C	M	3	3
Lorenzo	339	B	M	3	3
Lows	340	B	M	3	3
Loxley	341	O	M	4	4
Loyal	342	D	M	3	2
Ludington	343	E	L	4	4
Lundeen	746	D	M	3	3
Lunds (See Worcester)					
Lupton	344	O	H	4	4
Lutzke	345	A	M	3	3
Mackinac (See Charlevoix)					
Magnor	346	D	M	3	2
Magroc	347	D	M	3	2
Mahalasville	348	B	M	1	3
Mahtomedi	349	E	L	4	4

Table 4.1. Codes assigned to Wisconsin soils for soil group, subsoil sulfur, and corn and alfalfa yield potentials *(continued)*.

Soil name	Soil number[a]	Soil group[b]	Subsoil sulfur code[c]	Yield potential code[d]	
				Corn	Alfalfa
Mahtowa (See Capitola)					
Maincreek	747	D	M	3	3
Majik	350	E	L	4	4
Makwa	748	D	L	4	4
Manawa	351	C	M	2	2
Mancelona	352	E	L	4	4
Manistee	353	E	L	4	3
Manitowish	354	D	L	4	4
Mann	355	D	M	3	3
Maplehurst	356	D	M	3	2
Maraglade (See Magnor)					
Marathon	357	D	H	3	2
Marcellon	358	B	M	2	3
Markesan	359	B	M	2	2
Markey	360	O	H	4	4
Markham	361	B	M	2	1
Marshan	362	B	M	2	3
Marshfield	363	D	M	3	3
Martha	749	D	M	3	3
Martinton	364	B	M	1	2
Matherton	365	B	L	2	2
Maumee	366	E	L	4	4
Mayville	367	A	M	1	1
McHenry	368	A	M	2	2
McMillan	750	E	L	4	3
Meadland	369	D	M	3	2
Mecan	370	A	L	3	3
Mecosta	371	E	L	4	4
Medary	372	A	M	2	2
Meehan	373	E	L	4	4
Meenon	374	E	L	4	3
Menahga	375	E	L	4	4
Menasha	376	C	M	2	3
Mendota	377	B	M	2	2
Menomin	378	A	M	2	3
Menominee	379	E	L	4	3
Mequithy	380	D	M	4	3
Mequon	381	C	M	2	2
Meridian	382	A	M	3	3
Merimod	383	A	M	3	2
Merit	384	A	M	3	2
Merrillan	385	D	M	4	4
Merwin (See Greenwood)					
Metea	386	E	L	3	3
Metonga	387	D	M	4	3
Miami	388	A	L	2	2
Michagamme	389	D	M	3	3
Mickle	751	B	M	1	1
Mifflin	390	A	L	2	2
Milaca	752	D	M	3	3
Milford	391	B	M	1	3
Military	392	A	L	3	3
Milladore	393	D	M	3	2
Millerville (See Greenwood)					
Millington	394	B	M	1	3
Millsdale	395	B	M	2	4
Milton	396	A	M	3	2
Mindoro	397	E	L	4	4
Minocqua	398	D	M	4	4
Miskoaki	399	C	M	4	3
Moberg	400	D	L	4	4
Monico	401	D	M	3	2
Montello	402	B	M	2	1
Montgomery	403	B	M	2	3
Moodig	404	D	M	4	3
Mooselake (See Rifle)					
Moppet	405	D	M	4	3
Moquah	406	D	M	4	3
Mora	407	D	M	4	3
Morganlake	408	E	L	4	3
Morley	409	C	M	2	1
Morocco	410	E	L	4	4
Mosel	411	A	M	2	2
Mosinee	412	D	L	4	3
Moundville	413	E	L	4	4
Mt. Carroll	414	A	M	1	1
Mudlake	415	D	M	4	3
Mundelein	416	B	M	1	2
Munising (See Gogebic)					
Munuscong	417	C	M	4	4
Muscatine	418	B	M	1	2
Muscoda	753	A	M	3	3
Muskego	419	O	H	3	4
Mussey	420	B	L	3	4

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[b] Description of soil groups are given in Figure 4.1.

[c] Subsoil sulfur codes are defined in Table 8.1.

[d] Corn and alfalfa yield potential: 1 = very high; 2 = high; 3 = medium; 4 = low. For yield ranges associated with these categories, see Table 4.4.

Table 4.1. Codes assigned to Wisconsin soils for soil group, subsoil sulfur, and corn and alfalfa yield potentials *(continued)*.

Soil name	Soil number[a]	Soil group[b]	Subsoil sulfur code[c]	Yield potential code[d]	
				Corn	Alfalfa
Mylrea	421	D	M	3	2
Myrtle	422	A	M	1	1
Nadeau	423	D	L	4	3
Nahma	424	C	M	4	4
Namur	425	D	M	4	4
Navan	426	B	M	1	4
Nebago	427	C	M	4	3
Neconish	428	E	L	4	3
Neda	429	A	M	2	2
Neenah	430	C	M	2	2
Nemadji (See Au Gres)					
Nenno	431	B	M	2	3
Neopit	432	D	M	4	2
Nester	433	C	M	3	2
Newaygo (See Padus)					
Newglarus	434	A	H	3	2
Newlang	435	E	L	4	4
Newood	436	D	M	4	3
Newot	437	D	M	4	3
Newson	438	E	L	4	4
Newton	439	E	L	4	4
Newvienna (See Seaton)					
Nichols	440	A	L	2	2
Nickin	441	B	L	3	3
Nokasippi	442	B	M	4	4
Norden	443	A	M	2	2
Norgo	444	D	M	4	4
Norrie (See Kennan)					
Northbend	445	A	L	3	3
Northfield	446	E	L	4	4
Northmound	447	D	M	4	3
Norwalk (See Reedsburg)					
Noseum	448	E	L	4	4
Nuxmaruhanixete	754	B	M	2	2
Nymore	449	E	L	4	4
Oakville	450	E	L	4	4
Ockley	451	A	M	1	1
Oconto	452	D	L	3	3
Odanah	453	C	M	4	3
Oesterle	454	D	M	3	3
Ogden (See Willette)					
Ogle	455	B	M	1	1
Okee	456	E	L	4	3
Omega	457	E	L	4	4
Omena	458	D	M	3	3
Omro	459	C	M	2	2
Onamia (See Rosholt)					
Onaway	460	C	L	3	2
Ontonagon	461	C	M	4	3
Orienta (See Rimer)					
Orion	462	A	M	1	2
Oronto	463	C	M	4	3
Oshkosh	464	C	M	2	2
Oshtemo	465	A	M	3	3
Osseo (See Orion)					
Ossian	466	B	H	1	3
Ossmer	467	D	M	3	3
Ostrander	468	B	M	1	1
Otter	469	B	M	1	3
Otterholt	470	D	M	3	2
Owosso (See Kidder)					
Ozaukee	471	C	M	2	2
Padus	472	D	M	4	3
Padwet	473	D	M	4	3
Padwood	474	D	M	4	3
Paintcreek	709	A	M	1	1
Palms	475	O	H	2	4
Palsgrove	476	A	M	1	1
Pardeeville	477	A	M	3	3
Parent (See Capitola)					
Parkfalls	755	D	M	3	3
Partridge	478	E	L	4	4
Pearl	479	E	L	4	4
Pecatonica	480	A	M	1	1
Pecore	481	C	M	3	3
Peebles	482	C	M	2	1
Pelissier	483	E	L	4	4
Pelkie	484	E	L	4	4
Pella	485	B	M	1	3
Pence	486	D	L	4	3
Pepin	487	A	M	1	1
Pequaming	488	E	L	4	4
Perchlake	489	E	L	4	4
Perida	490	E	L	4	4
Perote	491	C	M	4	2
Pesabic	492	D	M	4	3
Peshekee	493	D	M	4	4
Peshtigo	494	C	M	4	3

Table 4.1. Codes assigned to Wisconsin soils for soil group, subsoil sulfur, and corn and alfalfa yield potentials *(continued)*.

Soil name	Soil number[a]	Soil group[b]	Subsoil sulfur code[c]	Yield potential code[d]	
				Corn	Alfalfa
Pickford	495	C	M	4	3
Pillot	496	B	H	2	2
Pinconning	497	E	L	4	4
Pistakee (See Radford)					
Plainbo	498	E	L	4	4
Plainfield	499	E	L	4	4
Plano	500	B	M	1	1
Pleine	756	D	M	4	4
Plover	501	D	M	3	3
Plumcreek	502	A	M	3	3
Point	503	E	L	3	3
Pomroy	504	E	L	4	3
Ponycreek	505	E	L	4	4
Port Byron	506	B	M	1	1
Portwing	507	C	M	4	2
Poskin	508	D	M	3	2
Poy	509	C	M	3	3
Poygan	510	C	M	2	3
Prebish (See Wormet)					
Prissel	511	E	L	4	3
Puchyan	512	E	L	3	3
Quarderer	513	D	M	1	1
Rabe	514	E	L	4	3
Racine	515	A	M	2	2
Radford	516	B	H	2	2
Rasset	517	B	M	3	3
Redrim	518	E	L	4	4
Reedsburg	519	A	M	1	2
Renova	520	A	M	1	2
Rib	521	D	M	4	4
Ribhill	522	D	M	3	3
Ribriver	523	D	M	3	2
Richford	524	E	M	4	3
Richter (See Gastrow)					
Richwood	525	B	M	1	1
Rietbrock	526	D	M	3	2
Rifle	527	O	H	4	4
Rimer	528	E	L	4	2
Ringwood	529	B	M	1	2
Ripon	530	B	M	2	2
Ritchey	531	A	M	4	4
Robago	532	D	M	4	3
Roby	533	A	M	2	2
Rockbluff	534	E	L	4	4
Rockbridge (See Tell)					
Rockdam	535	E	L	4	4
Rockers	536	E	L	4	3
Rockmarsh	757	D	M	3	3
Rockmont	537	C	M	4	2
Rockton	538	B	M	2	2
Rodman	539	B	L	4	4
Rollin (See Edwards)					
Romanpoint	540	C	L	4	4
Rondeau	541	O	H	4	4
Ronneby (See Glendenning)					
Roscommon	542	E	L	4	4
Rosholt	543	D	M	3	3
Rotamer	544	B	M	2	2
Rothschild (See Mahtomedi)					
Rousseau	545	E	L	4	4
Rowley	546	B	M	1	2
Rozellville	547	D	M	3	2
Rozetta	548	A	M	1	1
Rubicon	549	E	L	4	4
Rudyard (See Cuttre)					
Ruse	550	D	M	4	4
Rusktown	551	A	M	3	3
Sable	552	B	M	1	4
Salter	553	E	L	3	3
Sanborg	554	C	M	4	3
Sandbay	555	E	L	4	4
Santiago	556	D	M	3	2
Sargeant	557	D	M	3	3
Sarona	558	D	M	3	3
Sartell (See Shawano)					
Sarwet	559	D	M	3	3
Sattre	560	A	L	3	2
Saugatuck (See Au Gres)					
Sawmill	561	B	M	2	2
Saybrook	562	B	M	1	1
Saylesville	563	A	M	2	2
Sayner	564	E	L	4	4
Schapville	565	B	M	2	2
Schramm	566	C	L	4	2

[a] Soil numbers are not listed numerically because soils series names have been added since this coding scheme was initiated in 1998. Some soil series do not have numbers because these soils were eliminated during mapping/remapping by USDA-NRCS. For soil series names without a soil number, use the soil series described.

[b] Description of soil groups are given in Figure 4.1.

[c] Subsoil sulfur codes are defined in Table 8.1.

[d] Corn and alfalfa yield potential: 1 = very high; 2 = high; 3 = medium; 4 = low. For yield ranges associated with these categories, see Table 4.4.

Table 4.1. Codes assigned to Wisconsin soils for soil group, subsoil sulfur, and corn and alfalfa yield potentials *(continued)*.

Soil name	Soil number[a]	Soil group[b]	Subsoil sulfur code[c]	Yield potential code[d]	
				Corn	Alfalfa
Schweitzer	758	D	M	4	4
Scoba	567	D	M	3	3
Sconsin	568	D	M	3	3
Scotah	569	E	L	4	4
Scott Lake	570	D	M	3	3
Seaton	571	A	M	1	1
Sebbo	572	A	M	1	1
Sebewa	573	B	M	2	4
Sechler	574	A	M	3	3
Sedgwick	575	C	M	4	3
Seeleyville	576	O	H	3	4
Selkirk	577	C	M	4	2
Seward	578	E	L	4	3
Shag	759	D	M	3	3
Shawano	579	E	L	4	4
Sherry	580	D	M	3	3
Shiffer	581	A	M	2	3
Shiocton	582	D	M	3	2
Shullsburg	583	B	M	2	2
Silverhill	584	A	L	3	3
Simescreek	585	E	L	4	4
Siouxcreek	586	D	M	4	3
Siren	760	C	M	3	3
Sissabagama	587	E	L	4	4
Sisson	588	A	M	2	2
Skanee (See Tula)					
Skog	761	E	L	4	3
Skyberg	589	A	M	2	2
Slimlake	590	E	L	4	4
Smestad	591	E	L	4	3
Soderbeck	762	D	L	4	4
Soderville	592	E	L	4	3
Sogn	593	B	L	4	4
Solness	594	D	M	4	3
Solona	595	C	L	3	2
Sooner	596	A	M	2	3
Soperton	597	D	M	4	3
Spalding (See Greenwood)					
Sparta	598	E	L	4	4
Spear	763	D	M	3	3
Spencer	599	D	M	3	3
Spiderlake	764	D	M	3	3
Spinks	600	E	L	4	4
Spirit (See Monico)					
Spoonerhill	601	E	L	4	3
Springstead	765	E	L	4	4
St. Charles	602	A	M	1	1
Stambaugh	603	D	M	3	2
Stanberry	766	D	M	3	3
Stengel	604	E	L	4	4
Stinnett	767	D	M	3	2
Stronghurst	605	A	M	1	2
Sturgeon	606	D	M	4	4
Suamico (See Willette)					
Sultz	607	E	L	4	4
Summerville	608	D	M	4	3
Sundell (See Bonduel)					
Sunia	609	E	L	4	4
Sunkencamp	610	E	L	4	4
Superior	611	C	M	4	2
Sylvester	612	B	M	3	2
Symco	613	C	M	2	2
Symerton	614	B	M	1	2
Tacoosh	768	O	H	3	4
Tama	615	B	M	1	1
Tarr	616	E	L	4	4
Tawas	617	O	H	4	4
Taylor	618	C	M	4	2
Tedrow	619	E	L	4	4
Tell	620	A	M	2	2
Terrill	621	B	M	1	2
Thackery	622	A	M	1	2
Theresa	623	A	M	1	1
Tilleda	624	C	M	3	3
Tint	625	E	L	4	4
Tintson	626	E	L	4	4
Tipler	627	D	M	4	3
Toddville	628	B	M	1	1
Tonkey	629	D	M	4	4
Totagatic	769	E	L	4	4
Tourtillotte	630	E	L	4	4
Tradelake	631	D	M	4	3
Trempe	632	E	L	4	4
Trempealeau	633	B	M	3	3
Trenary (See Sarona)					
Troxel	634	B	M	1	1
Tula	635	D	M	4	3
Tuscola	636	A	M	2	2

Table 4.1. Codes assigned to Wisconsin soils for soil group, subsoil sulfur, and corn and alfalfa yield potentials *(continued)*.

Soil name	Soil number[a]	Soil group[b]	Subsoil sulfur code[c]	Yield potential code[d]	
				Corn	Alfalfa
Tustin	637	E	L	4	3
Twinmound	638	E	L	4	4
Udolpho (See Kane)					
Underhill (See Tilleda)					
Urne	639	A	M	4	3
Valton	640	A	M	2	2
Vancecreek	641	D	M	3	3
Vanzile	642	D	M	3	3
Varna	643	B	M	2	1
Vasa	644	A	M	1	2
Veedum	645	D	M	3	3
Vejo	646	E	L	4	4
Vesper	647	D	M	3	3
Vilas	648	E	L	4	4
Virgil	649	A	M	1	2
Vlasaty	650	D	M	2	2
Wabeno	651	D	M	4	3
Wacousta	652	B	M	1	3
Wahtohsah	653	D	M	4	3
Wainola	654	E	L	4	3
Waiska (See Pelissier)					
Wakefield	655	D	H	4	2
Wakeley	770	E	L	4	4
Wallkill	656	A	M	1	3
Warman	657	D	M	4	4
Warsaw	658	B	M	2	2
Wasepi	659	A	M	3	3
Washtenaw	660	A	M	1	3
Waskish (See Lobo)					
Watseka	661	E	L	4	4
Watton (See Denomie)					
Waucedah	771	D	M	4	4
Wauconda	662	A	M	1	2
Waukechon (See Sebewa)					
Waukegan	663	B	M	2	1
Waupaca	664	C	M	3	4
Wausau (See Mosinee)					
Wauseon	665	B	M	3	3
Wautoma	666	E	L	3	3
Wayka	667	D	M	4	3
Waymor	668	A	M	3	2
Weegwas	669	E	L	4	4
Wega	670	C	M	3	3
Westville	671	A	M	2	2
Whalan	672	A	M	2	3
Wheatley	673	E	L	4	4
Whisklake	674	D	M	3	3
Whitehall	675	B	M	2	2
Whittlesey	676	D	M	4	3
Wickware	677	A	M	2	2
Wien (See Marshfield)					
Wildale	678	A	M	3	3
Wildwood	679	C	M	4	4
Will	680	B	M	2	3
Willette	681	O	H	2	4
Windward	772	E	L	4	4
Winnebago	682	B	M	2	2
Winneconne	683	C	M	2	2
Winneshiek	684	A	M	2	3
Winterfield	685	E	L	4	4
Withee	686	D	M	3	2
Worcester	687	D	M	4	3
Wormet	688	D	L	4	4
Worthen	689	B	L	1	1
Worwood	690	D	M	4	3
Wozny	773	D	M	4	4
Wurtsmith	691	E	L	4	4
Wyeville	692	E	L	3	3
Wykoff	693	D	L	3	3
Wyocena	694	E	L	3	3
Yahara	695	B	M	3	2
Zeba	696	D	M	4	4
Zimmerman (See Graycalm)					
Zittau	697	C	M	3	2
Zurich	698	A	M	2	2
Zwingle	699	A	M	3	3

[a] Soil numbers are not listed numerically because soils series names have been added since this coding scheme was initiated in 1998. Some soil series do not have numbers because these soils were eliminated during mapping/remapping by USDA-NRCS. For soil series names without a soil number, use the soil series described.

[b] Description of soil groups are given in Figure 4.1.

[c] Subsoil sulfur codes are defined in Table 8.1.

[d] Corn and alfalfa yield potential: 1 = very high; 2 = high; 3 = medium; 4 = low. For yield ranges associated with these categories, see Table 4.4.

Table 4.2 County-based information for default soil groups, corn and alfalfa yield potential codes, and sulfur in precipitation.

