Interpreting a Soil Test

A soil test value for all nutrients except nitrate-nitrogen is an ***index*** of the availability of that nutrient to plants in the soil being tested. The University of Minnesota Soil Testing Laboratory reports soil test results as parts per million (ppm) and should be thought of as an index of the relative level. Older soil tests reported relative nutrient levels as lb/A; however, this unit was confusing since many incorrectly interpreted the result as actual lb of nutrient in the soil when in fact it only represented a small fraction of the total nutrient in the soil. To convert an older soil test reading of lb/A to ppm, divide lb/A by two.

The probability of response to applied fertilizer can conceptually be determined from relative soil test levels. As shown in **Table 1**, the higher the soil test level, the lower the probability of response to applied fertilizer. Conversely, a low soil test level would have a high probability of response to applied fertilizer.

Table 1. *Generalized relationship between relative soil test level and probability of response to applied fertilizer.*

Relative Soil Test Level	Probability of Response to Applied Fertilizer
low	greater than 90%
medium	60 to 90%
medium-high	30 to 60%
high	10 to 30%
very high	less than 10%

In contrast to the other nutrients, nitrate-nitrogen is expressed as lb/A when sampled to a 2-foot depth since it is a measure of the actual amount of nitrate-nitrogen present in the soil rooting zone at the time of sampling. Samples taken to other depths are reported as ppm and the nitrate test result is not then used in making the nitrogen recommendation.

Fertilizer Analyses and Calculating Fertilizer Rates

By convention, fertilizer phosphorus and potassium are expressed on the oxide basis, P_2O_5 and K_2O, respectively. In contrast, fertilizer nitrogen is expressed on the elemental basis, N. Minnesota state law requires that any material sold as fertilizer clearly shows the percent nitrogen expressed as N, percent phosphate expressed as P_2O_5, and percent potash expressed as K_2O on the bag. The percentages of each nutrient on the fertilizer label are referred to as the grade of fertilizer and are guaranteed by the manufacturer. All fertilizer recommendations are based on the amount of N, P_2O_5, and K_2O to apply per given area (usually per acre). Fertilizers can be sold as complete fertilizers, i.e., they contain all three primary nutrients—nitrogen, phosphorus, and potassium—such as 10-10-10, or they can be sold as single nutrient fertilizers such as 46-0-0 (only N), 0-0-60 (only K_2O), etc.

To determine the actual amount of nutrient in a given weight of fertilizer, multiply the percentage of nutrient by the weight of fertilizer and then divide by 100. For example, to determine the amount of actual nitrogen in 200 lb of urea (46-0-0): 200 X 46/100 = 92 lb of N. If 200 lb of 8-32-16 is applied per acre, then the total nutrients applied would be 16 lb N, 64 lb P_2O_5, and 32 lb K_2O.

If the fertilizer recommendation calls for a given amount of nutrient per acre, then to calculate the amount of fertilizer to apply, divide the recommended amount by the percent nutrient (fraction basis) in the fertilizer. For example, if the recommendation calls for 150 lb N per acre, and urea (46-0-0) is the fertilizer that will be used, the total amount of urea to apply per acre would be 150/0.46 = 326 lb urea per acre. If ammonium nitrate (33-0-0) is used, then 150/0.33 = 454 lb ammonium nitrate per acre would be required. Similar calculations can be made for phosphate and potash fertilizers.

Soil pH Modification

Soil pH is an important chemical property that affects nutrient availability and microbial activity. In general, the optimum pH for most fruit and vegetable crops is between 5.8 and 7.0 for mineral soils and 5.4 and 6.2 for organic soils (peats and mucks). Two exceptions are blueberries and potatoes. Blueberries are adapted to acid soil conditions and grow best at a soil pH between 4.5 and 5.2. Potatoes can tolerate a wide range in soil pH; however, potato scab can become more of a problem in scab-susceptible varieties as soil pH increases above 5.3.

Liming

Liming materials are used to increase the pH of soils. Not all soils in Minnesota need to be limed. In general, soils in the western part of the state were formed from limestone rocks and receive lower amounts of rainfall. Soils formed under these conditions have a high native pH. Many soils in eastern Minnesota were formed under conditions of higher rainfall and tend to be acidic. Intensive cropping and continuous use of manure and/or ammonium based fertilizers will acidify soils over time. In contrast, if high pH irrigation water is used on acid soils, soil pH may actually increase over time.

