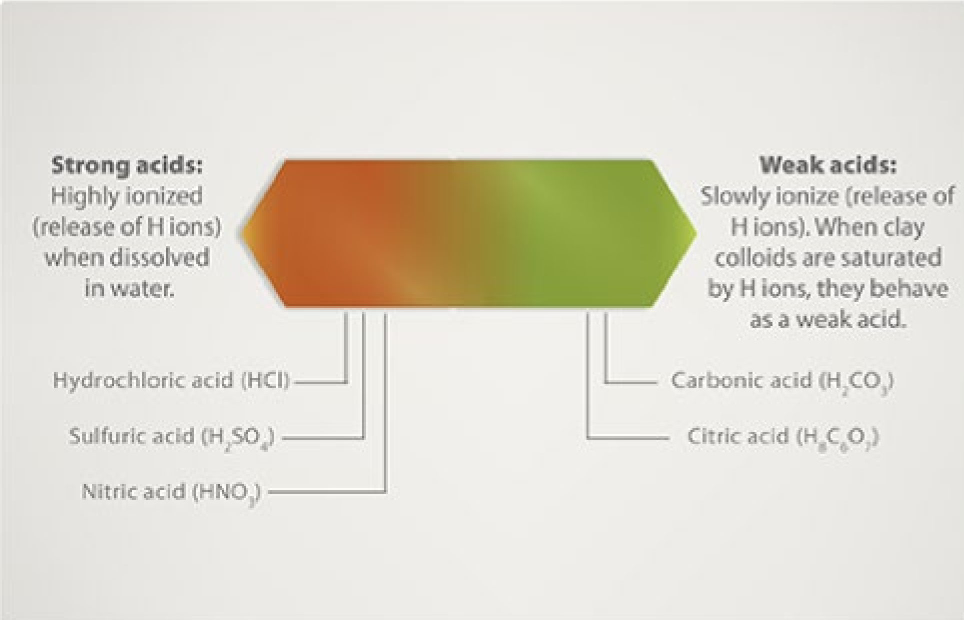
SOIL PH

JUMP TO:

SOIL ACIDITY

An acid is defined as a substance that tends to release hydrogen ions (H^+). Conversely, a base is defined as a substance that releases hydroxyl ions (OH^-). All acids contain hydrogen ions, and the strength of the acid depends upon the degrees of ionization (release of hydrogen ions) of the acid. The more hydrogen ions held by the exchange complex of a soil in relation to the basic ions (Ca, Mg, K) held, the greater the acidity of the soil.

NOTE: Aluminum (Al) also contributes to soil acidity, but for simplicity, further discussion of soil acidity will be limited to H as the cause of soil acidity.



Source: IPNI

DESIRABLE SOIL PH FOR OPTIMUM CROP PRODUCTION PH RANGE

The desirable pH range for optimum plant growth varies among crops. While some crops grow best in the 6.0 to 7.0 range, others grow well under slightly acidic conditions. Soil properties that influence the need for and response to lime vary by region. A knowledge of the soil and the crop is important in managing soil pH for the best crop performance.

Soils become acidic when basic elements such as calcium, magnesium, sodium and potassium held by soil colloids are replaced by hydrogen ions. Soils formed under conditions of high annual rainfall are more acidic than are soils formed under more arid conditions. Thus, most southeastern soils are inherently more acidic than soils of the Midwest and far West.

Soils formed under low rainfall conditions tend to be basic with soil pH readings around 7.0. Intensive farming over a number of years with nitrogen fertilizers or manures can result in soil acidification. In the wheat-growing regions of Kansas and Oklahoma, for example, which have soil pH of 5.0 and below, aluminum toxicity in wheat and good response to liming have been documented in recent years.

pH Range		
5.0 – 5.5	**5.5 – 6.5**	**6.5 – 7.0**
Blueberries	Barley	Alfalfa
Irish Potatoes	Bluegrass	Some Clovers
Sweet Potatoes	Corn	Sugar Beets
	Cotton	
	Fescue	
	Grain Sorghum	
	Peanuts	
	Rice	
	Soybeans	
	Watermelon	
	Wheat	

FACTORS AFFECTING SOIL ACIDITY

RAINFALL

Rainfall contributes to a soil's acidity. Water (H_2O) combines with carbon dioxide (CO_2) to form a weak acid — carbonic acid (H_2CO_3). The weak acid ionizes, releasing hydrogen (H^+) and bicarbonate (HCO_3). The released hydrogen ions replace the calcium ions held by soil colloids, causing the soil to become acidic. The displaced calcium (Ca^{++}) ions combine with the bicarbonate ions to form calcium bicarbonate, which, being soluble, is leached from the soil. The net effect is increased soil acidity.