County name	County code	Soil group[a]	Yield potential code: Corn	Yield potential code: Alfalfa	Sulfur in precipitation lb S/a
Adams	1	A,E	2	3	5
Ashland	2	C,D	4	3	5
Barron	3	D,E	3	2	5
Bayfield	4	C,D,E	4	3	5
Brown	5	C,E	2	1	10
Buffalo	6	A,E	2	2	5
Burnett	7	D,E	4	3	5
Calumet	8	A,C	2	1	10
Chippewa	9	D,E	3	3	5
Clark	10	D,E	3	2	5
Columbia	11	A,B,E	1	1	10
Crawford	12	A,E	2	1	5
Dane	13	A,B	1	1	10
Dodge	14	A,B,C,E	1	2	10
Door	15	C,D,E	3	3	10
Douglas	16	C,D,E	4	3	5
Dunn	17	A,E	2	2	5
Eau Claire	18	A,E	2	2	5
Florence	19	D	4	3	5
Fond du Lac	20	A,B,C	2	1	10
Forest	21	D	4	3	5
Grant	22	A,B,E	2	1	10
Green	23	A,B	1	1	10
Green Lake	24	A,B,E	2	1	5
Iowa	25	A,B,E	2	1	10
Iron	26	D,E	4	3	5
Jackson	27	A,E	2	2	5
Jefferson	28	A,B	1	2	10
Juneau	29	A,E	2	3	5
Kenosha	30	A,C	2	1	15
Kewaunee	31	C,D,E	2	1	10
La Crosse	32	A,E	2	2	5
Lafayette	33	A,B	2	1	10
Langlade	34	D,E	3	2	5
Lincoln	35	D,E	3	2	5
Manitowoc	36	A,C	2	1	10
Marathon	37	D,E	3	2	5
Marinette	38	C,D,E	3	3	5
Marquette	39	A,E	3	2	5
Menominee	40	D,E	3	2	5
Milwaukee	41	C	2	2	15
Monroe	42	A,E	2	2	5
Oconto	43	C,D,E	3	2	5
Oneida	44	D,E	4	3	5
Outagamie	45	C,E	2	1	10
Ozaukee	46	A,C	2	1	10
Pepin	47	A,E	2	2	5
Pierce	48	A	2	2	5
Polk	49	D,E	3	2	5
Portage	50	D,E	2	2	5
Price	51	D,E	4	3	5
Racine	52	A,C	2	1	15
Richland	53	A,E	2	1	5
Rock	54	A,B	1	1	10
Rusk	55	D,E	3	2	5
St. Croix	56	D	2	2	5
Sauk	57	A,E	2	1	10
Sawyer	58	D,E	4	3	5
Shawano	59	C,D,E	3	2	5
Sheboygan	60	A,C	2	1	10
Taylor	61	D,E	3	3	5
Trempealeau	62	A,E	2	2	5
Vernon	63	A,B,E	2	2	5
Vilas	64	D,E	4	3	5
Walworth	65	A,B	1	1	10
Washburn	66	D,E	4	3	5
Washington	67	A,C	2	1	10
Waukesha	68	A,C	2	1	10
Waupaca	69	C,D,E	2	2	5
Waushara	70	C,E	2	3	5
Winnebago	71	A,B,C	2	1	10
Wood	72	D,E	3	2	5

[a] The default soil groups are representative of soil groups with significant acreage in each county. If more than one soil group is listed for a county, the correct soil group can be determined as follows. Texture codes are defined in Figure 4.1.

1. If organic matter is greater than 10% or if texture code = 3, then soil group O;
2. If soil texture is sand or loamy sand (texture code 1), then soil group E;
3. If soil is medium or fine textured (texture code 2) and groups A or B are listed for a county, then use soil group A if organic matter is less than or equal to 3% or soil group B if organic matter is greater than 3%.
4. If soil is medium or fine textured (texture code 2) and groups A or B are not listed for a county, then use soil group D.
5. If soil is red (texture code 4), then use soil group C.

Table 4.3. Crop codes, typical yield range, moisture content at which yield is reported, phosphorus and potassium crop removals and demand levels, and target soil pH values for each crop.

Crop name	Crop code	Yield range (per acre)	Reporting moisture content [a] (%)	Crop removal P_2O_5 (lb/unit yield)	Crop removal K_2O (lb/unit yield)	P and K demand level	Target pH Mineral	Target pH Organic
Alfalfa, established	1	2.6–8.5 ton	DM	13	60	3	6.8	—
Alfalfa, seeding	2	1.5–2.5 ton	DM	13	60	3	6.8	—
Apple, establishment [b]	60	all	fresh	—	—	3	6.5	—
Asparagus	3	2000–4000 lb	fresh	0.0033	0.0067	5	6.0	5.6
Barley, grain	74	25–100 bu	14.5	0.40	0.35	4	6.6	5.6
Barley, grain + straw [c]	4	25–100 bu	—	—	—	4	6.6	5.6
Barley, straw [d]	—	1–3 ton	DM	10	32	—	—	—
Bean, dry (kidney, navy)	5	10–40 cwt	18	1.2	1.6	3	6.0	5.6
Bean, lima	6	2000–5000 lb	fresh	0.0086	0.017	3	6.0	5.6
Bean, snap	44	1.5–6.5 ton	fresh	5.0	20	3	6.8	5.6
Beet, table	7	5–20 ton	fresh	1.3	8.0	5	6.0	5.6
Blueberry, establishment [b]	61	all	fresh	—	—	3	5.6	5.4
Brassica, forage	8	2–3 ton	DM	10	48	3	6.0	5.6
Broccoli	9	4–6 ton	fresh	2.0	8.0	5	6.0	5.6
Brussels sprouts	10	4–6 ton	fresh	3.2	9.4	5	6.0	5.6
Buckwheat	11	1200–2000 lb	~15	0.013	0.013	2	5.6	5.4
Cabbage	12	8–30 ton	fresh	1.6	7.2	5	6.0	5.6
Canola	13	30–50 bu	8	1.1	2.0	1	5.8	5.6
Carrot	14	20–30 ton	fresh	1.8	9.6	5	5.8	5.6
Cauliflower	15	6–8 ton	fresh	2.9	7.1	5	6.0	5.6
Celery	16	25–35 ton	fresh	3.3	10	5	6.0	5.6
Cherry [b]	62	all	fresh	—	—	3	6.5	—
Clover, red	42	1.5–6.5 ton	DM	13	60	4	6.3	5.6
Corn, grain	17	70–220 bu	15.5	0.38	0.29	1	6.0	5.6
Corn, popcorn	38	60–80 bu	~14	0.36	0.29	3	6.0	5.6
Corn, silage	18	10–35 ton	65	3.6	8.3	3	6.0	5.6
Corn, stover [d]	—	3–10 ton	DM	4.6	32	—	—	—
Corn, sweet	19	2–10 ton	fresh	3.3	6.0	3	6.0	5.6
Cranberry, establishment [b]	63	all	fresh	—	—	3	5.6	5.4
CRP, alfalfa	66	—	—	0	0	3	6.6	—
CRP, grass	68	—	—	0	0	2	5.6	5.4
CRP, red clover	67	—	—	0	0	4	6.3	5.6
Cucumber	20	5–10 ton	fresh	1.2	3.6	5	5.8	5.6
Flax	21	20–40 bu	9	0.67	0.67	2	6.0	5.6
Ginseng	22	1000–3000 lb	DM	0.0075	0.030	5	—	—
Grape, establishment [b]	79	all	fresh	—	—	3	6.5	5.6
Lettuce	23	15–20 ton	fresh	2.3	9.1	5	5.8	5.6
Lupine	24	40–60 bu	~16	1.0	1.2	4	6.3	5.6

(continued)

Table 4.3. Crop codes, typical yield range, moisture content at which yield is reported, phosphorus and potassium crop removals and demand levels, and target soil pH values for each crop *(continued)*.

Crop name	Crop code	Yield range (per acre)	Reporting moisture content[a] (%)	Crop removal P_2O_5 (lb/unit yield)	Crop removal K_2O (lb/unit yield)	P and K demand level	Target pH Mineral	Target pH Organic
Melon	25	8–10 ton	fresh	4.4	16	5	5.8	5.6
Millet	26	40–60 bu	10	0.40	0.40	2	5.6	5.4
Mint, oil	27	35–55 lb	—	1.1	4.4	5	—	5.6
Oats, grain	75	30–120 bu	14	0.29	0.19	4	5.8	5.6
Oats, grain + straw [c]	28	30–120 bu	—	—	—	4	5.8	5.6
Oats, straw [d]	—	1–3 ton	DM	9.4	47	—	—	—
Onion	31	400–600 cwt	fresh	0.12	0.26	5	5.6	5.4
Pasture, legume-grass	34	2–5 ton	DM	13	51	4	6.0	—
Pasture, managed [e]	33	2–5 ton	DM	15	55	1	6.0	5.6
Pasture, unimproved	32	1–4 ton	DM	16	36	2	6.0	5.6
Pea, canning	35	1000–6000 lb	fresh	0.0046	0.0092	3	6.0	5.6
Pea, chick/field/cow	36	1–2 ton	10	20	24	3	6.0	5.6
Pepper	37	8–10 ton	fresh	1.1	5.6	5	6.0	5.6
Potato [f]	39	250–650 cwt	fresh	0.12	0.50	6	5.2/6.0	5.2/5.6
Pumpkin	40	15–20 ton	fresh	2.9	6.3	5	6.0	5.6
Raspberry, establishment [b]	64	all	fresh	—	—	3	6.5	5.6
Reed canarygrass	41	4–7 ton	DM	7.3	33	2	6.0	5.6
Rye, grain	76	15–70 bu	14	0.41	0.31	4	5.6	5.4
Rye, grain + straw [c]	43	15–70 bu	—	—	—	4	5.6	5.4
Rye, straw [d]	—	1–2 ton	DM	3.7	21	—	—	—
Small grain silage [g]	81	2.0–3.5 ton	DM	11	44	4	6.0	—
Small grain silage, under-seeded with alfalfa [g]	29	2.0–3.5 ton	DM	11	44	4	6.8	—
Small grain & legume silage [g,h]	82	2.0–3.5 ton	DM	11	44	4	6.0	—
Small grain & legume silage, underseeded with alfalfa [g,h]	30	2.0–3.5 ton	DM	11	44	4	6.8	—
Sod, establishment	45	all	—	—	—	2	6.0	5.6
Sorghum, grain	46	50–100 bu	14	0.40	0.40	2	5.6	5.4
Sorghum-sudan, forage	47	5–7 ton	65	15	60	2	5.6	5.4
Soybean, grain	48	15–85 bu	13	0.80	1.4	2	6.3	5.6
Soybean, grain + straw [c]	77	15–85 bu	—	—	—	2	6.3	5.6
Soybean, straw [d]	—	2–4 ton	DM	5.4	19	—	—	—
Spinach	49	4–6 ton	fresh	4.0	10	5	6.0	5.6
Squash	50	12–16 ton	fresh	2.8	6.4	5	6.0	5.6
Strawberry, establishment [b]	65	all	fresh	—	—	3	6.5	5.6
Sunflower	51	500–4000 lb	10	0.012	0.024	1	6.0	5.6
Tobacco	52	1600–2800 lb	cured leaf	0.0091	0.057	5	5.8	5.6
Tomato	53	20–25 ton	fresh	1.8	8.0	5	6.0	5.6

(continued)

Table 4.3. Crop codes, typical yield range, moisture content at which yield is reported, phosphorus and potassium crop removals and demand levels, and target soil pH values for each crop *(continued)*.

Crop name	Crop code	Yield range (per acre)	Reporting moisture content[a] (%)	Crop removal P_2O_5 (lb/unit yield)	Crop removal K_2O (lb/unit yield)	P and K demand level	Target pH Mineral	Target pH Organic
Trefoil, birdsfoot	54	1.5–5.5 ton	DM	13	60	4	6.0	5.6
Triticale, grain	55	1000–5000 lb	~13	0.011	0.0092	4	6.0	5.6
Triticale, grain + straw [c]	80	1000–5000 lb	—	—	—	4	6.0	5.6
Triticale, straw [d]	—	1–2 ton	DM	3.7	21	—	—	—
Truck crops	56	all	fresh	—	—	5	6.0	5.6
Vetch, crown/hairy	57	2–3 ton	DM	16	48	4	6.0	5.6
Wheat, grain	78	20–100 bu	13.5	0.50	0.35	3	6.0	5.6
Wheat, grain + straw [c]	58	20–100 bu	—	—	—	3	6.0	5.6
Wheat, straw [d]	—	1.5–3.5 ton	DM	6.0	28	—	—	—
Wildlife food plot, corn/forage brassicas	69	—	—	—	—	2	6.0	—
Wildlife food plot, legumegrass pasture	70	—	—	—	—	4	6.0	—
Wildlife food plot, oats/wheat/rye	71	—	—	—	—	4	6.0	—
Wildlife food plot, soybean	72	—	—	—	—	2	6.0	—
Wildlife food plot, sugar beet/turnip	73	—	—	—	—	4	6.3	—

[a] Reporting moisture content is the moisture content at which yield is reported. DM = yield is reported on a dry matter basis; fresh = yield is reported on a fresh, as harvested basis; cured leaf = yield is sold/reported on a cured leaf basis.

[b] Lime recommendations for apples and cherries apply only to pre-plant tests. Adjustment of pH is impractical once an orchard is established. Other perennial fruit crops must also be limed or amended with an acidifying material and incorporated prior to establishment.

[c] Use when both grain and straw are removed.

[d] Straw and stover do not have a crop code because no nutrient application guidelines are provided. Yield ranges and crop removals for straw and stover are given for information only. Crop removals for straw are used in calculating the phosphate and potash fertilizer recommendations for small grains, grain + stover, see Table 7.4.

[e] Includes bromegrass, fescue, orchardgrass, ryegrass, and timothy.

[f] Use higher target pH for scab-resistant varieties and lower target pH for varieties that are not scab resistant.

[g] Small grains include barley, oats, rye, triticale, and wheat.

[h] Legumes may include leguminous vegetables (pea, bean) and soybean, but not forage legumes (alfalfa, red clover).

Table 4.4. Accepted corn and alfalfa yield levels for each yield potential category [a]

Yield potential code [b]	Relative yield potential	Accepted yield goals: Corn (bu/a)	Accepted yield goals: Alfalfa (ton/a)
1	Very high	131–220	3.5–8.5
2	High	101–180	3.0–7.0
3	Medium	81–160	2.5–5.5
4	Low	61–140	1.0–4.0

[a] These are the levels allowed by the laboratory computer program that generates nutrient rate guidelines.

[b] Refer to Table 4.1 for yield potential codes for specific soils or to Table 4.2 for yield potential codes by county.

5 Chapter — Soil pH and lime requirement

The optimum pH for a soil depends on the crops that will be grown. Table 4.3 lists the optimum (target) pH levels for crops grown in Wisconsin. The amount of lime recommended is the amount needed to reach the target pH for the most acid-sensitive crop (the one with the highest target pH) that is to be grown during the next 4 years. If alfalfa will be grown on a field in the future, but is not indicated in the present rotation, the field lime needs may be underestimated.

Once a soil reaches the desired pH level, it will tend to remain at that level for a relatively long time without additional application of lime. This is because soils are naturally highly buffered against changes in pH. Coarse-textured soils (sands and loamy sands) are not as highly buffered against pH change as medium- and fine-textured soils, so they will generally not maintain their pH level as long. Sandy soils may need to be limed more frequently, but at much lower rates.

Lime requirement calculations

Lime should be applied if the soil pH is more than 0.2 units below the target pH. Minor fluctuations inherent in both sampling and pH measurement preclude calculating lime needs when the pH is within 0.2 units of the target. The lime requirement equations listed in Table 5.1 use soil pH and buffer pH values in calculating lime requirement for a sample.

The recommendations obtained using equations in Table 5.1 are for liming materials with a neutralizing index (NI) of 60-69. Because 80-89 NI lime is commonly used in much of the state, the necessary rate of 80-89 lime is normally listed on a soil test report along with the 60-69 rate. If using lime with an NI other than 60-69, adjust the lime requirement using the following formula:

Lime requirement (ton/a) of lime being used =
(ton/a of 60-69 lime recommended)
x (65 ÷ NI* of lime being used)

*When a range is given, use the midpoint (e.g., for 80-89 grade lime, use 85 in the calculation).

Lime requirement for 60-69 lime should be rounded to the nearest ton, while lime requirement for liming materials with a greater NI are rounded to the nearest 0.5 ton/a. The lime requirement for potato should be rounded to the nearest 0.1 ton/a because they are typically grown on poorly buffered soils and it is not desirable to overlime potato fields.

Plow depth adjustment

Adjusting the lime requirement for the depth of tillage is critical for reaching the desired soil pH. In the past, most tillage operations were limited to the top 7 inches of the soil, so the lime needs are based on that assumption. If tillage extends below 7 inches the lime requirement is greater, as more soil is being mixed with the applied lime. To adjust the lime recommendation for deeper tillage, multiply the lime requirement by the factor listed in Table 5.2.

An application rate of 1 ton/a of topdressed 60-69 lime is recommended for fields that have been under no-till management for more than 5 years and which have a surface (0–2 inches) pH that is more than 0.2 units below the target pH. These fields should be retested in 3–4 years to determine if additional lime applications are needed.

Table 5.1. Formulas used to calculate lime requirement at various target pH levels.

Target pH	**Lime requirement formula** [a] (tons/a 60–69 lime to apply [b])
5.2	36.1 – 3.29*BpH – 2.67*WpH
5.4	48.2 – 4.84*BpH – 3.03*WpH
5.6	51.0 – 5.40*BpH – 2.67*WpH
5.8	57.2 – 5.55*BpH – 3.50*WpH
6.0	72.7 – 7.59*BpH – 3.78*WpH
6.3	103 – 12.6*BpH – 3.18*WpH
6.5	134 – 17.2*BpH – 2.73*WpH
6.6	152 – 20.3*BpH – 2.17*WpH
6.8	195 – 28.4*BpH + 0.144*WpH

[a] Abbreviations: BpH = buffer pH, WpH = water pH

[b] An adjustment to compensate for inefficient field mixing and incomplete dissolution of ground limestone is already factored into the equation.

Table 5.2. Plow depth adjustment. Use the lime adjustment multiplier to calculate the new lime requirement for a given plow depth.

Plow depth (inches)	**Lime adjustment multiplier**
0–7.0	1.00
7.1–8.0	1.15
8.1–9.0	1.31
> 9.0	1.46

Averaging the lime requirement

On fields where multiple samples have been taken, a field average is normally used to determine the best overall rate. For samples where the lime requirement exceeds the field average by more than 2 tons/a, apply a higher rate of lime to the more acid part of the field. If a sample from the field indicates that the lime requirement is more than 2 tons/a below the mean, that sample should be excluded and an adjusted mean calculated using the remaining values. If only three or four samples were submitted from a field, no more than one sample will be eliminated from consideration. If five or more samples are taken to represent the field, no more than two samples will be excluded. This adjusted average is the value that is used to determine the lime needs for fields that are to be amended by applying a single uniform rate. If more than half of the samples on a field do not have a lime requirement, then the field lime requirement should be considered to be zero. However, growers should be aware that some parts of this field may benefit from liming and should consult the laboratory results section of the soil test report. If one-half or less of the samples in a field do not have a lime requirement, the field lime requirement should be based on the average of the samples with a lime requirement. Again, the laboratory results section of the soil test report should be consulted to determine which parts of the field may not benefit from liming.

Other factors affecting lime recommendations

Coarse-textured soils are not as well buffered against change in soil pH as are medium- and fine-textured soils. To help prevent over-liming on sandy soils with an average organic matter content of less than 1%, only 1 ton/a of lime should be applied when the calculated lime requirement is less than 1.5 tons/a. For silt loam and clay soils, the minimum application should be 2 tons/a of 60-69 NI lime or 1.5 tons/a of 80-89 grade lime. The rate of lime applied should never exceed 8 tons/a for potatoes or 12 tons/a for other crops even though more lime may be required to completely neutralize soil acidity. Where the lime need is greater than these levels, the field may not reach the desired target pH, but the smaller application is recommended for economic reasons.

If the field has been limed in the last 2 years, additional lime may not be needed, even though the target pH has not been reached. No additional lime should be applied until the most recent application has had 2–3 years to equilibrate with the soil and the pH retested.

Lowering soil pH

Most horticulture and agronomic crops grow best when soil pH is between 6.0 and 6.8. Many crops can adapt to higher or lower pH levels with no drop in crop quality or yield. However, some crops, like blueberries, require acid soil conditions (soil pH of 5.5 or less) to grow and perform as expected.

Many soils, especially those in southeastern Wisconsin, are alkaline (high pH), and may contain free carbonate, which is a source for alkalinity. Such soils require high levels of management to successfully grow crops that require acid soil conditions. If the soil pH is 7.5 or greater, growing crops that require low soil pH conditions is not recommended.

In the rest of Wisconsin, most soils with a pH of less than 7.5 can be amended to lower the pH to the desired level (Table 5.3). The most common materials used are elemental sulfur and aluminum sulfate. To lower the soil pH, elemental sulfur must be converted (oxidized) to sulfate by soil bacteria. As a result, the change in pH takes several months or longer. Sometimes the soil contains very small numbers of this special kind of bacteria. Under these conditions, the process may take 6 or more months. The oxidizing reaction brought about by the organisms is as follows:

$$S + \frac{3}{2} O_2 + H_2O \longrightarrow 2\,H^+ + SO_4^{2-}$$

It is not recommended to apply more than 20 lb S/1,000 sq. ft. per year. If more is required, use split applications of 20 lb S/1,000 sq. ft. and apply in succeeding years. Check the soil pH before making a second application to see how much change has taken place.