The need for lime is determined from a routine soil test. The pH value reported in a soil test indicates whether lime is needed, but cannot be used to determine how much lime is needed. The amount of lime to apply is dependent on reserve soil acidity, which is measured in the laboratory by the “buffer index” or SMP buffer test. The lower the buffer index, the more lime is required. In most cases, buffer index is related to soil texture and organic matter content. At the same soil pH value, soils with a high clay and organic matter content will require more lime than soils with a high sand and low organic matter content. The difference in lime application rates is determined by the SMP buffer index (**Table 2**). The SMP buffer test is not used if the soil pH is higher than 5.9 because of the high relative error above this level. The amount of lime recommended for mineral soils is that needed to raise the pH to 6.0 or 6.5. For peat and muck soils with a soil-water pH of 5.4 or less, lime is recommended to raise the pH to 5.5.

The amount of lime to apply is dependent on the type or quality of the liming material. The quality of a limestone is

Table 2. *Lime recommendations expressed on an effective neutralizing power (ENP) and ag lime basis.*

Where SMP buffer applies (soil-water pH values less than 6.0)	To raise pH to 6.0 for 6-inch plow depth[1]				To raise pH to 6.5 for 6-inch plow depth[1]			
	Area 1[2]		Area 2		Area 1[2]		Area 2	
Mineral Soils / SMP buffer index	ENP[3] to apply (lb/A)	Ag lime[4] to apply (tons/A)	ENP to apply (lb/A)	Ag lime to apply (tons/A)	ENP to apply (lb/A)	Ag lime to apply (tons/A)	ENP to apply (lb/A)	Ag lime to apply (tons/A)
6.8	2000	2.0	0	0	3000	3.0	2000	2.0
6.7	2000	2.0	0	0	3000	3.0	2000	2.0
6.6	2000	2.0	0	0	4000	4.0	2000	2.0
6.5	2500	2.5	0	0	4500	4.5	2000	2.0
6.4	3000	3.0	2000	2.0	5000	5.0	2500	2.5
6.3	3500	3.5	2000	2.0	6000	5.5	2500	2.5
6.2	4000	4.0	2000	2.0	6500	6.5	3000	3.0
6.1	4500	4.5	2000	2.0	6500	6.5	3000	3.0
6.0	5000	5.0	2500	2.5	7000	7.0	3500	3.5
5.9	6000	6.0	2500	2.5	7500	7.5	3500	3.5
5.8	6500	6.5	3000	3.0	8000	8.0	4000	4.0
5.7	7000	7.0	3000	3.0	8500	8.5	4000	4.0
5.6	7500	7.5	3500	3.5	9000	9.0	4500	4.5
Where SMP buffer does not apply (soil-water pH values of 6.0 & higher)								
Mineral Soils / Soil-water pH								
6.5					0	0	0	0
6.4					2000	2.0	0	0
6.3					2000	2.0	0	0
6.2					3000	3.0	0	0
6.1					3000	3.0	0	0
6.0					3000	3.0	2000	2.0

Organic Soils (peats and mucks)	To raise pH to 5.5 for 6-inch plow depth[1]			
Soil-water pH	Area 1[2]		Area 2	
5.4	2000	2.0	2000	2.0
5.3	2000	2.0	2000	2.0
5.2	2000	2.0	2000	2.0
5.1	2000	2.0	2000	2.0
5.0	2000	2.0	2000	2.0
4.9	3000	3.0	3000	3.0
4.8	3000	3.0	3000	3.0
4.7	4000	4.0	4000	4.0
4.6	4000	4.0	4000	4.0
4.5 or less	5000	5.0	5000	5.0

[1] *For 9 inch plow depth, multiply rates by 1.5.*

[2] *Refer to* **Figure 1**.

[3] *To obtain tons of liming material to apply per acre, divide the ENP value given in the table by the actual ENP analysis value provided by the ag lime dealer or lime producer.*

[4] *Ag lime recommendation is based on a liming material having a value of 1000 lb ENP per ton. This value is typical of that for lime from a Minnesota quarry.*