NITROGEN FERTILIZERS

Nitrogen levels affect soil pH. Nitrogen sources — fertilizers, manures, legumes — contain or form ammonium. This increases soil acidity unless the plant directly absorbs the ammonium ions. The greater the nitrogen fertilization rate, the greater the soil acidification. As ammonium is converted to nitrate in the soil (nitrification), H ions are released. For each pound of nitrogen as ammonium, it takes approximately 1.8 pounds of pure calcium carbonate to neutralize the residual acidity. Also, the nitrate that is provided or formed can combine with basic cations like calcium, magnesium and potassium and leach from the topsoil into the subsoil. As these bases are removed and replaced by H ions, soils become more acidic.

PLANTS

Legumes like soybeans, alfalfa and clovers tend to take up more cations in proportion to anions. This causes H ions to be released from plant roots to maintain the electrochemical balance within their tissues. The result is a net soil acidification.

SUBSOIL ACIDITY

Even if the top 6 inches of soil show a pH above 6.0, the subsoil may be extremely acidic. When subsoil pH's drop below 5.0, aluminum and manganese in the soil become much more soluble, and in some soils may be toxic to plant growth. Cotton and, to some extent, soybeans are examples of crops that are sensitive to highly soluble aluminum levels in the subsoil, and crop yields may be reduced under conditions of low subsoil pH. If you've observed areas of stunted plants in your field, take a subsoil sample in these areas. If the soil pH is extremely acidic (below 5.2), lime should be applied early in the fall and turned as deeply as possible.

LIMING SOIL PAYS

Correcting soil acidity by the use of lime is the foundation of a good soil fertility program. Lime does more than just correct soil acidity. It also:

- Supplies essential plant nutrients, Ca and Mg, if dolomitic lime is used
- Makes other essential nutrients more available
- Prevents elements such as Mn and Al from being toxic to plant growth.

Limestone Increases Fertilizer Efficiency and Decreases Soil Acids

SOIL ACIDITY	NITROGEN	PHOSPHATE	POTASH	FERTILIZER WASTED
Extremely Acid — 4.5 pH	30%	23%	33%	71.34%
Very Strong Acid — 5.0 pH	53%	34%	52%	53.67%
Strongly Acid — 5.5 pH	77%	48%	77%	32.69%
Medium Acid — 6.0 pH	89%	52%	100%	19.67%
Neutral — 7.0 pH	100%	100%	100%	00.0%

LIMING MATERIALS

Liming materials contain calcium and/or magnesium in forms, which when dissolved, will neutralize soil acidity. Not all materials containing calcium and magnesium are capable of reducing soil acidity. For instance, gypsum ($CaSO_4$) contains Ca in appreciable amounts, but does not reduce soil acidity. Because it hydrolyzes in the soil, gypsum converts to a strong base and a strong acid as shown in the following equation:

$CaSO_4 + 2H_2O = Ca\ (OH)^2 + H_2SO_4$

The formed Ca $(OH)^2$ and H_2SO_4 neutralize each other, resulting in a neutral soil effect. On the other hand, when calcitic ($CaCO_3$) or dolomitic lime (Ca Mg $(CO_3)^2$) is added to the soil, it hydrolyzes (dissolves in water) to a strong base and a weak acid.

$CaCO3 + 2H_2O = Ca\ (OH)^2 + H_2CO_3$

Calcium hydroxide is a strong base and rapidly ionizes to Ca^{++} and OH^- ions. The calcium ions replace absorbed H ions on the soil colloid and thereby neutralize soil acidity. The carbonic acid formed (H_2CO_3) is a weak acid and partially ionizes to H^+ and CO_2^{-2} ions. Therefore, the net effect is that more Ca than H ions are released in the soil, and consequently, soil acidity is neutralized.