Aluminum sulfate ($Al_2(SO_4)_3$) can also be used to lower soil pH. Its effect is nearly immediate, but the cost to lower soil pH is higher than using elemental sulfur. The amount of aluminum sulfate needed to achieve the same decrease in pH is 6 times the amount of elemental sulfur required. Because too much aluminum can be toxic to plants, aluminum sulfate should not be applied at rates exceeding 50 lb $Al_2(SO_4)_3$/1,000 sq. ft. at any one application. Keep in mind that fertilizer products containing sulfate-sulfur are not effective in lowering soil pH. This includes products such as potassium sulfate (K_2SO_4) and gypsum ($CaSO_4$).

Table 5.3. Amount of finely ground elemental sulfur needed to lower soil pH (increase acidity).

Desired reduction in soil pH	**Soil organic matter content** (%)					
	0.5–2	**2–4**	**4–6**	**6–8**	**8–10**	**>10**
	———————— lb S/1,000 sq. ft. ————————					
0.25	6	18	28*	40*	53*	62*
0.50	12	35*	56*	80*	106*	125*
1.00	24*	70*	112*	120*	212*	250*

* Do not apply more than 20 lb S/1,000 sq. ft. per year; retest soil between applications.

Nitrogen application rate guidelines

Most non-legume crops need additional nitrogen (N) to improve crop yield and quality and to optimize economic return to the grower. However, excess nitrogen can reduce yields and lower the quality of some crops. Excess nitrogen can also cut economic returns to producers, degrade water quality, and cause other undesirable environmental effects. Wisconsin's nitrogen rate guidelines are based on crop yield, quality, and economic return. Using these guidelines will help to minimize excess nitrogen applications and reduce environmental risks. These guidelines are based on field studies where crop responses to several rates of nitrogen are measured on soils typically used for production of various crops. Nitrogen application rate guidelines vary according to the crop to be grown, soil characteristics and yield potential, and soil organic matter content.

Corn nitrogen rate guidelines

As noted above, the optimum nitrogen rate for corn grain and silage was developed through experiments that measured corn yield response to several rates of nitrogen on soils typically used for corn production. These studies found that the economic optimum nitrogen rate for corn grown on a given soil tends to be similar in high- and low-yielding years. Apparent recovery of fertilizer nitrogen by corn is high under favorable growing conditions and low when growing conditions are poor or include stress such as drought. The characteristic for optimum nitrogen rates to remain fairly constant across a wide yield range on similar soils has recently been called nitrogen resiliency.

Soil fertility specialists in several midwestern states, including Wisconsin, recently agreed upon a uniform approach to developing nitrogen rate guidelines for corn. The group recognized that yield objectives or yield goals are not good predictors of the economic optimum nitrogen rate. Instead, they focused on the relationship between corn and nitrogen prices. The specialists examined the results from hundreds of corn nitrogen response experiments conducted throughout the region. The new nitrogen rate guideline strategy, based on the data, is designed to maximize economic return to the grower. Because the philosophy of this approach is based on maximizing economic return to nitrogen (MRTN), that acronym is widely used to refer to these guidelines.

Although the MRTN approach emerged from a regional effort, the Wisconsin MRTN rate guidelines in this publication are based entirely on experiments conducted on numerous Wisconsin soils. The MRTN guidelines for corn (Table 6.1) are based on soil characteristics, previous crop, and the nitrogen:corn price ratio that is applicable to the specific production situation. Similar to the previous Wisconsin nitrogen rate recommendations, the MRTN rate guidelines are soil-specific. As shown in Table 6.1, medium- and fine-textured soils are separated into two soil yield potential categories: very high and high, and medium and low. This separation is needed because corn grown on soils in these two categories shows a different response to nitrogen fertilization. Sandy soils (sands and loamy sands) are given separate nitrogen rate guideline values depending on whether or not they are irrigated. The lower nitrogen rates for non-irrigated sandy soils reflect the lower yield potential where moisture is often inadequate. All irrigated non-sandy soils are presumed to be very high yield potential soils, and therefore receive the nitrogen rates suggested in Table 6.1 for medium- and fine-textured very high and high yield potential soils.

The soil name is the key to placing soils in the appropriate yield potential category, and the corn yield potential category for each soil is given in Table 4.1. Thus, providing the predominant soil name for a field on the soil information sheet is critical for obtaining an accurate nitrogen application rate value. When the soil name is not provided, the nitrogen application rate is estimated based on the texture code (sands versus other soils), county of origin (Table 4.2), and the soil organic matter level.

Selecting soil yield potential and previous crop options

For medium- and fine-textured soils, the suggested application rate varies according to the previous crop (Table 6.1). Where corn follows a forage legume, a leguminous vegetable, or a green manure crop or where manure has been applied, the appropriate nitrogen credits must be subtracted from the nitrogen rate values shown in Table 6.1. (See Tables 9.1–9.6 for information on crediting nitrogen from legumes and manure).

Previously, nitrogen application rates for corn following soybean involved subtracting a soybean nitrogen credit. Now the nitrogen needs are determined directly from the nitrogen response information for this cropping system. Although nitrogen response data for corn following small grains is somewhat limited, these results show that corn nitrogen needs in this cropping system are similar to those found where corn follows soybean. Suggested nitrogen rates for sands and loamy sands are appropriate for all previous crops, but nitrogen credits for previous forage legumes and manure applications must be subtracted from these values.

Where nitrogen rates are adjusted for nitrogen contributions from organic sources, such as manure, or other land-applied waste materials, it is important to recognize that this adjustment should be made on the basis of first-year available nitrogen content of the material and not its total nitrogen content. See Chapter 9 Nutrient Credits for details.

Table 6.1. Suggested nitrogen application rates for corn (grain) at different nitrogen:corn price ratios.

Soil	Previous crop	Nitrogen:corn price ratio 0.05	0.10	0.15	0.20
		——— lb N/a (total to apply)[a] ———			
High/very high yield potential soils	Corn, forage legumes, legume vegetables, green manures [d]	165 [b] 135—*—190 [c]	135 120—*—155	120 100—*—135	105 90—*—120
	Soybean, small grains [e]	140 110—*—160	115 100—*—130	100 85—*—115	90 70—*—100
Medium/low yield potential soils	Corn, forage legumes, legume vegetables, green manures [d]	120 100—*—140	105 90—*—120	95 85—*—110	90 80—*—100
	Soybean, small grains [e]	90 75—*—110	60 45—*—70	50 40—*—60	45 35—*—55
Sands/loamy sands	Irrigated—all crops [d]	215 200—*—230	205 190—*—220	195 180—*—210	190 175—*—200
	Non-irrigated—all crops [d]	120 100—*—140	105 90—*—120	95 85—*—110	90 80—*—100

[a] Includes N in starter.

[b] Rate is the nitrogen rate that provides the maximum return to nitrogen (MRTN).

[c] Range is the range of profitable nitrogen rates that provide an economic return to nitrogen within $1/a of the MRTN.

[d] Subtract N credits for forage legumes, legume vegetables, animal manures, green manures. This includes first, second, and third year credits where applicable. Do not subtract nitrogen credits for leguminous vegetables on sand and loamy sand soils.

[e] Subtract N credits for animal manures and second-year forage legumes.

Calculating nitrogen:corn price ratios

MRTN nitrogen rate guidelines are based on the nitrogen:corn price ratio that is applicable to the specific production situation. This allows the user flexibility in identifying the nitrogen rate likely to maximize economic return at prevailing nitrogen and corn prices. To determine the nitrogen:corn price ratio, divide the cost of nitrogen ($/lb) by the price of corn ($/bu). For example, if the cost of nitrogen is $0.30/lb and the price of corn is $2.50/bu, the nitrogen:corn price ratio is $0.30 ÷ $2.50 = 0.12. If the per ton price for fertilizer nitrogen is known, the nitrogen cost can be calculated as follows: Price of nitrogen ($/lb) = [$/ton of fertilizer N x (100 ÷ % N in fertilizer)] ÷ 2000. Table 6.1 shows the nitrogen rates likely to maximize economic return for four price ratios. Also shown is a range of nitrogen rates that would be within $1.00 per acre of maximizing economic return. With this approach, growers can select rates higher or lower than the MRTN rate depending on their experience with using various nitrogen rates and their risk tolerance. In general, corn yields will be at or near maximum levels if the nitrogen rates indicated for the 0.05 price ratio are used. At rates shown for the higher ratios, yields will likely be somewhat lower, but economic return to the grower will be maximized. For all soil types, the nitrogen rate at the MRTN for the 0.20 nitrogen:corn price ratio produces, on average, 94–95% of maximum yield.

Valuing corn grain and manure nitrogen

While the value of purchased fertilizer nitrogen is relatively easy to determine, estimating a realistic value for corn grain and manure nitrogen requires some calculations based on anticipated end use. The value of grain will vary depending on where the grain is sold and how it is marketed. For example, grain that will be used on the farm as livestock feed should be valued at the price it would cost to purchase grain if feedstocks run short.

The value of nitrogen in manure may vary between farms and between fields on farms depending upon the availability of land on which to spread manure. If a large enough land base is available to spread all manure, then the value of the nitrogen in manure could be considered to be equivalent to fertilizer nitrogen. This would mean that it would be more useful to spread the manure on as many acres as possible and reduce purchased nitrogen fertilizer. If the land base is limited, then spreading manure at a rate not to exceed the amount needed to maximize yield (top end of the profitability range for a nitrogen:corn price ratio of 0.05) would be appropriate. On some farms, there may be some fields that cannot receive manure and others that can. Thus, nitrogen application rates may be higher for fields receiving manure and lower for fields receiving fertilizer nitrogen.

Selecting nitrogen rates for corn silage

The relationship between silage yield and nitrogen application rate is similar to that for grain yield and nitrogen rate. Silage quality is not greatly influenced by nitrogen application rates over the range of nitrogen rates provided in the rate guidelines table. If growing silage for on-farm feed, usually growers want to maximize yield to minimize purchased feed costs. In this situation using a nitrogen rate in the mid- to upper end of the 0.05 price ratio would be appropriate. If silage is being sold, and a producer would like to reduce nitrogen rates to improve profitability, then they should choose a nitrogen rate using a nitrogen:corn price ratio that reflects typical prices for nitrogen and grain.

Deciding which end of the MRTN range to use

Additional suggestions for selecting optimum nitrogen rates from Table 6.1 are listed below:

- If residue covers more than 50% of the soil at planting, use the upper end of the range.
- If 100% of the nitrogen will come from organic sources, use the top end of the range. In this situation, up to 20 lb/a nitrogen in starter fertilizer may also be applied.
- For medium- and fine-textured soils with more than 10% organic matter, use the low end of the range.
- For medium- and fine-textured soils with less

than 2% organic matter, use the high end of the range.

- For coarse-textured soils with less than 2% organic matter, use the high end of the range.
- For coarse-textured soils with more than 2% organic matter, use the middle to low end of the range.
- For corn following small grains on medium- and fine-textured soils, the middle to low end of the range is most appropriate.
- If there is a likelihood of residual nitrogen (carry-over nitrogen), use the low end of the range or use the high end of the range and subtract preplant nitrate test (PPNT) credits.

Nitrogen rate guidelines for other crops

Nitrogen rate guidelines for crops other than potatoes are also based on the concept that desired yield or yield goal is not a good predictor of optimum nitrogen rates in the production of these crops. However insufficient nitrogen response data from research studies on a range of Wisconsin soils is available to allow application of the MRTN approach to nitrogen rate guidelines for these crops. Therefore, a single nitrogen rate suggestion is given regardless of yield level for these crops in Table 6.2. The suggested nitrogen rates are adjusted for soil organic matter content.

Considerations for potato

The potato nitrogen recommendations (Table 6.2) use yield as a criteria primarily to help separate early, short-season varieties from longer, full-season varieties. On medium- to fine-textured soils, apply the entire amount at planting; there is no advantage to splitting applications. On sandy soils, however, either apply 25–50% of the crop nitrogen need at emergence and the remainder at tuberization or apply the remaining nitrogen in multiple split applications. During years with high precipitation, multiple split applications improve yield and quality; during years with normal to low precipitation, splitting nitrogen applications at emergence and tuberization consistently produces high-yielding, high-quality potatoes. Excessive nitrogen splitting may increase the percentage of cull potatoes. Nitrogen can be applied up to 60 days after emergence. Later applications do not improve yield or quality.

When potatoes follow a legume crop, reduce nitrogen applications according to the legume nitrogen credits shown in Tables 9.4–9.6. Take appropriate credits if manure has been applied (Tables 9.1–9.3). Broadcasting or applying nitrogen with the irrigation water, especially early in the season, results in less efficient nitrogen use because as water moves downward in the furrows, the nitrogen bypasses the plant roots.

Petiole nitrate (NO_3-N) testing can help determine the need for late nitrogen application. Table 6.3 indicates optimum petiole NO3-N levels for several potato varieties and stages of growth. If petiole NO_3-N levels are below optimum and the crop has at least 45 days to vine kill, apply 30–50 lb N /a. This additional nitrogen may be applied through fertigation. If petiole NO_3-N testing will be used to monitor crop nitrogen status, early season nitrogen rates applied at hilling can be reduced by 25–30%.

Using soil nitrate tests to adjust nitrogen application rates

Nitrogen application rates suggested for corn, sweet corn, and winter wheat grown on medium- and fine-textured soils can be adjusted using soil nitrate tests. (Soil nitrate testing is not reliable on coarse-textured sandy soils because their nitrate content can change rapidly.) Soil nitrate testing allows nitrogen fertilizer recommendations to be adjusted for field-specific conditions that can influence crop nitrogen need. These adjustments can lower costs by avoiding nitrogen applications in excess of crop needs. They also help the environment by lowering the potential for nitrate movement to groundwater by avoiding over-application of nitrogen.

Soil nitrate tests estimate the amount of plant-available nitrate-nitrogen in the root zone. This nitrogen may have carried-over from fertilizer applications during the previous growing season or the nitrogen may have been supplied by preceding legume crops, manure applications, or mineralization of soil organic matter. If the amount of soil nitrate-nitrogen is significant, subsequent nitrogen fertilizer applications can be reduced or, in some cases, eliminated.

In Wisconsin, two tests are available: a preplant soil nitrate test (PPNT) that is appropriate for corn, sweet corn, and winter wheat and a presidedress soil nitrate test (PSNT) that can be used for corn and sweet corn. The PPNT involves deep soil sampling, to a depth of 2 feet, before planting the crop. This test measures the amount of residual or carryover nitrate in the soil. The second test, the PSNT, consists of shallower soil sampling, to a depth of 1 foot, when corn is 6 to 12 inches tall. This test is intended to predict the amount of plant-available nitrogen that will be released from organic sources during the growing season.

Choosing which of the soil nitrate tests to use depends on a grower's cropping system and field management. Generally, the PPNT works best under the following field conditions:

- Medium- and fine-textured soils.
- Previous growing season and over-winter precipitation normal or below normal.
- Previous crop nitrogen application in excess of crop need.

Using the PPNT is not recommended in the following situations:

- On medium- and fine-textured soils when the previous season and overwinter precipitation was above normal.
- On sandy soils.
- When the previous crop was nitrogen deficient.
- On first-year crops following alfalfa or other forage legume. (Refer to Table 9.4 for nitrogen credits for previous forage legume crops.)

Some nitrate carry-over occurs in most years on well-drained medium-textured soils in Wisconsin. The PPNT should be used when a grower suspects nitrate carry-over while the PSNT is most useful for confirming legume and manure nitrogen credits and providing a site-specific estimate of soil nitrogen availability. More information on using the PPNT and PSNT in various production situations is provided below.

Using the preplant soil nitrate test (PPNT)

For corn and sweet corn, soil samples for the PPNT should be collected in early spring after frost has left the soil and prior to planting or any preplant applications of nitrogen. For winter wheat, samples should be taken in late summer. Soil samples need to be collected in 1-foot increments to a depth of 2 feet. The program predicts the soil nitrate content in the 2- to 3-foot depth based on the nitrate content in the 1- to 2-foot depth, eliminating the need for deeper sampling (Ehrhardt and Bundy, 1995; Bundy and Andraski, 2001; Bundy and Andraski, 2004). For best results, take a minimum of 15 soil cores randomly from 20 acres. Be sure to take separate samples from field areas that differ in soil characteristics or past management practices. After collection, soil samples should be kept cool because the nitrate content in moist soil samples stored under warm conditions can increase quickly and cause erroneous test results. If samples cannot be delivered to the soil testing laboratory within 1 to 2 days after collection, the samples should be frozen or air-dried to prevent changes in soil nitrate content.

Nitrogen credits for recent manure applications (Tables 9.1–9.3) must be taken separately and in addition to any credits based on PPNT results. Another option for assessing these credits would be the use of the presidedress nitrate test (PSNT). See the following section for further information on using the PSNT.

Nitrogen credits based on the PPNT can be calculated using the information given in Table 6.4. These nitrogen credits should be subtracted from the nitrogen application rates for corn, sweet corn, and wheat (Tables 6.1 and 6.2) to arrive at an adjusted nitrogen application rate. The nitrogen credit is adjusted for background soil nitrate content by subtracting 50 lb N/a from the nitrate test result. More information on the PPNT is available in Extension publication *Wisconsin's Preplant Soil Nitrate Test* (A3512).

Table 6.2. Nitrogen rate guidelines for crops other than corn.

Crop	Yield range per acre	Soil organic matter content (%) < 2.0	2.0–9.9	10.0–20.0	> 20.0
		————————lb N/a to apply [a]————————			
Alfalfa, established	2.6–8.5 ton	0	0	0	0
Alfalfa, seeding	1.0–2.5 ton	30	0	0	0
Apple, establishment [b]	—	2	2	2	2
Asparagus	2000–4000 lb	80	60	40	20
Barley [c]	25–100 bu	70	50	30	15
Bean, dry (kidney, navy)	10–40 cwt	40	30	20	10
Bean, lima	2000–5000 lb	60	40	20	10
Beet, table	5–20 ton	120	100	80	30
Blueberry, establishment [d]	—	30	30	30	30
Brassica, forage	2–3 ton	120	100	80	40
Broccoli	4–6 ton	100	80	60	25
Brussels sprouts	4–6 ton	100	80	60	25
Buckwheat	1200–2000 lb	50	30	20	0
Cabbage	8–30 ton	180	140	100	40
Canola	30–50 bu	80	60	40	20
Carrot	20–30 ton	120	100	80	40
Cauliflower	6–8 ton	120	100	80	40
Celery	25–35 ton	140	120	100	50
Cherry, establishment [b]	—	2	2	2	2
Clover, red, established	2.0–6.5 ton	0	0	0	0
Clover, red, seeding	0.5-1.9 ton	30	0	0	0
Corn, popcorn	60–80 bu	110	90	70	50
Corn, sweet	2–10 ton	150	130	110	70
Cranberry, establishment [d]	—	150	150	150	150
CRP, alfalfa [e]	—	20	0	0	0
CRP, grass [e]	—	30	15	0	0
CRP, red clover [e]	—	20	0	0	0
Cucumber	5–10 ton	100	80	60	30
Flax	20–40 bu	50	30	20	0
Ginseng	1000–3000 lb	60	40	20	0
Grapes, establishment [b]	—	2	2	2	2
Lettuce	15–20 ton	120	100	80	40
Lupine	40–60 bu	10	0	0	0
Melon	8–10 ton	100	80	60	30
Millet	40–60 bu	80	60	40	20
Mint, oil	35–55 lb	120	100	80	50
Oats [c]	30–120 bu	60	40	20	0
Onion	400–600 cwt	150	140	130	120
Pasture, legume-grass, established	2–5 ton	0	0	0	0
Pasture, legume-grass, seeding	0.5-1.9 ton	40	20	0	0
Pasture, managed [f, g]	2–5 ton	160	130	100	50
Pasture, unimproved [f]	1–4 ton	120	100	70	30
Pea, canning	1000–6000 lb	40	30	20	0

Table 6.2. Nitrogen rate guidelines for crops other than corn *(continued)*.