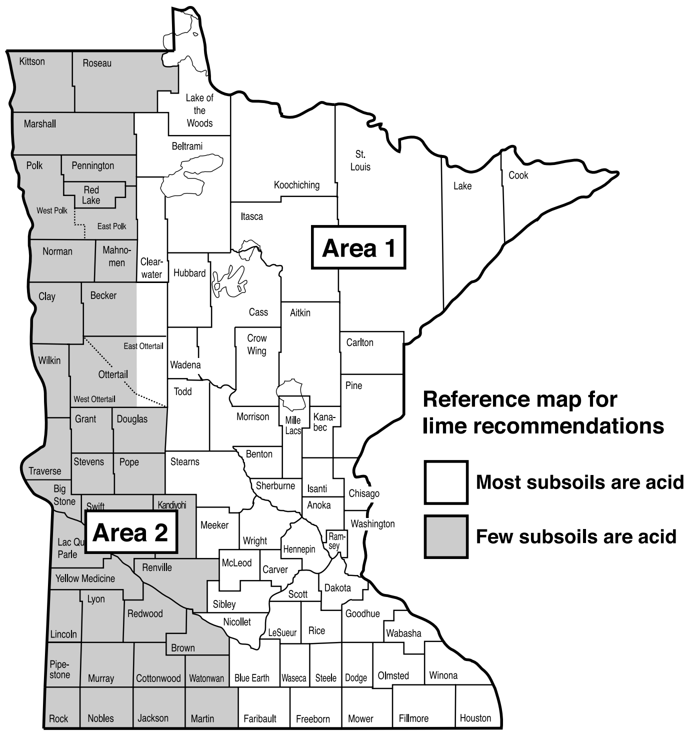

Figure 1. *Reference map for use in making lime recommendations.*

based on its calcium carbonate equivalent (CCE) and particle size. The higher the CCE, the greater the liming potential. The smaller the particle size, the faster it will react with the soil to raise pH. The effective neutralizing power (ENP) takes into account the fineness factor, CCE, and percent dry matter. The ENP can be thought of as a way to compare one lime source to another for effectiveness, similar to the way a comparison between fertilizers is made. For example, recommendations for nitrogen are based on the amount of actual N required and not on how much of a product like ammonium nitrate or urea is needed. There are many different liming materials sold in Minnesota; ENP simply provides a means to compare the effectiveness of these different sources.

By law, all liming materials sold in Minnesota must have the pounds of ENP per ton of lime provided by the ag lime dealer or lime producer at the time of purchase. Liming recommendations are based on the pounds of ENP to apply per acre. To determine how much of a particular liming material per acre is required, divide the ENP value given in the soil test report by the actual ENP analysis value provided by the ag lime dealer or lime producer. **Table 2** gives recommendations in both pounds of ENP per acre and tons of a typical ag lime per acre. Using the ENP method of calculating the rate of lime to apply will be more accurate than using the amount of typical ag lime to apply.

Agricultural limestone is the most common material used for liming. Limestone consists of either calcium carbonate (calcitic limestone) or calcium/magnesium carbonate (dolomitic limestone). In Minnesota, dolomitic limestone is usually the most economical form to apply and is particularly beneficial on low magnesium testing soils. Other liming sources include various waste products such as sugarbeet lime, water treatment lime, wood ash, and other industrial by-products. When considering the use of these sources, be sure that particle size and CCE (ENP), impurities, water content, and cost are taken into account. For further information on liming materials, see FS-05957, *Liming Materials for Minnesota Soils*, available online at: http://www.extension.umn.edu/distribution/cropsystems/DC5957.html.

Most agricultural lime takes several months to react with the soil and should be applied and incorporated to a depth of 6 inches, 6 months to 1 year before planting. Moisture is required for the neutralizing reaction with little change in pH occurring in a dry soil. An application of agricultural lime at recommended rates usually lasts 3 to 5 years. Fine lime (smaller than 60 mesh) takes only a few weeks to react with the soil and can be applied and incorporated the spring of planting. Fine lime is usually applied at lower rates, but has to be applied more often.

For apples and asparagus, lime is recommended to increase soil pH to 6.5 if the soil pH is 6.4 or less. For all other fruit and vegetable crops except blueberries and potatoes, lime applications are recommended to increase the soil pH to 6.0 if the soil pH is 5.7 or less.

When lime is recommended in western Minnesota (**Figure 1**) where subsoils tend to be very alkaline, the amount of lime to apply is half that recommended for a soil with the same SMP buffer test in eastern Minnesota.