Crop	Yield range per acre	Soil organic matter content (%) < 2.0	2.0–9.9	10.0–20.0	> 20.0
		————————lb N/a to apply [a]————————			
Pea, chick/field/cow	1–2 ton	40	30	20	0
Pepper	8–10 ton	100	80	60	30
Potato [h]	250–350 cwt	145	120	100	60
Potato [h]	351–450 cwt	180	155	130	75
Potato [h]	451–550 cwt	220	180	150	85
Potato [h]	551–650 cwt	250	210	175	95
Pumpkin	15–20 ton	100	80	60	30
Raspberry, establishment [d]	—	30	30	30	30
Reed canarygrass	4–7 ton	270	250	220	100
Rye	15–70 bu	60	40	20	0
Small grain silage	2.0–3.5 ton	60	40	20	0
Small grain silage, underseeded with alfalfa	2.0–3.5 ton	30	20	10	0
Small grain & legume silage	2.0–3.5 ton	25	15	0	0
Small grain & legume silage, underseeded with alfalfa	2.0–3.5 ton	15	10	0	0
Snapbean	1.5–6.5 ton	60	40	20	0
Sod [i]	all	250	250	250	250
Sorghum, grain	50–100 bu	130	100	80	40
Sorghum-sudan, forage	5–7 ton	120	100	80	40
Soybean	15–85 bu	0	0	0	0
Spinach	4–6 ton	100	80	60	30
Squash	12–16 ton	80	60	40	20
Strawberry, establishment [d]	—	30	30	30	30
Sunflower	500–4000 lb	100	80	60	30
Tobacco	1600–2800 lb	140	120	100	0
Tomato	20–25 ton	140	120	100	50
Trefoil, birdsfoot, established	1.5–5.5 ton	0	0	0	0
Trefoil, birdsfoot, seeding	0.5–1.4 ton	30	0	0	0
Triticale	1000–5000 lb	60	40	20	0
Truck crops	all	140	120	120	60
Vetch, crown/hairy, established	2–3 ton	0	0	0	0
Vetch, crown/hairy, seeding	0.5–1.9 ton	30	0	0	0
Wheat [j]	20–100 bu	90	70	40	0

[a] This is the total amount of nitrogen to apply including starter fertilizer.

[b] These rates are in oz/plant, not lb/a. Rates apply for the establishment year only. The rate is 1 oz/plant applied twice during the establishment year. After establishment use tissue testing to guide fertilizer application.

[c] Where barley or oat are underseeded with a legume forage, eliminate or reduce nitrogen by half.

[d] Rates apply for the establishment year only. After establishment, use tissue testing to guide fertilizer application. For blueberry, raspberry, and strawberry, split that total application rate into two or three applications in the establishment year. For cranberries, apply no more than 15 lb N/a at any one time during the establishment year.

[e] Apply some nitrogen (15–30 lb N/a), seeding year only.

[f] Split nitrogen applications into two to three applications per year.

[g] Includes bromegrass, fescue, orchardgrass, ryegrass, and timothy.

[h] Rates include nitrogen in starter fertilizer. Reduce nitrogen rate by 25% if petiole nitrate test is used to guide in-season nitrogen applications.

[i] Apply total amount of nitrogen in split applications and/or use slow release fertilizers. These guidelines are for sod farms only.

[j] Reduce nitrogen rate by 10 lb N/a for spring wheat.

Using the presidedress soil nitrate test (PSNT)

The presidedress soil nitrate test (PSNT) provides a diagnostic tool for adjusting corn nitrogen application rates. It measures the amount of plant-available nitrogen released from organic nitrogen sources such as previous forage legume crops, manure applications, and soil organic matter. The PSNT can be a valuable technique for confirming the amount of nitrogen that should be credited from manure or previous legume crops where insufficient information is available to assign these credits.

Samples for the PSNT should be taken when corn plants are 6–12 inches tall, usually 4–6 weeks after planting. Unlike preplant nitrate (PPNT) samples, PSNT soil samples are collected only to a depth of 1 foot. As with PPNT, a minimum of 15 soil cores should be randomly taken from every 20 acres. Samples should be refrigerated. (See previous section on sampling for the preplant test). The PSNT is not recommended on sandy soils (sands and loamy sands). While soil sampling for the PSNT is easier than for the PPNT, growers using the PSNT are locked into sidedress applications if additional nitrogen is needed. Users of this test should also be aware that all operations including soil sampling, laboratory analysis, and sidedress nitrogen applications must be completed within 1–2 weeks.

For corn and sweet corn, soil nitrate measured by the PSNT is credited against the nitrogen application rate (Table 6.1 or 6.2) using the values shown in Table 6.5. For example, if the target application rate for a corn field on high yield potential soils is 150 lb N/a and the PSNT value is 16 ppm N, a credit of 60 lb N/a would be subtracted from the target application rate (150 – 60 = 90 lb N/a) to arrive at the nitrogen rate to apply.

Because mineralization of nitrogen from organic sources is a biological process, the amounts measured by the PSNT are influenced by average temperatures during the period before sample collection. When early growing season temperatures are cool, mineralization occurs more slowly, causing the PSNT to underestimate the amount of organic nitrogen that will become available during the growing season. When this occurs, nitrogen credits based on the PSNT will be low, resulting in application rates that are higher than necessary.

Wisconsin research with the PSNT shows that optimum nitrogen rates for corn are sometimes overestimated when average temperatures in May–June are more than 1°F below the long-term average (Andraski and Bundy, 2002). When average temperatures in May and June are normal or higher, the PSNT seldom overestimates crop nitrogen needs. Where the PSNT is used to adjust nitrogen rates for nitrogen contributions from organic nitrogen sources in growing seasons with below normal average temperatures for May and June, users should consider the book value

Table 6.3. Optimum petiole NO_3-N levels for several potato varieties at different growth stages.

Stage of growth (days after emergence)	Dry weight basis			Sap basis		
	Norkota Norland Atlantic Kennebec	Shepody R.Burbank Snowden	Onaway Superior	Norkota Norland Atlantic Kennebec	Shepody R.Burbank Snowden	Onaway Superior
	—————% NO_3-N—————			—————ppm NO_3-N —————		
30	2.5–2.8	2.0–2.3	2.3–2.5	1900–2100	1600–1800	1800–1900
40	2.3–2.5	1.7–2.2	2.0–2.3	1800–2000	1600–1700	1600–1800
50	1.8–2.3	1.2–1.6	1.5–1.9	1400–1800	1000–1300	1200–1500
60	1.3–1.9	0.8–1.1	0.9–1.2	1100–1500	700–900	500–1000
70	0.8–1.1	0.5–0.8	0.4–0.6	700–900	500–700	400–600

nitrogen credit for the manure application or the previous legume crop together with the PSNT nitrogen credit in arriving at a nitrogen application rate decision. If the PSNT value is > 21 ppm N, no additional nitrogen is needed. If the PSNT nitrogen credit is substantially less than the book value nitrogen credits, the book value credits are likely to be more reliable. Low PSNT nitrogen credits are most likely to occur with spring manure applications or following spring killed or spring tilled alfalfa.

Using soil nitrate tests in Wisconsin cropping systems

Selecting the soil nitrate test that is most appropriate for a particular production situation depends on the cropping system, management practices, and climatic conditions. The following suggestions are intended to provide guidance on the most useful test for various cropping systems common to Wisconsin.

Corn following corn. Where corn follows corn in a crop rotation, residual soil nitrate accumulation is likely on medium- and fine-textured soils if previous precipitation was normal or below and/or previous nitrogen applications exceeded crop uptake. In this cropping system, the PPNT is the preferred soil nitrate test because the deeper sampling depth allows more complete assessment of the amount of residual nitrate in the soil profile. The PSNT can be used to provide a partial estimate of nitrogen carryover and to estimate the amounts of available nitrogen likely to be released for organic sources. In the corn following corn crop sequence, the PSNT can identify sites that do not need additional nitrogen fertilization based on the 21 ppm critical level.

Manured sites. Both the PPNT and the PSNT can be used on manured fields; however, there are differences in the interpretation of the test results depending on which test is used. The PSNT

Table 6.4. Nitrogen credits based on preplant nitrate test (PPNT) results.

Crop	PPNT results	Nitrogen credit (lb N/a to credit)
Corn, sweet corn	0–50 lb/a	0
	50–200 lb/a	PPNT – 50 lb N/a (apply a minimum of 50 lb N/a)
	>200 lb/a	—*
Winter wheat	<50 lb/a	0
	>50 lb/a	PPNT – 50 lb N/a

* No additional nitrogen is needed.

Table 6.5. Nitrogen credits for the presidedress soil nitrate test (PSNT).

PSNT value	Soil yield potential: Very high/high	Soil yield potential: Medium/low
	Nitrogen credit	
ppm N	——————lb N/a——————	
> 21	—*	—*
18–20	100	80
15–17	60	80
13–14	35	40
11–12	10	40
< 10	0	0

* No additional nitrogen is needed

provides a direct estimate (nitrogen credit) of the amount of available nitrogen likely to be released during the growing season. The PPNT measures only nitrate nitrogen present when the sample is taken and thus will not reflect nitrogen release from the manure. When using the PPNT, a separate manure nitrogen credit (Tables 9.1–9.3) must be taken in addition to the credit based on the test result.

Corn following alfalfa. When corn follows alfalfa in a crop rotation, the previous alfalfa crop can provide most, if not all, of the nitrogen required by the corn crop. The best method for determining corn nitrogen needs following alfalfa is to subtract the appropriate legume nitrogen credit (Table 9.4) from the unadjusted nitrogen application rate. Corn following a good or fair stand of alfalfa on medium- and fine-textured soils usually does not need additional nitrogen. Where there is a need to confirm the alfalfa nitrogen credit, the PSNT should be used. If the PSNT result is less than 21 ppm N, no more than 40 lb N/a should be applied. The PPNT should not be used for corn following alfalfa.

Corn following soybean. Nitrogen rate guidelines for corn following soybean (Table 6.1) reflect the effect of the soybean-corn rotation on corn nitrogen needs. The PPNT can be used to refine these nitrogen rate suggestions for the effect of residual soil nitrate. Where PPNT results are available, subtract the nitrate test nitrogen credit from the appropriate nitrogen rate guideline value for the soybean-corn crop sequence in Table 6.1. The PSNT should not be used for adjusting nitrogen application rates in soybean-corn sequences.

Confirming second-year manure and legume credits. Manure and legume residues release nitrogen and other crop nutrients as they decompose. While the largest release of available nitrogen occurs in the first year after manure or legume residues are added to the soil, this process is not complete after 1 year. Additional nitrogen is released during the second growing season after manure application or alfalfa plowdown. Where corn follows corn, the PPNT is the preferred soil nitrate test. However, this test will not measure any nitrogen released by manure or legume residues during the second cropping year. Therefore, second year manure or legume nitrogen credits in Tables 9.1–9.3 and Table 9.4, respectively, must be taken in addition to the adjustment for the PPNT. With the later sampling date of the PSNT, second year nitrogen contributions due to mineralization of organic sources have already been converted to nitrate-nitrogen and will be measured by the test. Therefore, nitrogen credits for the PSNT should not be adjusted further for second-year manure or legume nitrogen credits.

Managing nitrogen to avoid losses

The nitrogen application rate guidelines, nitrogen credits, and soil nitrate test suggestions presented in this publication assume that best management practices will be used to control nitrogen losses. If best management practices are not followed and losses occur, the nitrogen rates suggested are likely to be inadequate to meet crop needs. Nitrogen losses hurt both the bottom line and the environment. The major nitrogen management options to help avoid nitrogen losses are summarized below.

Nitrogen rate

Deciding how much nitrogen to apply is the most important nitrogen management practice affecting profitability and nitrogen use efficiency. Applying more nitrogen than the crop needs is the primary source of nitrate losses to the environment. Using the nitrogen rate guidelines in this publication together with appropriate nitrogen crediting for manure and previous legume crops are essential for arriving at the best nitrogen rate decision. Application rates can be further refined for some crops through use of soil nitrate testing.

Note also that as nitrogen rates increase, crop recovery of nitrogen decreases and the potential for nitrate loss to the environment increases. Therefore, the risk of nitrate loss to groundwater is reduced at lower nitrogen rates; however, yields and economic returns are also likely to be less. See Chapter 11 in Extension publication *Management of Wisconsin Soils* (A3588) for additional information on this subject. Nitrogen rates below those specified for maximum economic return can be selected to accomplish individual management or environmental objectives. Yields will vary depending on growing conditions and management.

Nitrogen deficiencies become more likely as nitrogen rates are decreased from those shown in this publication.

Nitrogen source

All fertilizer nitrogen sources are effective in supplying nitrogen to crops, but ammonia volatilization or nitrate leaching can lower the effectiveness of some. Urea and urea-containing fertilizers such as urea-ammonium nitrate solutions (UAN) will volatilize if surface-applied and conditions favoring loss develop. Losses are usually 25–30% of the applied nitrogen and can seriously reduce the fertilizer's effectiveness. Control measures include injecting or incorporating the fertilizer materials, including a urease inhibitor, or using a nitrogen source that does not contain urea. Rainfall of at least 1⁄4 inch within a few days after application will also minimize losses to volatilization.

Fertilizers that contain nitrate such as urea-ammonium nitrate solution, ammonium nitrate, calcium nitrate are susceptible to nitrogen losses through leaching if substantial rainfall occurs soon after application. Under conditions where leaching is likely, using all-ammonium nitrogen sources, slow-release fertilizer materials, or delaying the nitrogen application to match crop uptake can help control these losses.

Nitrogen timing

Timing of nitrogen applications can play an important role in controlling nitrogen losses. Ideally, nitrogen would be applied just before the period of crop nitrogen use, providing adequate nitrogen to the crop when it needs it and avoiding nitrogen losses that could occur when applied earlier than needed. In practice, though, other times of nitrogen application can be used with equal effectiveness. Typically, nitrogen timing options for corn include fall, preplant, and sidedress or split applications. Fall applications are subject to higher risks of nitrogen loss than other timing options, and require specific management practices to obtain acceptable performance. In all cases, fall applications should be limited to well-drained, medium- and fine-textured soils. Fall applications should be delayed until soil temperatures remain below 50°F, and nitrogen should be applied as anhydrous ammonia containing a nitrification inhibitor. Even when these practices are employed, fall applications are usually 10–15% less effective than spring applications of the same amount of nitrogen.

Preplant nitrogen applications are as effective as other timing options on most medium- and fine-textured soils with moderate or better drainage. Sidedress nitrogen applications can be used effectively on these soils; however, reduced optimum nitrogen rates or yield enhancements should not be expected solely from the use of sidedress nitrogen. In contrast, sidedress or split applications are essential for controlling nitrogen losses on coarse-textured sandy soils (leaching) and on some poorly drained soils (denitrification).

In some situations, use of a nitrification inhibitor with preplant-applied ammonium forms of nitrogen or use of slow-release nitrogen fertilizers may also be effective in controlling nitrogen losses. The relative probability of obtaining a corn yield increase from use of a nitrification inhibitor is influenced by soil characteristics and the timing of the nitrogen applications (Table 6.6). Usually, a

Table 6.6. Relative probability of increasing corn yield using a nitrification inhibitor.

	Time of nitrogen application		
Soil type	Fall	Spring preplant	Spring sidedress
Sands and loamy sands	Not recommended	Good	Poor
Sandy loams and loams	Fair	Good	Poor
Silt loams and clay loams			
Well drained	Fair	Poor	Poor
Somewhat poorly drained	Good	Fair	Poor
Poorly drained	Good	Good	Poor

positive response will occur only where use of the inhibitor reduced or eliminated nitrogen losses due to leaching or denitrification.

Nutrient management planning

Nitrogen (N) recommendations provided to producers by Land Grant Universities and Extension Services are receiving increasing scrutiny because of continuing concerns about the effects of agricultural nitrogen use on water quality. Specifically, nitrogen losses from agricultural systems have been identified as likely contributors to elevated groundwater nitrate concentrations and to the hypoxic (low-oxygen) zone in the Gulf of Mexico. In addition, university nitrogen recommendations are being widely used as the technical criteria for nutrient management regulatory policy. These policies often view university recommendations as a vehicle for achieving environmental objectives, while the basis for developing the recommendations is agronomic. These issues and the need to provide producers with reasonable economic returns from nitrogen use in crop production emphasize the need for reliable, science-based nitrogen recommendations.

Phosphorus and potassium — Chapter 7

Soil tests for phosphorus and potassium are indices of available nutrients present in the soil. These indices provide estimates of the amount of additional phosphate or potash that should be added to optimize profit for the farmer. Phosphorus and potassium soil test levels are reported in parts per million (ppm).

Soil test phosphorus and potassium interpretation categories vary by soil group because soils in each group vary in the amount of phosphorus and potassium that the soil can supply. Additionally, crops have been grouped into categories (demand levels) based on their responsiveness to phosphorus and potassium (Table 4.3). Tables 7.1 and 7.2 provide the soil test interpretation categories for each crop demand level. Definitions of the interpretive levels used to indicate the soil's relative nutrient supply of phosphorus and potassium are provided in Table 3.2. Crops grown on soils testing in the optimum range will have optimum yield and profit when the quantity of nutrients applied is about equal to the amount removed in the harvested portion of the crop. The optimum soil test ranges for phosphorus and potassium are set somewhat higher for vegetables, potatoes, and irrigated field crops because of their high crop values.

Each soil's ability to hold phosphorus and potassium along with phosphorus and potassium buffering capacity (the amount of fertilizer required to change soil test level by 1 ppm) is related to soil texture, mineralogy, and organic matter content. The approximate nutrient buffer capacity of each soil group is provided in Table 7.3. Note that soil group X applies only to soil test phosphorus interpretation category and the nutrient buffer capacity is based on a soil series' primary soil group.

Phosphorus and potassium application rate guidelines

When the soil test is optimum (Opt), the fertilizer application rate is equivalent to the amount of phosphate and potash removed in the harvested portion of the crop. This is considered a maintenance application, resulting in little change in soil test level. For soils that test greater than optimum, the objective of the nutrient application guidelines is to rely on the soil to supply the bulk of the nutrients needed for crop growth and reduce the soil test level to optimum. For soils testing high (H), the phosphorus and potassium application rate is one-half the rate at optimum. On very high (VH) testing soils (used only for soil test potassium interpretation), the potassium fertilizer application rate is one-quarter of the rate at optimum.

For soils testing excessively high (EH) the application rate is zero, with the exception of potato and corn which may respond to an application of 20–30 lb/a each of P_2O_5 and K_2O as starter fertilizer. See Chapter 10 Starter Fertilizers for details. The lower limit for the excessively high category is set such that 2–4 years of crop nutrient removal without fertilizing will not reduce soil test levels below the optimum category, except for crops where the whole plant is removed (corn silage, alfalfa and other forage legumes). These crops remove large amounts of potassium, so retest soils with very high and excessively high test levels every 2 years.

For soils that test less than optimum, it is desirable to build up soil test levels to the optimum category. The fertilizer application rates in the low (L) and very low (VL) categories include the amount of fertilizer that will be removed by the harvested portion of the crop (application rate at optimum) plus an additional amount to build up soil test levels over a 4- to 6-year period. In the low category, the buildup amount is calculated as the change in soil test level that is desired (ppm difference between the middle of the optimum category and the middle of the low category) multiplied by the nutrient buffering capacity for the soil group divided by four to six years. In the very low category, the buildup amount is calculated as the change in soil test level that is desired (ppm difference between the middle of the optimum category and the top of the very low category) multiplied by the nutrient buffering capacity for the soil group divided by four to six years.

Once the soil test interpretation categories have been identified, the phosphate and potash fertilizer application rates may be determined. Table 7.4 provides the phosphate and potash fertilizer application rate based on the soil test interpretation category for each crop.

Table 7.1. Soil test phosphorus interpretation categories.

Soil group	Soil test category Very low (VL)	Low (L)	Optimum (Opt)	High (H)	Excessively high (EH)
	——— Soil test phosphorus, ppm [a] ———				
Demand level 1 (corn grain)					
A	<5	5–10	11–15	16–25	>25
B	<10	10–15	16–20	21–30	>30
C	<10	10–15	16–20	21–30	>30
D	<8	8–12	13–18	19–28	>28
E	<12	12–22	23–32	33–42	>42
O	<12	12–22	23–32	33–42	>42
X	<5	5–8	9–15	16–25	>25
Demand level 2 (soybeans and low-demand field crops)					
A	—	<6	6–10	11–20	>20
B	—	<6	6–10	11–20	>20
C	—	<8	8–13	14–23	>23
D	—	<6	6–10	11–20	>20
E	—	<10	10–15	16–25	>25
O	—	<10	10–15	16–25	>25
X	—	<6	6–10	11–17	>17
Demand level 3 (alfalfa, corn silage, irrigated field crops, and low-demand vegetable crops)					
A	<10	10–15	16–23	24–32	>32
B	<10	10–17	18–23	24–30	>30
C	<12	12–17	18–25	26–35	>35
D	<10	10–15	16–23	24–30	>30
E	<18	18–25	26–37	38–55	>55
O	<18	18–25	26–37	38–55	>55
X	<5	5–10	11–15	16–23	>23
Demand level 4 (red clover and medium-demand field crops)					
A	<10	10–15	16–20	21–25	>25
B	<10	10–15	16–20	21–25	>25
C	<12	12–17	18–23	24–30	>30
D	<8	8–12	13–18	19–23	>23
E	<15	15–22	23–30	31–38	>38
O	<15	15–22	23–30	31–38	>38
X	<5	5–10	11–15	16–20	>20
Demand level 5 (high-demand vegetable crops)					
A	<15	15–30	31–45	46–75	>75
B	<15	15–30	31–45	46–75	>75
C	<15	15–30	31–45	46–75	>75
D	<15	15–30	31–45	46–75	>75
E	<18	18–35	36–50	51–80	>80
O	<18	18–35	36–50	51–80	>80
X	<10	10–25	26–40	41–60	>60
Demand level 6 (potato)					
A	<100	100–160	161–200	>200	––
B	<100	100–160	161–200	>200	––
C	<100	100–160	161–200	>200	––
D	<100	100–160	161–200	>200	––
E	<60	60–90	91–125	126–160	>160
O	<60	60–90	91–125	126–160	>160
X	<36	36–60	61–75	76–120	>120

[a] ppm (wt/vol; g/m^3)

Table 7.2. Soil test potassium interpretation categories.

Soil group	Very low (VL)	Low (L)	Optimum (Opt)	High (H)	Very high (H)	Excessively high (EH)
	Soil test potassium, ppm [a]					
Demand level 1 (corn grain)						
A	<60	60–80	81–100	101–140	—	>140
B	<70	70–90	91–110	111–150	—	>150
C	<60	60–70	71–100	101–140	—	>140
D	<70	70–100	101–130	131–160	—	>160
E	<45	45–65	66–90	91–130	—	>130
O	<45	45–65	66–90	91–130	—	>130
Demand level 2 (soybeans and low-demand field crops)						
A	<50	50–80	81–100	101–120	121–140	>140
B	<50	50–80	81–100	101–120	121–140	>140
C	<40	40–70	71–90	91–110	111–130	>130
D	<70	70–100	101–120	121–140	141–160	>160
E	––	<60	60–80	81–100	101–120	>120
O	––	<60	60–80	81–100	101–120	>120
Demand level 3 (alfalfa, corn silage, irrigated field crops and low-demand vegetable crops)						
A	<70	70–90	91–120	121–150	151–220	>220
B	<70	70–90	91–120	121–150	151–220	>220
C	<55	55–70	71–100	101–130	131–200	>200
D	<90	90–110	111–140	141–170	171–240	>240
E	<50	50–80	81–120	121–160	161–220	>220
O	<50	50–80	81–120	121–160	161–220	>220
Demand level 4 (red clover and medium-demand field crops)						
A	<55	55–70	71–100	101–120	121–150	>150
B	<55	55–70	71–100	101–120	121–150	>150
C	<50	50–65	66–90	91–110	111–130	>130
D	<60	60–80	81–120	121–140	141–160	>160
E	<45	45–60	61–90	91–110	111–130	>130
O	<45	45–60	61–90	91–110	111–130	>130
Demand level 5 (high-demand vegetable crops)						
A	<60	60–120	121–180	181–200	201–220	>220
B	<60	60–120	121–180	181–200	201–220	>220
C	<50	50–110	111–160	161–180	181–200	>200
D	<80	80–140	141–200	201–220	221–240	>240
E	<50	50–100	101–150	151–165	166–180	>180
O	<50	50–100	101–150	151–165	166–180	>180
Demand level 6 (potato)						
A	<80	80–120	121–160	161–180	181–210	>210
B	<80	80–120	121–160	161–180	181–210	>210
C	<70	70–100	101–150	151–170	171–190	>190
D	<80	80–120	121–170	171–190	191–220	>220
E	<70	70–100	101–130	131–160	161–190	>190
O	<70	70–100	101–130	131–160	161–190	>190

[a] ppm (wt/vol; gm/m^3)

If the realistic yield goal for a particular crop on a given field is greater than the yield levels provided in Table 7.4, a fertilizer application rate for the optimum category can be determined by multiplying the yield goal by the amount of phosphorus or potassium that will be removed in the harvested portion of the crop (see Table 4.3). If the soil test interpretation category is something other than optimum, the fertilizer rate can be determined using the approach outlined above.

Additional considerations

Nutrient recommendations for crops grown on sands and organic soils are limited by the nutrient holding capacity of these soils, particularly for potassium. Because potassium leaches readily from organic soils and irrigated sands, and because specialty crop growers tend to use larger amounts of fertilizer, soil test values may fluctuate rapidly. For this reason, irrigated fields and fields in vegetable production should be soil sampled every year or every other year. If the crop to be grown has a demand level of 1, 2, or 4, and will be irrigated, then demand level 3 should be used.

Soils with relatively low potassium buffering capacities (soil groups D, E, and O) should be monitored more closely by testing every 2 years. These soils do not hold sufficient potassium to allow for several years of high-yielding crops when the whole plant is removed. Because group O soils hold so little potassium, these soils are not suited for growing alfalfa, or other crops where large amounts of potassium are removed (corn silage, forage legumes). While group D soils have a low potassium buffering capacity, they can hold much more potassium than soils in groups E and O.

Where alfalfa is to be grown, increase the recommended K_2O application rate by 20% if stand persistence is of primary importance and the stand is to be maintained for more than 3 years. If phosphorus and potassium fertilizer applications were made for corn grain but the corn was instead harvested for silage, increase fertilizer application rates for the next crop by 30 lb P_2O_5/a and 90 lb K_2O/a if soil test phosphorus and potassium were less than excessively high. If soil test phosphorus and/or potassium were excessively high, then there is no need to apply an additional amount of that nutrient.

For fruit crops, phosphorus and potassium nutrient application rates are provided for establishment of the crop. Nutrient application rates after the establishment year should be based on tissue testing with the goal of achieving and maintaining tissue nutrient concentration sufficiency.

Sample averaging

The fertilizer application rate guidelines for phosphorus and potassium should be based on the average of all samples from a given field. If the soil test value of an individual sample is significantly

Table 7.3. Phosphorus and potassium buffer capacities; the rate of fertilizer (oxide basis) required to increase soil test level 1 ppm.

Soil group	P buffer capacity	K buffer capacity
	lb P_2O_5/a per 1 ppm soil test P	lb K_2O/a per 1 ppm soil test K
A	18	7
B	18	7
C	18	7
D	18	6
E	12	6
O	18	5

higher than the average, then the value for that sample can be eliminated and the average recalculated. The remaining values are then reexamined against the new mean. For phosphorus, values that exceed the mean by more than 5 ppm should be removed; for potassium, values that exceed the mean by more than 20 ppm should be removed. Where only two samples were taken in a field, no samples can be discarded. No more than one soil sample can be eliminated from fields with three or four samples, and no more than two soil samples can be excluded from fields containing five or more samples. After samples have been removed, if needed, the adjusted average soil test value can be used to obtain a phosphorus and potassium recommendation.

Phosphorus and the environment

Phosphorus loss from the soil via surface runoff and leaching is a concern with regard to water quality. Wisconsin research has found that as soil test phosphorus levels increase, phosphorus loss to surface water also increases. A balance must be struck between crop production and environmental quality. For most field and forage crops (demand levels 1, 2, 3, and 4) there is very little probability of a yield response to additional phosphorus (from fertilizer or manure) once the soil test level exceeds about 30 ppm (Table 3.2). Thus, it is not desirable to maintain excessively high soil test levels for these crops. If crop rotations do not contain a high phosphorus demanding crop (demand levels 5 and 6) and soil test phosphorus levels are between 50 and 100 ppm, phosphorus applications from fertilizer and manure should be reduced and crops with a high phosphorus removal should be grown. If soil test phosphorus exceeds 100 ppm, no additional phosphorus should be applied until soil test levels are drawn down. Maintaining soil test phosphorus levels near optimum will ensure adequate yield and provide flexibility in nutrient management planning.

For more information on phosphorus and water quality see *Understanding Soil Phosphorus* (A3771).

Table 7.4. Phosphorus and potassium fertilizer application rate guidelines.

Crop	Yield goal	P_2O_5 rate guidelines					K_2O rate guidelines					
		VL [a]	L [a]	Opt	H	EH	VL [b]	L [b]	Opt	H	VH	EH
	per acre	lb P_2O_5/a to apply [c]					lb K_2O/a to apply [d]					
Alfalfa, established [e]	2.6–3.5 ton	80	65	40	20	0	230	220	180	90	45	0
Alfalfa, established [e]	3.6–4.5 ton	90	75	50	25	0	290	280	240	120	60	0
Alfalfa, established [e]	4.6–5.5 ton	105	90	65	35	0	350	340	300	150	75	0
Alfalfa, established [e]	5.6 –6.5 ton	120	105	80	40	0	410	400	360	180	90	0
Alfalfa, established [e]	6.6–7.5 ton	130	115	90	45	0	470	460	420	210	105	0
Alfalfa, established [e]	7.6–8.5 ton	145	130	105	55	0	530	520	480	240	120	0
Alfalfa, seeding	1.0–2.5 ton	65	50	25	15	0	155	145	105	55	25	0
Apple [f]	all	200	125	NA	NA	NA	250	200	NA	NA	NA	NA
Asparagus	2000–4000 lb	85	60	10	5	0	120, 145	80, 105	20	10	5	0
Barley, grain	25–50 bu	50	40	15	10	0	55	45	15	10	5	0
Barley, grain	51–75 bu	60	50	25	15	0	60	50	20	10	5	0
Barley, grain	76–100 bu	70	60	35	20	0	70	60	30	15	10	0
Barley, grain + straw [g]	25–50 bu	70	60	35	20	0	115	105	75	40	20	0
Barley, grain + straw [g]	51–75 bu	80	70	45	25	0	125	115	85	45	20	0
Barley, grain + straw [g]	76–100 bu	90	80	55	30	0	135	125	95	50	25	0
Bean, dry (kidney, navy)	10–20 cwt	60	45	20	10	0	75	65	25	15	5	0
Bean, dry (kidney, navy)	21–30 cwt	70	55	30	15	0	90	80	40	20	10	0
Bean, dry (kidney, navy)	31–40 cwt	80	65	40	20	0	105	95	55	30	15	0
Bean, lima	2000–3000 lb	60	45	20	10	0	95	85	45	25	10	0
Bean, lima	3001–4000 lb	70	55	30	15	0	110	100	60	30	15	0
Bean, lima	4001–5000 lb	80	65	40	20	0	125	115	75	40	20	0
Bean, snap	1.5–2.5 ton	50	35	10	5	0	90	80	40	20	10	0
Bean, snap	2.6–3.5 ton	55	40	15	10	0	110	100	60	30	15	0
Bean, snap	3.6–4.5 ton	60	45	20	10	0	130	120	80	40	20	0
Bean, snap	4.6–5.5 ton	65	50	25	15	0	150	140	100	50	25	0
Bean, snap	5.6–6.5 ton	70	55	30	15	0	170	160	120	60	30	0
Beet, table	5–10 ton	85	60	10	5	0	160, 185	120, 145	60	30	15	0
Beet, table	10.1–15.0 ton	90	65	15	10	0	200, 225	160, 185	100	50	25	0
Beet, table	15.1–20.0 ton	100	75	25	15	0	240, 265	200, 225	140	70	35	0
Blueberry [f]	all	200	125	NA	NA	NA	250	200	NA	NA	NA	NA
Brassica, forage	2–3 ton	65	50	25	15	0	170	160	120	60	30	0

Table 7.4. Phosphorus and potassium fertilizer application rate guidelines *(continued)*.

Crop	Yield goal	P_2O_5 rate guidelines					K_2O rate guidelines					
		VL [a]	L [a]	Opt	H	EH	VL [b]	L [b]	Opt	H	VH	EH
	per acre	lb P_2O_5/a to apply [c]					lb K_2O/a to apply [d]					
Broccoli	4–6 ton	85	60	10	5	0	140, 165	100, 125	40	20	10	0
Brussels sprouts	4–6 ton	90	65	15	10	0	145, 170	105, 130	45	25	10	0
Buckwheat	1200–2000 lb	—	30	20	10	0	80	35, 60	20	10	5	0
Cabbage	8–12 ton	90	65	15	10	0	170, 195	130, 155	70	35	20	0
Cabbage	12.1–20.0 ton	100	75	25	15	0	215, 240	175, 200	115	60	30	0
Cabbage	20.1–30.0 ton	115	90	40	20	0	280, 305	240, 265	180	90	45	0
Canola	30–50 bu	80	70	45	25	0	125	110	80	40	20	0
Carrot	20–30 ton	120	95	45	25	0	340, 365	300, 325	240	120	60	0
Cauliflower	6–8 ton	95	70	20	10	0	150, 175	110, 135	50	25	15	0
Celery	25–35 ton	175	150	100	50	0	400, 425	360, 385	300	150	75	0
Cherry [f]	all	200	125	NA	NA	NA	250	200	NA	NA	NA	NA
Clover, red, established	2.6–3.5 ton	75	65	40	20	0	220	210	180	90	45	0
Clover, red, established	3.6–4.5 ton	85	75	50	25	0	280	270	240	120	60	0
Clover, red, established	4.6–5.5 ton	100	90	65	35	0	340	330	300	150	75	0
Clover, red, established	5.5–6.5 ton	115	105	80	40	0	400	390	360	180	90	0
Clover, red, seeding	1.0–2.5 ton	60	50	25	15	0	145	135	105	55	25	0
Corn, grain [h]	71–90 bu	65	55	30	15	0	70	55	25	15	5	0
Corn, grain [h]	91–110 bu	75	65	40	20	0	75	60	30	15	10	0
Corn, grain [h]	111–130 bu	80	70	45	25	0	80	65	35	20	10	0
Corn, grain [h]	131–150 bu	90	80	55	30	0	85	70	40	20	10	0
Corn, grain [h]	151–170 bu	95	85	60	30	0	90	75	45	25	10	0
Corn, grain [h]	171–190 bu	105	95	70	35	0	95	80	50	25	15	0
Corn, grain [h]	191–220 bu	110	100	75	40	0	105	90	60	30	15	0
Corn, popcorn	60–80 bu	65	50	25	15	0	70	60	20	10	5	0

[a] Where there are two application rates in a category the lower rate is for soils in groups E, O, and X, and the higher rate is for soils in groups A–D.

[b] Where there are two application rates in a category the lower rate is for soils in groups E and O, and the higher rate is for soils in groups A–D.

[c] Total amount of P_2O_5 to apply including starter fertilizer.

[d] Total amount of K_2O to apply including starter fertilizer.

[e] If stand will be maintained for more than 3 years, increase top-dressed K_2O by 20%.

[f] Rates only applicable prior to establishment of fruit crops. Incorporate all P_2O_5 and K_2O before planting. For established fruit crops, use tissue testing to guide fertilizer application rates.

[g] Includes removal of both mature grain and straw. Recommendations at optimum were calculated by adding phosphate/potash removal in the grain for each yield level to a fixed amount of phosphate/potash removed by straw. Phosphate and potash removals by straw were calculated assuming the following constant straw yield: barley, 2 ton/a; oats, 2 ton/a; rye, 1.5 ton/a; soybean, 3 ton/a; triticale, 1.5 ton/a; wheat, 2 ton/a. Straw yield level assumptions are based on Wisconsin research and data in Havlin et al. 1999.

[h] At EH soil test levels P_2O_5 and K_2O is not recommended; however, there are some situations where corn will benefit from some P_2O_5 and K_2O in starter fertilizer. See Chapter 10 Starter Fertilizer for more detail.

[i] Includes bromegrass, fescue, orchardgrass, ryegrass, and timothy.

[j] Most P_2O_5 and K_2O should be incorporated prior to seeding. These guidelines are for sod farms only.

Table 7.4. Phosphorus and potassium fertilizer application rate guidelines *(continued)*.

		P_2O_5 rate guidelines					K_2O rate guidelines					
Crop	Yield goal	VL [a]	L [a]	Opt	H	EH	VL [b]	L [b]	Opt	H	VH	EH
	per acre	lb P_2O_5/a to apply [c]					lb K_2O/a to apply [d]					
Corn, silage	10–16 ton	85	70	45	25	0	160	150	110	55	30	0
Corn, silage	16.1–20.0 ton	105	90	65	35	0	200	190	150	75	40	0
Corn, silage	20.1–25.0 ton	120	105	80	40	0	235	225	185	95	45	0
Corn, silage	25.1–35.0 ton	150	135	110	55	0	300	290	250	125	65	0
Corn, sweet	2–4 ton	50	35	10	5	0	70	60	20	10	5	0
Corn, sweet	4.1–6.0 ton	55	40	15	10	0	80	70	30	15	10	0
Corn, sweet	6.1–8.0 ton	65	50	25	15	0	90	80	40	20	10	0
Corn, sweet	8.1–10.0 ton	70	55	30	15	0	105	95	55	30	15	0
Cranberry [f]	all	200	125	NA	NA	NA	250	200	NA	NA	NA	NA
CRP, alfalfa	—	40	25	0	0	0	50	40	0	0	0	0
CRP, grass	—	—	10	0	0	0	60	15, 40	0	0	0	0
CRP, red clover	—	35	25	0	0	0	40	30	0	0	0	0
Cucumber	5–10 ton	85	60	10	5	0	125, 150	85, 110	25	15	5	0
Flax	20–40 bu	—	30	20	10	0	80	35, 60	20	10	5	0
Ginseng	1000–3000 lb	90	65	15	10	0	160, 185	120, 145	60	30	15	0
Grape [f]	all	200	125	NA	NA	NA	250	200	NA	NA	NA	NA
Lettuce	15–20 ton	115	90	40	20	0	260, 285	220, 245	160	80	40	0
Lupine	40–60 bu	85	75	50	25	0	100	90	60	30	15	0
Melon	8–10 ton	115	90	40	20	0	245, 270	205, 230	145	75	35	0
Millet	40–60 bu	—	30	20	10	0	80	35, 60	20	10	5	0
Mint, oil	35–55 lb	125	100	50	25	0	300, 325	260, 285	200	100	50	0
Oats, grain	30–60 bu	50	40	15	10	0	50	40	10	5	5	0
Oats, grain	61–90 bu	55	45	20	10	0	55	45	15	10	5	0
Oats, grain	91–120 bu	65	55	30	15	0	60	50	20	10	5	0
Oats, grain + straw [g]	30–60 bu	65	55	30	15	0	145	135	105	55	25	0
Oats, grain + straw [g]	61–90 bu	75	65	40	20	0	150	140	110	55	30	0
Oats, grain + straw [g]	91–120 bu	85	75	50	25	0	155	145	115	60	30	0
Onion	400–600 cwt	135	110	60	30	0	230, 255	190, 215	130	65	35	0
Pasture, legume-grass	2–3 ton	70	60	35	20	0	170	160	130	65	35	0
Pasture, legume-grass	3.1–4.0 ton	80	70	45	25	0	220	210	180	90	45	0
Pasture, legume-grass	4.1–5.0 ton	95	85	60	30	0	270	260	230	115	60	0

Table 7.4. Phosphorus and potassium fertilizer application rate guidelines *(continued)*.