Soil Acidification

Lowering soil pH is generally only practical and economical for blueberry production. Optimum soil pH for blueberries is 4.5-5.2. To lower soil pH to 4.5, use **Table 3** to determine the amount of finely ground elemental sulfur required. Elemental sulfur may take several months to react with the soil and

Table 3. *Rates of elemental sulfur required to lower soil pH to 4.5 for a 6 inch plow depth.*

	Amount of Elemental Sulfur to Apply			
Initial pH	Sand, loamy sand, sandy loam[1]		loam, silt loam[1]	
	lb/100 sq ft	lb/A	lb/100sq ft	lb/A
7.0	1.9	800	5.8	2500
6.5	1.5	650	4.6	2000
6.0	1.2	525	3.5	1500
5.5	0.8	350	2.4	1000
5.0	0.4	170	1.2	500

[1] *Sand, loamy sand, sandy loam = coarse-textured soil; loam, silt loam = medium-textured soil.*

Table 4. ***Relative soluble salt sensitivity levels.***

mmhos/cm[1]	Description	Effect on crops
0 to 2	non-saline	none
2.1 to 4	very slightly saline	sensitive crops restricted
4.1 to 8	moderately saline	many crops restricted
8.1 to 16	strongly saline	most crops restricted
more than 16	very strongly saline	few plants tolerant

[1] *Based on saturated paste extract*.

therefore should be applied 1 year before planting. Test the pH of the soil 3 to 4 months after the initial application. If the soil pH is not in the desired range, reapply according to **Table 3**. In situations where irrigation water contains lime, additional annual applications of 300-400 lb/A elemental sulfur may be necessary to maintain pH in the desired range. Iron sulfate can also be used to acidify soils. This material reacts much faster than elemental sulfur, usually within 3 to 4 weeks. Multiply the rate of elemental sulfur recommended by 7 to determine the rate of iron sulfate needed. For high rates of iron sulfate, split applications are recommended. **Do not** apply more than 2 tons per acre of iron sulfate at a time. Use of ammonium sulfate as the nitrogen source will also help in maintaining a low soil pH. **Caution**—do not use more ammonium sulfate than that required for meeting the nitrogen requirements. Too much nitrogen can cause excessive vegetative growth, and may increase the potential for winter injury and reduce fruit quality. High lime soils with a pH greater than about 7.3 require higher rates of acidifying amendments and are not recommended for commercial blueberry production.

Soluble Salts (electrical conductivity)

The term *soluble salts* refers to the inorganic soil constituents (ions) that are dissolved in the soil water. Pure water is a very poor conductor of electric current, whereas water containing dissolved salts conducts current approximately in proportion to the amount of salt present. Thus, the measurement of the electrical conductivity of a soil extract gives an indication of the total concentration of salts. The electrical conductivity measurement is reported in millimhos per centimeter (mmhos/cm). Crops differ in their sensitivity to soluble salts. High soluble salts can restrict root growth, cause burning of the foliage, and limit crop yields. The relative values for soluble salt sensitivity levels are described in **Table 4.**

Most soils in Minnesota are nonsaline (0 to 2 mmhos/cm); however, a few soils in western Minnesota have formed under high sodium/alkaline conditions and may be high in soluble salts. Other conditions where soluble salts may limit plant growth are when fertilizers are overapplied or placed too close to the roots.

The relative salt tolerance of various fruit and vegetable crops is presented in **Table 5.**

Organic and Inorganic Fertilizers

Plant roots absorb the majority of their nutrients from the soil solution in the ionic (inorganic charged) form. Larger molecules can also be absorbed by roots, but their rate of absorption is slow. Thus, if a fertilizer (organic or inorganic) is applied, it must first be broken down to its simplest forms to be used efficiently by plants.

According to the Minnesota Department of Agriculture, a natural organic fertilizer has to be derived from either plant or animal materials containing one or more elements (other than carbon, oxygen, and hydrogen) that are essential for plant growth. Organic food production, however, allows for a broader definition that includes naturally occurring inorganic substances such as elemental sulfur and gypsum, and naturally occurring mineral materials that are not chemically modified.

Table 5. ***Soluble salt test[1] values and relative salt tolerance of fruit and vegetable crops.***

0-2 mmhos/cm* Nontolerant	3-4 mmhos/cm* Slightly Tolerant	5-7 mmhos/cm* Moderately Tolerant	8-16 mmhos/cm* Tolerant
blueberries	apples	broccoli	asparagus
carrots	cabbage	beets, table	Swiss chard
green beans	celery	cucumbers	
onions	grapes	muskmelons	
radishes	lettuce	squash	
raspberries	peppers	tomatoes	
strawberries	potatoes	spinach	
	sweet corn		

[1] *Based on saturated paste extract.* ***Plants can be successfully grown at these test levels or lower.