Crop	Yield goal	P_2O_5 rate guidelines					K_2O rate guidelines					
		VL [a]	L [a]	Opt	H	EH	VL [b]	L [b]	Opt	H	VH	EH
	per acre	lb P_2O_5/a to apply [c]					lb K_2O/a to apply [d]					
Pasture, managed [i]	2–3 ton	75	65	40	20	0	185	170	140	70	35	0
Pasture, managed [i]	3.1–4.0 ton	90	80	55	30	0	240	225	195	100	50	0
Pasture, managed [i]	4.1–5.0 ton	105	95	70	35	0	295	280	250	125	65	0
Pasture, unimproved	1–2 ton	—	35	25	15	0	115	70, 95	55	30	15	0
Pasture, unimproved	2.1–3.0 ton	—	50	40	20	0	150	105, 130	90	45	25	0
Pasture, unimproved	3.1–4.0 ton	—	65	55	30	0	185	140, 165	125	65	30	0
Pea, canning	1000–2500 lb	50	35	10	5	0	65	55	15	10	5	0
Pea, canning	2501–4000 lb	55	40	15	10	0	80	70	30	15	10	0
Pea, canning	4001–6000 lb	65	50	25	15	0	95	85	45	25	10	0
Pea, chick/field/cow	1–2 ton	70	55	30	15	0	85	75	35	20	10	0
Pepper	8–10 ton	85	60	10	5	0	150, 175	110, 135	50	25	15	0
Potato	250–350 cwt	130, 235	105, 165	65	65	30	205, 240	190, 210	180	120	75	30
Potato	351–450 cwt	145, 250	120, 180	80	70	30	255, 290	240, 260	230	145	90	30
Potato	451–550 cwt	155, 260	130, 190	90	75	30	305, 340	290, 310	280	170	100	30
Potato	551–650 cwt	165, 270	140, 200	100	80	30	355, 390	340, 360	330	195	115	30
Pumpkin	15–20 ton	125	100	50	25	0	210, 235	170, 195	110	55	30	0
Raspberry [f]	all	200	125	NA	NA	NA	250	200	NA	NA	NA	NA
Reed canarygrass	4–7 ton	—	50	40	20	0	240	195, 220	180	90	45	0
Rye, grain	15–30 bu	45	35	10	5	0	45	35	5	5	0	0
Rye, grain	31–50 bu	50	40	15	10	0	55	45	15	10	5	0
Rye, grain	51–70 bu	60	50	25	15	0	60	50	20	10	5	0
Rye, grain + straw [g]	15–30 bu	50	40	15	10	0	80	70	40	20	10	0
Rye, grain + straw [g]	31–50 bu	55	45	20	10	0	85	75	45	25	10	0
Rye, grain + straw [g]	51–70 bu	65	55	30	15	0	90	80	50	25	15	0

[a] Where there are two application rates in a category the lower rate is for soils in groups E, O, and X, and the higher rate is for soils in groups A–D.

[b] Where there are two application rates in a category the lower rate is for soils in groups E and O, and the higher rate is for soils in groups A–D.

[c] Total amount of P_2O_5 to apply including starter fertilizer.

[d] Total amount of K_2O to apply including starter fertilizer.

[e] If stand will be maintained for more than 3 years, increase top-dressed K_2O by 20%.

[f] Rates only applicable prior to establishment of fruit crops. Incorporate all P_2O_5 and K_2O before planting. For established fruit crops, use tissue testing to guide fertilizer application rates.

[g] Includes removal of both mature grain and straw. Recommendations at optimum were calculated by adding phosphate/potash removal in the grain for each yield level to a fixed amount of phosphate/potash removed by straw. Phosphate and potash removals by straw were calculated assuming the following constant straw yield: barley, 2 ton/a; oats, 2 ton/a; rye, 1.5 ton/a; soybean, 3 ton/a; triticale, 1.5 ton/a; wheat, 2 ton/a. Straw yield level assumptions are based on Wisconsin research and data in Havlin et al. 1999.

[h] At EH soil test levels P_2O_5 and K_2O is not recommended; however, there are some situations where corn will benefit from some P_2O_5 and K_2O in starter fertilizer. See Chapter 10 Starter Fertilizer for more detail.

[i] Includes bromegrass, fescue, orchardgrass, ryegrass, and timothy.

[j] Most P_2O_5 and K_2O should be incorporated prior to seeding. These guidelines are for sod farms only.

Table 7.4. Phosphorus and potassium fertilizer application rate guidelines *(continued)*.

Crop	Yield goal	P_2O_5 rate guidelines					K_2O rate guidelines					
		VL [a]	L [a]	Opt	H	EH	VL [b]	L [b]	Opt	H	VH	EH
	per acre	lb P_2O_5/a to apply [c]					lb K_2O/a to apply [d]					
Small grain silage	2–3.5 ton	65	55	30	15	0	160	150	120	60	30	0
Small grain silage, underseeded with alfalfa	2–3.5 ton	65	55	30	15	0	160	150	120	60	30	0
Small grain & legume silage	2–3.5 ton	65	55	30	15	0	160	150	120	60	30	0
Small grain & legume silage, underseeded with alfalfa	2–3.5 ton	65	55	30	15	0	160	150	120	60	30	0
Sod, establishment [j]	all	130	90	45	45	45	90	45	45	45	45	45
Sorghum, grain	50–100 bu	—	40	30	15	0	90	45, 70	30	15	10	0
Sorghum-sudan forage	5–7 ton	—	100	90	45	0	420	375, 400	360	180	90	0
Soybean, grain	15–25 bu	—	25	15	10	0	90	45, 70	30	15	10	0
Soybean, grain	26–35 bu	—	35	25	15	0	100	55, 80	40	20	10	0
Soybean, grain	36–45 bu	—	40	30	15	0	115	70, 95	55	30	15	0
Soybean, grain	46–55 bu	—	50	40	20	0	130	85, 110	70	35	20	0
Soybean, grain	56–65 bu	—	60	50	25	0	145	100, 125	85	45	20	0
Soybean, grain	66–75 bu	—	65	55	30	0	160	115, 140	100	50	25	0
Soybean, grain	76–85 bu	—	75	65	35	0	170	125, 150	110	55	30	0
Soybean, grain + straw [g]	15–25 bu	—	40	30	15	0	145	100, 125	85	45	20	0
Soybean, grain + straw [g]	26–35 bu	—	50	40	20	0	160	115, 140	100	50	25	0
Soybean, grain + straw [g]	36–45 bu	—	60	50	25	0	175	130, 155	115	60	30	0
Soybean, grain + straw [g]	46–55 bu	—	65	55	30	0	185	140, 165	125	65	30	0
Soybean, grain + straw [g]	56–65 bu	—	75	65	35	0	200	155, 180	140	70	35	0
Soybean, grain + straw [g]	66–75 bu	—	80	70	35	0	215	170, 195	155	80	40	0
Soybean, grain + straw [g]	76–85 bu	—	90	80	40	0	230	185, 210	170	85	45	0
Spinach	4–6 ton	95	70	20	10	0	150, 175	110, 135	50	25	15	0
Squash	12–16 ton	115	90	40	20	0	190, 215	150, 175	90	45	25	0
Strawberry [f]	all	200	125	NA	NA	NA	250	200	NA	NA	NA	NA
Sunflower	500–1200 lb	45	35	10	5	0	65	50	20	10	5	0
Sunflower	1201–2500 lb	55	45	20	10	0	90	75	45	25	10	0
Sunflower	2501–4000 lb	75	65	40	20	0	125	110	80	40	20	0
Tobacco	1600–2000 lb	90	65	15	10	0	205, 230	165, 190	105	55	25	0
Tobacco	2001–2400 lb	95	70	20	10	0	225, 250	185, 210	125	65	30	0
Tobacco	2401–2800 lb	100	75	25	15	0	250, 275	210, 235	150	75	40	0

Table 7.4. Phosphorus and potassium fertilizer application rate guidelines *(continued)*.

Crop	Yield goal	P_2O_5 rate guidelines					K_2O rate guidelines					
		VL [a]	L [a]	Opt	H	EH	VL [b]	L [b]	Opt	H	VH	EH
	per acre	lb P_2O_5/a to apply [c]					lb K_2O/a to apply [d]					
Tomato	20–25 ton	115	90	40	20	0	280, 305	240, 265	180	90	45	0
Trefoil, birdsfoot, established	2.6–3.5 ton	75	65	40	20	0	220	210	180	90	45	0
Trefoil, birdsfoot, established	3.6–4.5 ton	85	75	50	25	0	280	270	240	120	60	0
Trefoil, birdsfoot, established	4.6–5.5 ton	100	90	65	35	0	340	330	300	150	75	0
Trefoil, birdsfoot, seeding	1–2.5 ton	60	50	25	15	0	145	135	105	55	25	0
Triticale, grain	1000–5000 lb	70	60	35	20	0	70	60	30	15	10	0
Triticale, grain + straw [g]	1000–5000 lb	75	65	40	20	0	100	90	60	30	15	0
Truck crops	all	115	90	40	20	0	220, 245	180, 205	120	60	30	0
Vetch, crown/hairy	2–3 ton	75	65	40	20	0	160	150	120	60	30	0
Wheat, grain	20–40 bu	55	40	15	10	0	60	50	10	5	5	0
Wheat, grain	41–60 bu	65	50	25	15	0	70	60	20	10	5	0
Wheat, grain	61–80 bu	75	60	35	20	0	75	65	25	15	5	0
Wheat, grain	81–100 bu	85	70	45	25	0	80	70	30	15	10	0
Wheat, grain + straw [g]	20–40 bu	65	50	25	15	0	115	105	65	35	15	0
Wheat, grain + straw [g]	41–60 bu	75	60	35	20	0	125	115	75	40	20	0
Wheat, grain + straw [g]	61–80 bu	85	70	45	25	0	130	120	80	40	20	0
Wheat, grain + straw [g]	81–100 bu	95	80	55	30	0	140	130	90	45	25	0
Wildlife food plot, corn/forage brassicas	—	—	10	0	0	0	60	15, 40	0	0	0	0
Wildlife food plot, legume grass pasture	—	35	25	0	0	0	40	30	0	0	0	0
Wildlife food plot, oats/wheat/rye	—	35	25	0	0	0	40	30	0	0	0	0
Wildlife food plot, soybean	—	—	10	0	0	0	60	15, 40	0	0	0	0
Wildlife food plot, sugar beet/turnip	—	35	25	0	0	0	40	30	0	0	0	0

[a] Where there are two application rates in a category the lower rate is for soils in groups E, O, and X, and the higher rate is for soils in groups A–D.

[b] Where there are two application rates in a category the lower rate is for soils in groups E and O, and the higher rate is for soils in groups A–D.

[c] Total amount of P_2O_5 to apply including starter fertilizer.

[d] Total amount of K_2O to apply including starter fertilizer.

[e] If stand will be maintained for more than 3 years, increase top-dressed K_2O by 20%.

[f] Rates only applicable prior to establishment of fruit crops. Incorporate all P_2O_5 and K_2O before planting. For established fruit crops, use tissue testing to guide fertilizer application rates.

[g] Includes removal of both mature grain and straw. Recommendations at optimum were calculated by adding phosphate/potash removal in the grain for each yield level to a fixed amount of phosphate/potash removed by straw. Phosphate and potash removals by straw were calculated assuming the following constant straw yield: barley, 2 ton/a; oats, 2 ton/a; rye, 1.5 ton/a; soybean, 3 ton/a; triticale, 1.5 ton/a; wheat, 2 ton/a. Straw yield level assumptions are based on Wisconsin research and data in Havlin et al. 1999.

[h] At EH soil test levels P_2O_5 and K_2O is not recommended; however, there are some situations where corn will benefit from some P_2O_5 and K_2O in starter fertilizer. See Chapter 10 Starter Fertilizer for more detail.

[i] Includes bromegrass, fescue, orchardgrass, ryegrass, and timothy.

[j] Most P_2O_5 and K_2O should be incorporated prior to seeding. These guidelines are for sod farms only.

8 Chapter — Secondary and micronutrients

Secondary nutrients

Sulfur

Several research studies since 1968 have shown that sulfur (S) may be deficient in some parts of Wisconsin. Sulfur deficiencies are most likely to occur when high sulfur-demanding crops such as alfalfa, canola, or forage brassicas are grown on sandy soils or on other soils low in organic matter that are far from urbanized areas and have not received manure within the last 2 years.

Sulfur avilability index (SAI). The sulfur availability index (SAI) is used to determine the relative level of plant available sulfur. The SAI is composed of soil test sulfate-sulfur (SO4-S) along with estimates of sulfur from subsoil, precipitation, organic matter mineralization, and manure applications. This index, first developed in 1991, was modified in 2005 to reflect lower atmospheric sulfur inputs as well as reduced subsoil sulfur levels. These inputs are added together and reported as the SAI. The following equation is used to calculate the SAI value and the assumptions for each input are described below:

SAI = (soil test SO_4-S x 4) + subsoil-S + precipitation-S + (% organic matter x 2.8 lb/a) + available manure-S

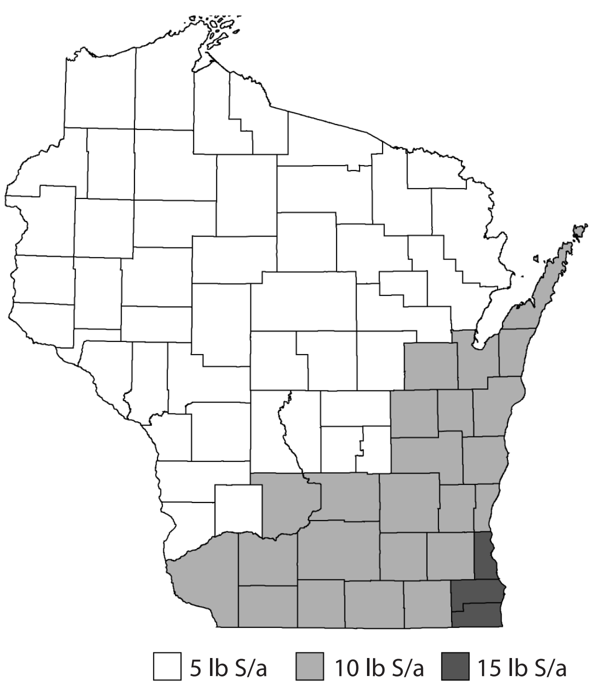
Subsoil sulfur. Some subsoils, especially those that are acidic and clayey, may contain enough sulfur for high-yielding crops even though the plow layer may test low. The relative level of sulfur in subsoil is provided as the subsoil sulfur code in Table 4.1. The subsoil sulfur code is either low, medium, or high. The estimated amount of available sulfur for each suboil sulfur code is dependent upon the soil group. See Table 8.1 for interpretation of the subsoil sulfur codes. These subsoil sulfur estimates are based on surveys conducted in 1974, 1985, and 1989. If a profile sulfate-sulfur test has been conducted on a field (with a profile nitrate-nitrogen test, for example), the results can be used to adjust the SAI. To adjust the SAI, substitute the measured subsoil sulfur (converted to lb/a) for the estimated subsoil sulfur.

Precipitation. The amount of sulfur from precipitation is based on surveys performed by the National Atmospheric Deposition Program, 1999. Estimates of precipitation sulfur by county are given in Table 4.2 and are provided graphically in Figure 8.1.

Organic matter. The sulfur contributed by organic matter is estimated by assuming that soil organic matter contains 0.56% total sulfur and that 2.5% of this is made available annually. This translates to 2.8 lb S/a per 1% organic matter in the plow layer.

Manure. The amount of sulfur available from manure depends on the total amount applied and its availability. The amount of total manure sulfur applied varies with the animal species and application rate. For estimates of total sulfur in various types of manures see Table 9.2. It is assumed that 55% of the total manure sulfur applied will be available the first year after application, 10% will be available the second year, and 5% will be available the third year. If a manure analysis has been performed and includes total sulfur, then a farm/field specific value of total manure sulfur can be used to estimate available sulfur in the calculation of SAI.

Figure 8.1. Sulfate-sulfur in precipitation.



SAI interpretation and sulfur recommendations are provided in Table 8.2.

All sulfate forms of fertilizer are equally effective when surface-applied or incorporated. Elemental sulfur, however, is insoluble and must be transformed into sulfate-sulfur by soil bacteria before plants can use it. The rate of this transformation depends on particle size, degree of mixing with the soil, and soil temperature. To be effective, elemental sulfur should be worked into the soil well in advance of the time the crop needs it. Without mechanical incorporation, elemental sulfur is incorporated to some extent by falling into cracks when the soil dries or by the activity of earthworms and burrowing insects.

Crops such as alfalfa and corn silage can remove large amounts of sulfur in one season. Table 8.3 provides a relative ranking of a crop's sulfur requirement based on crop removal of sulfur. Be sure to evaluate sulfur need through soil and tissue testing when growing crops with a high sulfur need.

Shallow-rooted crops grown on low-sulfur soils will generally benefit from annual applications of smaller amounts of sulfur. For annuals, incorporate elemental sulfur. If alfalfa will be grown on soils needing sulfur, either elemental sulfur or sulfate forms such as potassium sulfate, ammonium sulfate, potassium-magnesium sulfate, or calcium sulfate (gypsum) can be used. If the soil is known to be deficient in sulfur, include some sulfate-sulfur in topdress applications for immediate sulfur availability. When applied at recommended rates, sulfate-sulfur will generally last for two or more years while elemental sulfur should last for the term of the stand. Sandy soils may require annual applications of sulfate forms of sulfur because the sulfate leaches through these soils relatively rapidly. Irrigation water, however, may contain sufficient sulfate-sulfur for the crop. In these cases, response to fertilizer sulfur is likely only in years with above-average rainfall, when little irrigation water is applied. Additional information on sulfur is available in Extension publication *Soil and Applied Sulfur* (A2525).

Table 8.1. Interpretation of subsoil sulfur codes by soil group.

Soil group	Subsoil S code L	M	H
	— lb S/a in the subsoil —		
A	5	10	10
B	5	10	10
C	5	5	10
D	5	5	10
E	5	5	—
O	—	—	20

Table 8.2. Sulfur availability index (SAI) interpretation and sulfur fertilizer recommendations.

Crop	Sulfur availability index <30 (low)	30–40 (optimum)	>40 (adequate)
	————— lb S/a to apply ————		
Forage legumes			
Incorporated at seeding	25–50	tissue test [a]	0
Topdressed on established stands	15–25	tissue test [a]	0
Corn, small grains, vegetable and fruit crops	10–25	tissue test [a]	0

[a] If SAI is 30–40, then confirm the need for sulfur with a tissue test. If tissue test is below optimum, apply sulfur at the rate specified for an SAI < 30.

Calcium

Calcium (Ca) is unlikely to be deficient for most crops if lime recommendations are followed. Under Wisconsin conditions, the soil pH would likely have to be below 5.0 before calcium deficiency becomes apparent for most crops. Where plant storage organs are not part of the plant water transpiration stream (such as with potatoes and apples) and where soil test calcium is low, supplemental calcium may be needed. Assuming that a pH increase is appropriate, the most effective way to supply this calcium is with application of the most economical liming material available in your area.

Soil test interpretation categories for calcium are provided in Table 8.4. For soils testing optimum or greater, response to calcium is unlikely. Except for potato, response to calcium is also unlikely for soils testing low and very low. If potato is to be grown and there is no lime recommendation, 200 lb Ca/a should be applied to soils testing very low, and 100 lb Ca/a should be applied to soils testing low. If potato is to be grown and there is a lime recommendation, the calcium applied in the lime will be adequate for low testing soils; for very low testing soils, apply 50–100 lb Ca/a in addition to the lime.

For additional information on calcium see Extension publication *Soil and Applied Calcium* (A2523).

Magnesium

The magnesium content of Wisconsin soils varies widely, but in most instances use of dolomitic limestone has prevented deficiency. Some soils, however, are low in magnesium. These soils usually are: 1) where applied liming materials are low in magnesium (examples include paper mill waste, marl, or calcitic limestone); 2) very acid and sandy soils (usually in central and north-central areas of the state) where large amounts of potassium have been applied repeatedly; or 3) calcareous organic soils. In sandy soils, high application rates of potassium or fertilizers containing ammonium often heighten magnesium deficiency. High concentrations of these cations in the soil solution interfere with magnesium uptake by plants. This interference, called antagonism, usually does not occur when the soil contains more exchangeable magnesium than exchangeable potassium.

Soil test interpretation categories for magnesium are provided in Table 8.4. For soils testing high or above, a response to magnesium is unlikely. For optimum testing soils, magnesium levels should be maintained through the use of dolomitic limestone. Magnesium deficiencies can be expected on sands and loamy sand soils (texture code 1) which test less than optimum and have a soil test potassium level above optimum. On these soils, application of magnesium is necessary and potash application should be reduced. For all other soils with a very low or low magnesium soil test, magnesium should be applied to increase soil test levels.

The most economical way to apply magnesium and/or avoid a magnesium deficiency is to follow a good liming program with dolomitic limestone. When magnesium is recommended, a row application of 10–20 lb Mg/a can be applied annually where liming with dolomitic lime is undesirable or where rapid correction is needed. Broadcast applications of magnesium are generally not recommended except when applying dolomitic lime. Additional information on magnesium is available in Extension publication *Soil and Applied Magnesium* (A2524).

Calcium vs. magnesium

Claims are made that an imbalance sometimes exists between calcium and magnesium levels in the soil. Proponents of this theory have suggested that Wisconsin soils are adequate in calcium but contain excessive or harmful levels of magnesium. They suggest that calcitic limestone (CaCO3) or gypsum (CaSO4) is needed to correct this condition. At present, no research data exists to support this claim. Soil test level has proven to be a much more reliable predictor of nutrient need than the ratio of nutrients. Similarly, there is no evidence to support claims that magnesium is toxic or that Wisconsin soils have calcium to magnesium ratios that are too low. Research shows that calcium to magnesium ratios for virtually all Wisconsin soils fall within a rather wide optimum range. Applying calcitic limestone or gypsum solely to add calcium or change the calcium to magnesium ratio is not recommended. Dolomitic limestone has a calcium to magnesium ratio close to that found in most crops. For additional information on calcium/magnesium ratios see Extension publications *Soil Calcium to Magnesium Ratios—Should You Be Concerned?* (A2986) and *Soil Cation Ratios for Crop Production* (FO-06437-GO).

Micronutrients

Plants only need very small amounts of micronutrients for maximum growth. When present in the soil at excessive concentrations, micronutrients can harm plants. Thus, while a deficiency of any essential element will greatly reduce plant growth, the overuse of micronutrients can produce a harmful level of these nutrients in the soil which may be more difficult to correct than a deficiency. This is particularly true on coarse-textured soils such as sands, loamy sands, and sandy loams.

Micronutrients should be applied when the soil test is low, when verified deficiency symptoms appear in the plant, or when certain crops have very high requirements, such as boron for beets. Relative micronutrient requirements of crops are provided in Table 8.3. Currently, Wisconsin soil tests are available for boron, manganese, and zinc. The tests are interpreted in Table 8.4. Soil tests for copper, iron, and molybdenum are not sufficiently calibrated for accurately predicting the supply of these nutrients in Wisconsin soils. Analysis of plant tissue is a more reliable diagnostic tool than soil testing for identifying micronutrient problems.

Boron

The interpretation of the soil test for boron (B) depends on the texture of the soil. Sandy soils do not hold boron as tightly as clayey soils. A high test in a sandy soil may be only optimum in a silt loam. See Table 8.4 for interpretation of the soil test categories. Table 8.5 provides boron application rate guidelines based on the soil test interpretation category and a crop's relative need for boron. On sandy soils where alfalfa is grown, 1 lb B/a should be applied annually because of the relatively low boron retention of these soils. For more information about boron, consult Extension publication *Soil and Applied Boron* (A2522).

Manganese

Manganese (Mn) deficiency is usually associated with neutral or calcareous mineral soils, with calcareous muck, and with organic soils that have been burned. Manganese deficiency is highly unlikely on soils that have a pH below 6.8. Interpretation of manganese soil tests is appropriate for soils with organic matter contents less than or equal to 6.0%; see Table 8.4 for interpretation categories. If soils have an organic matter content greater than 6.0%, then manganese fertilizer recommendations are based on soil pH. For these soils, manganese is considered to be low if soil pH is > 6.9, optimum if soil pH is 6.0–6.9, and high if soil pH is <6.0.

Application rates for manganese are based on soil test interpretation categories (Table 8.4) and relative crop need (Table 8.3). For soils testing optimum or high, crop response to applied manganese is unlikely. Additionally, crop response is unlikely on soils testing low for crops with a low relative need for manganese. For low testing soils, apply 3 or 5 lb Mn/a for crops with medium or high relative need, respectively. Because of rapid soil fixation, broadcast manganese applications are not effective. Instead, manganese should be applied in the row for row crops or in the grain drill for small grains. Sulfate forms are recommended for soil application. Chelate forms of manganese are not effective when applied to the soil. For crops with a medium relative need growing on low testing soils, foliarly apply 1 lb Mn/a as a sulfate or 0.15 lb Mn/a as a chelate. For crops with a high relative need and low soil test, foliarly apply 1.25 or 0.2 lb Mn/a as sulfate or chelate forms, respectively.

To correct in-season manganese deficiencies, foliar applications can be used at 1 lb Mn/a of as sulfate or 0.15 lb Mn/a as chelate. Multiple foliar applications may be necessary to alleviate the deficiency. Additional information on manganese is available in Extension publication *Soil and Applied Manganese* (A2526).

Zinc

Scalped or severely eroded soils are more likely to be deficient in zinc (Zn) than well-managed soils. Zinc deficiencies are more common on sands, sandy loams, and organic soils because these soils originally contain low total zinc levels. Zinc availability decreases markedly as the soil pH increases; therefore, zinc deficiency usually is limited to soils with a pH above 6.5. Zinc deficiency has been observed in tree fruits and ornamentals in southern Wisconsin where irrigation with alkaline or hard water has resulted in high soil pH.

Application rates for zinc are based on soil test interpretation category (Table 8.4) and relative crop need (Table 8.3). Zinc should not be applied to soils testing excessively high. Response to zinc fertilizer is unlikely on soils testing optimum or high and on low testing soils where the crop to be grown has a low relative need. For crops with a medium and high relative need and a low or very low soil test, confirm the need for zinc with plant analysis.

Zinc deficiencies may be corrected with either banded or broadcast applications of 2–4 lb Zn/a or 4–8 lb Zn/a, respectively. If using a chelated form, apply 0.5–1.0 lb Zn/a in the band or 1–2 lb Zn/a broadcast. Deficiencies may also be corrected with a foliar application by using 1.0 lb Zn/a of zinc sulfate or 0.15 lb Zn/a of zinc chelate. More than one foliar application may be required for severe deficiencies. Additional information on zinc is available in Extension publication *Soil and Applied Zinc* (A2528).

Copper

Copper (Cu) deficiency is usually only seen on very acid soils, particularly mucks. Because copper is not easily leached from the soil, and it is not readily fixed in unavailable forms, repeated fertilization with copper is not necessary. It is unlikely that there is any benefit from additions of more than a total of 30 lb Cu/a to a soil over several years. In addition, some toxicities have been reported at high levels of use. Copper application rate guidelines are listed in Table 8.6. Additional information on copper is available in Extension publication *Soil and Applied Copper* (A2527).

Molybdenum

The availability of molybdenum (Mo) decreases as soil pH decreases. On soils with a pH below 5.5, crops with a high molybdenum requirement (e.g., broccoli and table beets) should be seed-treated with 0.2 oz Mo/a as ammonium or sodium molybdate. Foliar treatment with 0.8 oz Mo/a is an alternative treatment. Liming soils to optimal pH levels usually eliminates molybdenum problems. Additional information on molybdenum is available in Extension publication *Soil and Applied Molybdenum* (A3555).

Iron

Iron (Fe) deficiency has not been observed on any field or vegetable crops in Wisconsin. Turfgrass, pin oak trees, and some ornamentals such as yews have shown iron deficiency on soils with a pH greater than 7.5. This deficiency can be corrected by spraying the foliage with iron compounds such as ferrous sulfate or iron chelates or by decreasing soil pH where practical. Additional information on iron is available in Extension publication *Soil and Applied Iron* (A3554).

Chlorine

Crops require only very small amounts of chlorine (Cl). Chlorine deficiency has never been observed in Wisconsin fields. This micronutrient is unlikely to become deficient in Wisconsin because it is often applied in fertilizer salts such as potassium chloride, is present in manure, and is a universal contaminant in dust and rainwater. Additional information on chlorine is available in Extension publication *Soil and Applied Chlorine* (A3556).

Table 8.3. Relative micronutrient and sulfur requirements of Wisconsin crops.

Crop	Boron	Copper	Manganese	Molybdenum	Zinc	Sulfur [a]
Alfalfa, established	High	Medium	Low	Medium	Low	High
Alfalfa, seeding	High	Medium	Low	Medium	Low	Medium
Apple	Medium	Medium	—	—	Medium	—
Asparagus	Medium	Low	Low	Low	Low	—
Barley, grain	Low	Medium	Medium	Low	Medium	Low
Barley, grain + straw	Low	Medium	Medium	Low	Medium	Medium
Bean, dry (kidney, navy)	Low	Low	High	Medium	Medium	Medium
Bean, lima	Low	Low	High	Medium	Medium	—
Bean, snap	Low	Low	—	—	—	—
Beet, table	High	High	Medium	High	Medium	—
Blueberry	—	—	—	—	—	—
Brassica, forage	High	—	—	High	—	High
Broccoli	Medium	Medium	Medium	High	—	—
Brussels sprouts	Medium	Medium	Medium	High	—	—
Buckwheat	Low	—	—	—	—	—
Cabbage	Medium	Medium	Medium	Medium	Low	High
Canola	High	Medium	Medium	Medium	Medium	High
Carrot	Medium	Medium	Medium	Low	Low	—
Cauliflower	High	Medium	Medium	High	—	—
Celery	High	Medium	Medium	Low	—	—
Cherry	—	—	—	—	—	—
Clover, Red	Medium	Medium	Low	Medium	Low	Medium
Corn, grain	Low	Medium	Medium	Low	High	Medium
Corn, popcorn	—	—	—	—	—	—
Corn, silage	Low	Medium	Medium	Low	High	High
Corn, sweet	Low	Medium	Medium	Low	High	—
Cranberry	—	—	—	—	—	—
CRP, alfalfa	High	Medium	Low	Medium	Low	—
CRP, grass	Low	Low	Medium	Low	Low	—
CRP, red clover	Medium	Medium	Low	Medium	Low	—
Cucumber	Low	Medium	Medium	Low	Medium	—
Flax	—	—	—	—	—	Low
Ginseng	—	—	—	—	—	—
Grape	—	—	—	—	—	—
Lettuce	Medium	High	High	High	Medium	—
Lupine	Low	Low	Low	Medium	Medium	—
Melon	Medium	—	—	—	—	—
Millet	Low	—	—	—	—	Low
Mint, oil	Low	Low	Medium	Low	Low	—
Oats, grain	Low	Medium	High	Low	Low	Low
Oats, grain + straw	Low	Medium	High	Low	Low	Medium
Onion	Low	High	High	High	High	High

— = no data

(continued)

[a] Relative sulfur needs are based on average annual crop removal rates: low = <10 lb S/a, medium = 10–20 lb S/a, and high = >20 lb S/a.

Table 8.3. Relative micronutrient and sulfur requirements of Wisconsin crops *(continued)*.

Crop	Boron	Copper	Manganese	Molybdenum	Zinc	Sulfur [a]
Pasture, legume-grass	High	Medium	Low	High	Low	—
Pasture, managed	Low	Low	Medium	Low	Low	—
Pasture, unimproved	Low	Low	Medium	Low	Low	—
Pea, canning	Low	Low	Medium	Medium	Low	—
Pea, chick/field/cow	Low	Low	Medium	Medium	Low	—
Pepper	—	—	—	—	—	—
Potato	Low	Low	Medium	Low	Medium	Medium
Pumpkin	—	—	—	—	—	—
Raspberry	—	—	—	—	—	—
Reed canarygrass	Low	Low	Medium	Low	Low	—
Rye, grain	Low	Low	Low	Low	Low	Low
Rye, grain + straw	Low	Low	Low	Low	Low	Low
Small grain silage	Low	Medium	High	Low	Low	—
Small grain silage, underseeded with alfalfa	Low	Medium	High	Low	Low	—
Small grain & legume silage	Low	Medium	High	Low	Low	—
Small grain & legume silage, underseeded with alfalfa	Low	Medium	High	Low	Low	—
Sod	Low	Low	Medium	Low	Low	—
Sorghum, grain	Low	Medium	High	Low	High	Medium
Sorghum-sudan, forage	Low	Medium	High	Low	Medium	High
Soybean, grain	Low	Low	High	Medium	Medium	Low
Soybean, grain + straw	Low	Low	High	Medium	Medium	High
Spinach	Medium	High	High	High	High	—
Squash	—	—	—	—	—	—
Strawberry	—	—	—	—	—	—
Sunflower	High	High	—	—	—	Low
Tobacco	Medium	Low	Medium	—	Medium	Medium
Tomato	High	High	Medium	Medium	Medium	High
Trefoil, birdsfoot	High	—	—	—	—	—
Triticale	Low	Low	Medium	—	—	—
Truck crops	Medium	Medium	—	—	—	—
Vetch, crown/hairy	Medium	—	—	—	—	—
Wheat, grain	Low	Medium	High	Low	Low	Low
Wheat, grain + straw	Low	Medium	High	Low	Low	Medium
Wildlife food plot, corn/forage brassicas	—	—	—	—	—	—
Wildlife food plot, legume grass pasture	—	—	—	—	—	—
Wildlife food plot, oats/wheat/rye	—	—	—	—	—	—
Wildlife food plot, soybean	—	—	—	—	—	—
Wildlife food plot, sugar beet/turnip	—	—	—	—	—	—

— = no data

[a] Relative sulfur needs are based on average annual crop removal rates: low = <10 lb S/a, medium = 10–20 lb S/a, and high = >20 lb S/a.

Table 8.4. Soil test interpretation categories for secondary nutrients and micronutrients.

Nutrient	Soil texture code [a]	Very low (VL)	Low (L)	Optimum (O)	High (H)	Excessively high (EH)
		——— Soil test (ppm) ———				
Calcium	1	0–200	201–400	401–600	>600	—
	2, 3, 4	0–300	301–600	601–1000	>1000	—
Magnesium	1	0–25	26–50	51–250	>250	—
	2, 3, 4	0–50	51–100	101–500	>500	—
Boron	1	0.0–0.2	0.3–0.4	0.5–1.0	1.1–2.5	>2.5
	2, 4	0.0–0.3	0.4–0.8	0.9–1.5	1.6–3.0	>3.0
	3	0.0–0.5	0.6–1.0	1.1–2.0	2.1–4.0	>4.0
Zinc	1, 2, 3, 4	0.0–1.5	1.6–3.0	3.1–20.0	21.0–40.0	>40.0
Manganese [b]	1, 2, 3, 4	—	0–10	11–20	>20	—

[a] Soil texture codes: 1 = sandy soils; 2 = loams, silts, and clays; 3 = organic soils; 4 = red soils. See Figure 4.1 for definitions of each texture code.

[b] For manganese, soil tests are only used for soils with an organic matter content less than or equal to 6.0%. If soils have organic matter content greater than 6.0 %, then soil pH is used as the basis for determining manganese requirements. See text for more detail.

Table 8.5. Boron application rate guidelines.

Soil test category	Relative crop need [a] Low	Medium	High
	——— lb B/a to apply ———		
Very low	Plant analysis [b]	2	3
Low	Plant analysis [b]	1	2
Optimum	Response unlikely	Response unlikely	Response unlikely
High	Response unlikely	Response unlikely	Response unlikely
Excessively high	Do not apply	Do not apply	Do not apply

[a] Refer to Table 8.3 for a list of relative crop needs for boron.

[b] Confirm need for boron with plant analysis.

Table 8.6. Copper fertilizer application rate guidelines. [a]

	Soil texture					
	Sands		Loams, silts, clays		Organic	
Crop	Broad [b]	Band [b]	Broad	Band	Broad	Band
	——— lb Cu/a ———					
Lettuce, onion, spinach	10	2	12	3	13	4
Alfalfa, carrot, cauliflower, celery, clover, corn, oat, radish, sudangrass, wheat	4	1	8	2	12	3
Asparagus, barley, bean, beet, broccoli, cabbage, cucumber, mint, pea, potato, rye, soybean	0	0	0	0	0	2

[a] Guidelines are for inorganic sources of copper. Copper chelates can also be used at one-sixth of the rates recommended above. Do not apply copper unless a deficiency has been verified by plant analysis.

[b] Broad = broadcast application, band = banded application.

9 Chapter — Nutrient credits

Animal manures and leguminous crops contain nutrients. When animal manures are applied to a field, nitrogen, phosphorus, and/or potassium fertilizer application rates should be reduced. When legumes, including green manures, are part of a crop rotation, nitrogen fertilizer (or manure) application rates should be reduced. Reducing fertilizer application rates to account for the nutrients supplied by manures and legumes is economically profitable, improves fertilizer use efficiency, and enhances water quality.

Manure

Nutrient credits from a manure application should be taken the first crop year after the application. Because the nutrients in manure are not 100% available the first year after application, nutrient credits may also be taken for the second and third years. Estimated nutrient availabilities are given in Table 9.1.

First-year nitrogen availability varies with animal species and depends upon whether or not the manure is incorporated within 3 days of application (Table 9.1). This is because nitrogen in manure is in both inorganic (immediately available) and organic (not immediately available) forms. The inorganic form is nearly all present as ammonium. Ammonium is easily volatilized to ammonia and lost if manure lies on the soil surface. After 3 days, all of the ammonium is assumed to have volatilized unless significant rainfall has occurred. For this reason, the nitrogen credits for surface applied, unincorporated manure are less than when manure is incorporated. Organic nitrogen availability is dependent upon animal species and management plus environmental factors such as moisture and temperature that affect microbial decomposition.

Phosphorus in manures is present in both inorganic and organic forms. For most animal species, the inorganic phosphorus forms are dominant. Availability of manure phosphorus depends on the amount of inorganic phosphorus, mineralizable fraction of organic phosphorus, and interactions with the soil. For all manures first-year phosphorus availability is considered to be 60%.

Potassium in manures is in the inorganic form and is readily available to plants. For all manures first-year potassium availability is considered to be 80%.

Manure sulfur is in both inorganic and organic forms. First-year availability of manure sulfur is estimated at 55%.

Manure nutrients are available to crops the second and third years after application. For all nutrients, second- and third-year availabilities are estimated at 10% and 5%, respectively, of the total amount applied in the first year. The sum of the first-, second-, and third-year availabilities for a nutrient does not equal 100%. This is because some losses will occur, particularly with nitrogen, and because manure applications are not always uniform in rate and composition across a field. These estimates of nutrient availability are agronomically conservative to ensure that adequate nutrients are available for the crop.

To calculate the nutrient credits from manure it is necessary to know the application rate and total nutrient content of the manure. Total nutrient content can be measured on a manure sample sent to most soil testing laboratories. For details on

Table 9.1. Estimated nutrient availability for various manures.

	—— N ——				
Species	Surface [a]	Inc. [a]	P_2O_5	K_2O	S
	—————— % ——————				
First-year availability					
Dairy	30	40	60	80	55
Veal calf	40	50	60	80	55
Beef	25	35	60	80	55
Swine	50	65	60	80	55
Poultry [b]	50	60	60	80	55
Sheep	25	35	60	80	55
Horse	25	35	60	80	55
Second-year availability					
All species	10	10	10	10	10
Third-year availability					
All species	5	5	5	5	5

[a] Surface = surface applied; Inc. = incorporated within 3 days of application.

[b] Poultry includes chicken, duck, and turkey

how to sample manure for testing, see Extension publication *Recommended Methods of Manure Analysis* (A3769). Where specific nutrient analysis for a manure is unknown, typical nutrient contents (also called book values) based on animal species and management can be used. Typical nutrient contents of Wisconsin manures are provided in Table 9.2. Because manure nutrient content can vary greatly from farm to farm and book values represent an average nutrient content, it is preferable to occasionally have all manure types on a farm analyzed. Once manure application rate and total nutrient content are known, nutrient credits can be calculated as follows.

First-year credits = total nutrient content x % of nutrient that is available the first year after application x application rate

Second-year credits = total nutrient content x % of nutrient that is available the second year after application x application rate

Third-year credits = total nutrient content x % of nutrient that is available the third year after application x application rate

If manure is applied in multiple years, the credits are additive. In other words, take credits for current year nutrients plus any nutrient credits from the previous 2 years.

1. Example calculations:

What are the first-year nutrient credits from solid dairy manure that is surface-applied at a rate of 15 tons/a?

From Table 9.2 the total N, P_2O_5, and K_2O content are 10, 5, and 9 lb/ton, respectively. From Table 9.1 the first-year nutrient availability is 30, 60, and 80% for N, P_2O_5, and K_2O, respectively.

N credit = 10 lb/ton x 0.3 x 15 ton/a = 45 lb N/a

P_2O_5 credit = 5 lb/ton x 0.6 x 15 ton/a = 45 lb P_2O_5/a

K_2O credit = 9 lb/ton x 0.8 x 15 ton/a = 108 lb K_2O/a

What are the second-year nutrient credits from dairy manure that is surface-applied at a rate of 20 tons/a?

From Table 9.2 the total N, P_2O_5, and K_2O content are 10, 5, and 9 lb/ton, respectively. From Table 9.1 the second-year nutrient availability is 10% for N, P_2O_5, and K_2O.

N credit = 10 lb/ton x 0.1 x 20 ton/a = 20 lb N/a

P_2O_5 credit = 5 lb/ton x 0.1 x 20 ton/a = 10 lb P_2O_5/a

K_2O credit = 9 lb/ton x 0.1 x 20 ton/a = 18 lb K_2O/a

2. Example calculation:

From the previous example, let's say that 20 tons/a of dairy manure was surface-applied last year and 15 tons/a of dairy manure was surface-applied this year.

What are the total amount of manure nutrient credits for this year's crop?

Total nutrient credits this season:

N credit = 45 + 20 = 65 lb N/a

P_2O_5 credit = 45 + 10 = 55 lb P_2O_5/a

K_2O credit = 108 + 18 = 126 lb K_2O/a

Estimates of first-year available nutrients from typical manures in Wisconsin are provided in Table 9.3. This table should be used if manure has not been tested and book value nutrient contents will be used to determine nutrient credits. First-year nutrient credits are calculated by multiplying the estimated available nutrients (Table 9.3) by the manure application rate.

Guidelines for using manure as a nutrient source can be found in Extension publication *Guidelines for Applying Manure to Cropland and Pasture in Wisconsin* (A3392). Before applying manure, be sure you understand all applicable state and federal regulatory requirements.

Table 9.2. Typical total nutrient contents of manures tested in Wisconsin.

Species/ management	Dry matter	N	P_2O_5	K_2O	S
Solid manure	%	———— lb/ton ————			
Dairy	24	10	5	9	1.5
Beef	35	14	9	11	1.6
Swine	20	14	10	9	2.7
Duck	35	17	21	30	3.9
Chicken	60	40	50	30	3.9
Turkey	60	40	40	30	3.9
Sheep	45	26	18	40	2.7
Horse	45	10	6	10	2.5
Liquid manure	%	——— lb/1000 gal ———			
Dairy	6	24	9	20	4.2
Veal calf	2	15	10	25	4.5
Beef	5	20	9	20	4.7
Swine indoor pit	7	50	42	30	2.4
Swine outdoor pit	4	34	16	20	2.4
Swine, farrow—nursery indoor pit	3	25	23	22	4.0
Poultry	3	16	10	12	9.1

Table 9.3. Estimated first year available nutrient contents of manures. [a]

Species/ management	N Surface [b]	N Inc. [b]	P_2O_5	K_2O	S
Solid manure	———————— lb/ton ————————				
Dairy	3	4	3	7	1
Beef	4	5	5	9	1
Swine	7	9	6	7	1
Duck	9	10	13	24	2
Chicken	20	24	30	24	2
Turkey	20	24	24	24	2
Sheep	7	9	11	32	1
Horse	3	4	4	8	1
Liquid manure	—————— lb/1000 gal ——————				
Dairy	7	10	5	16	2
Veal calf	6	8	6	20	2
Beef	5	7	5	16	3
Swine indoor pit	25	33	25	24	1
Swine outdoor pit	17	22	10	16	1
Swine, farrow—nursery indoor pit	13	16	14	18	2
Poultry	8	10	6	10	5

[a] These estimates are based on the typical total nutrient contents of manures tested in Wisconsin (Table 9.2) multiplied by the estimated first year nutrient availability (Table 9.1).

[b] Surface = surface applied; Incorp. = incorporated within 3 days of application.

Municipal biosolids and other wastes

Municipal biosolids, also known as municipal sewage sludge, are the residual solid material created from the treatment of wastewater. Municipal biosolids are commonly land applied in Wisconsin. Wastewater and residuals from other sources (e.g. cheese factories, food processing, paper mills) as well as solid wastes (municipal solid waste compost, construction debris, flyash) are also often land applied. These materials can supply nutrients to crops and in some cases are used as liming agents. Many also supply organic material that helps to improve soil structure and enhance other soil physical properties.

The application of these materials is regulated by the Wisconsin Department of Natural Resources (WDNR) according to a site-specific permit granted for each material. The application rate is based on an analysis of each material. Most municipal biosolids application rates are based on meeting the nitrogen need of the crop with the amount of first-year available nitrogen rather than the total nitrogen content of the biosolids. This rate assumes that all the ammonium-nitrogen will be available in the year of application if the material is incorporated (or 50% if not incorporated) and that 25% of the organic nitrogen will become plant available in the first year. The remaining organic nitrogen from an initial application must be credited in the second and third year following application at a value of 12 and 6%, respectively.

Biosolids contain a disproportionately greater amount of phosphorus relative to nitrogen, which often results in the over-application of phosphorus when the selected rate is intended to meet the nitrogen need of the crop. The availability of phosphorus in biosolids is generally thought to be less than 100% and is variable between different treatment processes. Research data to support estimated phosphorus availability is unavailable at this time. The WDNR has exempted the phosphorus in biosolids in nutrient management planning. However, biosolids application may affect future nutrient management planning if soil test levels become elevated from biosolids and its use is discontinued. The potassium in biosolids should be considered to be similar in availability to potassium in manures; 80% available the first year after application. Soil testing every three to four years can be used to monitor changes in soil test phosphorus and potassium levels with application of biosolids and other wastes.

Several municipalities have opted to use lime stabilization in their biosolid management process. Lime-stabilized biosolids are an excellent liming material and could be used as a substitute for aglime as well as nitrogen fertilizer.

Consult with the local WDNR office before applying municipal biosolids or industrial waste materials. More information on site requirements and nutrient use from these materials can be obtained by consulting Wisconsin administrative code documents *Domestic Sewage Sludge Management* (NR 204), *Land Treatment of Industrial Liquid Wastes, By-product Solids, and Sludge* (NR 214), and *Landspreading of Solid Waste* (NR 518).

Legumes

Forage legumes

Forage legume nitrogen credits are provided in Table 9.4. The nitrogen credit is the amount of fertilizer nitrogen that can be subtracted from the recommended application rate for a particular crop on a given soil type. The same crediting system is used for pure legume as well as mixed legume-grass stands. The amount of nitrogen available to a first year crop is dependent on the density of the stand, the amount of regrowth, and soil type. Research in Wisconsin has shown that a substantial amount of plant-available nitrogen is released in the second year following a forage legume crop on medium and fine textured soils. Nitrogen credits are not affected by time or method of killing (tillage or herbicide) the forage legume stand. Forage legume nitrogen credits can be confirmed with a pre-sidedress soil nitrate test (PSNT) as described in Chapter 6 Nitrogen.

Some varieties of alfalfa have been bred to fix more nitrogen than others. As there has not been research showing that these varieties significantly change the amount of nitrogen available to the following crop or affect yields of the following crop, forage varieties should be selected for yield performance rather than nitrogen-fixing capability. There is not sufficient Wisconsin data to recommend changing nitrogen fertilizer replacement value based on variety.

Green manure crops

Forage legumes that are grown for only one growing season without forage harvest and then incorporated into the soil provide somewhat lower amounts of nitrogen than forage legumes grown for several seasons. The amount of nitrogen depends on the length of time that the legume has had to grow. A summer or fall-seeded legume that is incorporated into the soil in the spring will have comparatively little time to grow and will

Table 9.4. Forage legume nitrogen credits.

	Medium/fine textured soils		Sands/loamy sands	
	——— Regrowth (inches) ———			
Crop/stand density	> 8	< 8	> 8	< 8
	——— lb N/a to credit ———			
First-year credit				
Alfalfa				
Good (70–100% alfalfa, >4 plants/ft^2)	190	150	140	100
Fair (30–70% alfalfa, 1.5–4 plants/ft^2)	160	120	110	70
Poor (0–30% alfalfa, <1.5 plants/ft^2)	130	90	80	40
Red clover, birdsfoot trefoil	80% of alfalfa credit for similar stands			
Vetch	160	90	110	40
Second-year credit				
All crops, good or fair stand	50	50	0	0

therefore provide less nitrogen than one that is seeded in the spring or early summer.

Green manure nitrogen credits are provided in Table 9.5. The age of a green manure stand should be taken into account when determining what credit to take from the ranges provided in Table 9.5. For spring-seeded green manures that are plowed under the following spring, use the upper end of the range given in Table 9.5; whereas fall-seeded green manure credits should be the lower end of the range.

Field crop legumes

Leguminous field crops provide much smaller nitrogen credits compared to forage legumes and green manures. Nitrogen credits for crops following leguminous field crops are given in Table 9.6. Do not take a soybean credit when corn (grain or silage) is grown. The rotational effect of soybean grown prior to corn is already accounted for in the new nitrogen rate guidelines for corn outlined in Chapter 6 Nitrogen.

Table 9.5. Green manure nitrogen credits.

Crop	< 6″ growth	> 6″ growth
	———— lb N/a to credit ————	
Alfalfa	40	60–100 [a]
Clover, red	40	50–80 [a]
Clover, sweet	40	80–120 [a]
Vetch	40	40–90 [a,b]

[a] Use the upper end of the range for spring seeded green manures that are plowed under the following spring. Use the lower end of the range for fall seedings.

[b] If top growth is more than 12 inches before tillage credit 110–160 lb N/a.

Table 9.6. Field crop legume nitrogen credits.

Crop	Medium/fine textured soils	Sandy soils
	lb N/a to credit	
Soybean [a]	40	0
Leguminous vegetables (pea; snap, lima, or dry bean)	20	0

[a] Soybean credit does not apply to corn grown after soybean. See Chapter 6 Nitrogen for nitrogen rate guidelines for corn grown after soybean.

10 Chapter — Starter fertilizers

Use of relatively low fertilizer rates placed near the seed at planting (starter fertilizer) is a well-established and often profitable practice for several crops commonly grown in Wisconsin, especially for corn and potatoes. In addition to enhancing yields, starter fertilizers often increase early season plant growth and development and may result in lower corn grain moisture content at harvest.

Corn

Factors affecting response to starter fertilizer

Mechanisms of crop response to starter fertilizers are not always clear, but several factors frequently influence these responses including existing soil fertility status (soil test level), rate, placement, composition of the fertilizer, date of planting, soil compaction, and tillage. Where soil test levels are in the responsive range, starter fertilizers usually increase yields because plants require more nutrients than the soil can supply. This response is likely regardless of other management practices. At high soil fertility levels, the response to starter, when it occurs, is probably caused by a placement effect that enhances early season plant growth or helps overcome limitations to nutrient uptake imposed by the management system. Broadcast applications of nutrients at similar rates are not likely to duplicate this placement response. Although soil test phosphorus levels in major corn-producing areas are often in the non-responsive range, results from numerous studies indicate profitable responses to various starter fertilizer treatments.

Starter composition, rates, and placement

Most fertilizers used as starters contain nitrogen and phosphorus or nitrogen, phosphorus, and potassium. While the influence of starter composition on crop response varies by geographic region, numerous recent experiments with no-till corn in the Midwest have shown consistent, significant yield increases from application of complete (N-P-K) starter fertilizers in a 2- by 2-inch placement relative to the seed (Bundy et al., 2005). Frequently these responses occurred where soil test levels were in the optimum or high categories. This consistent response to starter fertilizer across a wide range of production conditions and geographic locations indicates the importance of using N-P-K starter fertilizers, especially in no-till or high residue corn production systems. In addition, band applications of fertilizers containing potassium have been shown to partially offset corn yield reductions caused by soil compaction.

Rates and placement of starter fertilizers can influence their performance. Typical placements include with the seed at planting (pop-up) and 2- by 2-inch band placement. Seed-placed starter rates must be limited to avoid seedling damage and reduced plant populations. Nitrogen and potassium rather than phosphorus are the rate limiting factors, and the N + K_2O in the fertilizer should not exceed 10 lb/a. Maximum application rates for seed-and side-placed starter fertilizer are shown in Table 10.1. In addition, fertilizers containing urea or ammonium thiosulfate should never be used as the N source in starter fertilizers. Urea breakdown in soil produces gaseous ammonia that inhibits germination and damages seedlings.

Application rates typically recommended for seed-placed starters may not maximize corn yield response [Wolkowski and Kelling (1985); see also Table 9-16 in Extension publication *Management of Wisconsin Soils* (A3588)]. Corn response to 2- by 2-inch side-placed starter on a high-P testing soil was maximized with an application of about 10-20-20 (N-P_2O_5-K_2O), and rates typically recommended for seed-placed starters were inadequate to maximize response. This work also found that rates higher than 10-20-20 gave no additional response and that no differences were detected between liquid and dry fertilizer materials at similar nutrient application rates. Higher starter rates may be needed to optimize production where soil P and K tests are in the responsive range than where the tests are in the high categories.

In environments, such as Wisconsin, where the available growing period is not always adequate to achieve the full crop yield potential, the early acceleration of plant development from starter use often translates into improved yield even at high soil test levels. Wisconsin research (Bundy and Andraski, 1999) shows that yield increases caused by starter use on soils with high P and K tests are likely if soil test K levels are less than 140 ppm and/or the combined effect of corn hybrid relative maturity (RM) and planting date result in an inadequate growth period for the crop to achieve its full yield potential. Results from numerous on-farm studies with corn response to starter fertilizer in Wisconsin showed more frequent response to starter with later planting dates and longer season relative maturity (RM) hybrids. Table 10.2 shows the probabilities of response to starter fertilizer with various hybrid RM and planting date combinations and illustrates the increasing probabilities of economic response (value of yield increase exceeds starter cost) to starter fertilizer as planting dates become later.

Potato

For potatoes, starter fertilizer rates up to 800 lb/a of fertilizer material may be applied at planting if these amounts of nutrients are required according to soil test results. Where soil test levels are in the excessively high range for potato, a minimal starter application of about 30-30-30 (N-P_2O_5-K_2O) may be applied, and these nutrients must be counted against the total crop nutrient requirement.

Soybean and snap bean

Starter fertilizer research with soybean and snap bean generally indicates little or no advantage to banded fertilizer treatments relative to broadcast applications.

Accounting for nutrients in starter fertilizers

For all crops, all nutrients (nitrogen, phosphorus, and potassium) in starter fertilizers are counted against the amounts of nutrients recommended based on the crop to be grown and soil test results.

Table 10.1. Maximum recommended starter fertilizer rates for corn.

Placement method	Soil type: Sands/ loamy sands	Medium- and fine-textured
	lb/a of fertilizer material	
With seed (pop up)	50*	50*
Side placement (2″ x 2″)	300	500

* Limit combined nitrogen plus potash (K_2O) to 10 lb/a

Table 10.2. Probability of obtaining a positive economic return from starter fertilizer for several corn relative maturity ratings at various planting dates on soils with excessively high P and K levels. [a]

Relative maturity	Planting date: 4/25	5/1	5/5	5/10	5/15	5/20	5/25	5/30
	probability, %							
90	10	15	20	25	30	35	40	45
95	15	20	25	30	35	40	45	50
100	20	25	30	35	40	45	50	55
105	25	30	35	40	45	50	55	60
110	30	35	40	45	50	55	60	65

[a] This table does not alter current recommendations for early planting and selection of corn hybrids with appropriate relative maturities for the production zone.

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Related publications

The following publications, available from Extension Publications, contain more information about topics covered in this book. To order copies, visit http://learningstore.uwex.edu.

Guidelines for Applying Manure to Cropland and Pasture in Wisconsin

Management of Wisconsin Soils (A3588)

Sampling Soils for Testing (A2100)

Soil and Applied Sulfur (A2525)

Soil and Applied Calcium (A2523)

Soil and Applied Magnesium (A2524)

Soil Calcium to Magnesium Ratios—Should You Be Concerned? (A2986)

Soil and Applied Boron (A2522)

Soil and Applied Manganese (A2526)

Soil and Applied Zinc (A2528)

Soil and Applied Copper (A2527)

Soil and Applied Molybdenum (A3555)

Soil and Applied Iron (A3554)

Soil and Applied Chlorine (A3556)

Recommended Methods of Manure Analysis (A3769)

Wisconsin's Preplant Soil Nitrate Test (A3512)

Available from the University of Minnesota Extension Store (http://shop.extension.umn.edu):

Soil Cation Ratios for Crop Production (FO-06437-GO).

Fertilizer analysis

	N	P_2O_5	K_2O	other
Nitrogen				
Ammonium nitrate	34	0	0	
Ammonium sulfate (AMS)	21	0	0	24(S)
Ammonium thiosulfate (ATS)	12	0	0	26(S)
Anhydrous ammonia	82	0	0	
Aqueous ammonia	20	0	0	
Calcium nitrate (CN)	15	0	0	17(Ca)
Urea	46	0	0	
28% Urea ammonium nitrate (UAN)	28	0	0	
32% Urea ammonium nitrate (UAN)	32	0	0	
Phosphorus				
Ammonium polyphosphate (dry)	15	62	0	
Ammonium polyphosphate (liquid)	10	34	0	
Diammonium phosphate (DAP)	18	46	0	
Monoammonium phosphate (MAP)	11	52	0	
Triple superphosphate (TSP)	0	46	0	
Potassium				
Potassium chloride (muriate of potash)	0	0	60-62	
Potassium-magnesium sulfate	0	0	22	22(S),11(Mg)
Potassium nitrate	13	0	44	
Potassium sulfate	0	0	50	18(S)

Liquid weights:

1 gallon water weighs 8.3 lb

1 gallon UAN (28%) weighs 10.6 lb

1 gallon 10-34-0 weighs 11.6 lb

1 gallon 9-18-9 weighs 11.1 lb

Conversions

1 To get column 1, divide column 3 by column 2	2	3 To get column 3, multiply column 1 by column 2
acre (a)	43,560	square feet (ft^2)
acre (a)	0.405	hectare (ha)
square mile (mi^2)	640	acres (a)
cubic yard (yd^3)	27	cubic feet (ft^3)
cubic feet (ft^3)	7.48	gallons (gal)
bushel (bu)	1.244	cubic feet (ft^3)
bushel (bu)	8	gallons - dry
bushel (bu)	9.31	gallons - liquid
ounces (oz)	29.6	milliliters (ml)
gallon (gal)	3.78	liters (l)
gallon (gal)	128	fluid ounces (fl oz)
gallon (gal)	4	quart (qt)
acre-foot	43,560	cubic feet (ft^3)
acre-foot	325,851	gallons (gal)
chain (ch)	66	feet (ft)
chain (ch)	4	rods (r)
rods (r)	16.5	feet (ft)
mile (mi)	5,280	feet (ft)
ton (short)	2,000	pounds (lb)
ton (long)	2,230	pounds (lb)
gallons/acre (gal/a)	9.354	liters/hectare (l/ha)
miles/hour (mph)	88	feet/minute (ft/min)
pounds/acre (lb/a)	1.12	kilograms/hectare (kg/ha)
P_2O_5 (lb)	0.44	P (lb)
K_2O (lb)	0.83	K (lb)
ppm-plow layer (6 in)	2	lb/acre (lb/a)
ppm-top soil (12 in)	4	lb/acre (lb/a)

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