LIMING MATERIAL	COMPOSITION	CALCIUM CARBONATE EQUIVALENT (CCE)
Calcitic Limestone	$CaCO_3$	85-100
Dolomitic Limestone	$CaCO_3$; Mg CO_3	95-108
Oyster Shells	$CaCO_3$	90-110
Marls	$CaCO_3$	50-90
Hydrated Lime	$Ca(OH)_2$	120-135
Basic Slag	$CaSiO_3$	50-70
Gypsum	$CaSO_4$	None

CALCITIC LIMESTONE

Ground limestone contains mostly calcium carbonate and generally has less than 1 to 6 percent magnesium. Its neutralizing value depends on its purity and fineness of grinding.

DOLOMITIC LIMESTONE

Ground limestone is a mixture of calcium carbonate and magnesium carbonate. In some states, it must contain at least 6 percent Mg to be classified as dolomitic lime. Its neutralizing effect also depends upon its purity and fineness of grinding.

HYDRATED LIME

Hydrated lime (Ca $(OH)^2$) is calcium hydroxide, sometimes called slaked or builder's lime. Hydrated lime is powdery, quick-acting and somewhat unpleasant to handle. The neutralizing value ranges between 120 and 135 compared to pure calcium carbonate. Fifteen hundred pounds of hydrated lime with a neutralizing value of 135 is equivalent to 2,000 pounds of agricultural lime with a neutralizing value of 100.

MARLS

Marls are deposits of calcium carbonate mixed with clay and sand that are found mostly in the Coastal Plain section of the Eastern states. Their neutralizing value usually ranges from 70 to 90 percent, dependent on the amount of impurities, mostly clay, that they contain. Their usefulness as a liming material depends on their neutralizing value and the cost of processing. They are often plastic and lumpy, and must be dried and pulverized before application to the soil. Marls are usually low in magnesium. Their reaction with the soil is the same as calcitic lime.

BASIC SLAG

Basic slag is a product of the basic open-hearth method of making steel. The calcium contained is in the form of calcium silicate, and reacts with soil acids in a manner similar to ground limestone. Its neutralizing value ranges from 60 to 70, but since basic slag generally has smaller particles than agricultural lime, it tends to change soil pH more rapidly than conventional agricultural lime. It also contains P_2O_5 ranging from 2 to 6 percent and some micronutrients and magnesium.

GROUND OYSTER SHELLS

Oyster shells and other seashells are largely calcium carbonate. They make a satisfactory liming material when finely ground and have a neutralizing value of 90 to 110. Since they are composed of primarily calcium carbonate, they contain little or no magnesium.

FLUID LIME

A liming material commonly referred to as fluid lime generally consists of finely ground limestone suspended in water at a ratio of about 50 percent water to 50 percent limestone. In most instances, producers of fluid lime utilize very finely ground limestone – most of which will pass a 200-mesh screen. Fluid lime is capable of changing soil pH in a relatively short period of time. This is a distinct advantage in situations in which liming has been delayed to just before planting, or in situations in which low soil pH is discovered after a crop is planted. Keep in mind, since fluid lime contains approximately 50 percent water, this means that a farmer applying fluid lime at the rate of 1,000 pounds per acre would be applying only 500 pounds of limestone.

PELLETIZED LIME

Pelletized lime is finely ground agricultural limestone that is pelletized with the aid of clay or synthetic binders to produce pellets in the 5- to 14-mesh range. Usually, about 70 percent of the initial limestone, prior to pelletizing, passes 100- to 200-mesh sieves. It may be spread with conventional spinner fertilizer spreaders, which makes it attractive to use. Unpublished research indicates that pelletized lime should be allowed to react with a good rainfall or irrigation on the soil surface to disperse the pellets before it is mixed with the soil. If rates of 250 to 500 pounds of this liming material are mixed with the soil before the pellet "melts" down, a limited soil volume may be affected by each pellet, and desirable pH adjustment of the plow layer may not be achieved.

USE OF FLUID LIME AND PELLETIZED LIME

Fluid and pelletized lime are excellent sources of lime to be used under certain circumstances such as: Correction of a low soil pH condition after a crop is planted; A rapid change in soil pH if liming is delayed to just before planting a crop; For maintaining pH in the optimal range for plant growth and yield. However, these two liming materials should not be depended upon to maintain the soil pH during the full crop-growing season if applied at one-fourth of the recommended lime rate.

FINENESS OF GRINDING IS IMPORTANT IN SELECTING LIMING MATERIALS

Lime quality is measured by how effectively it neutralizes soil acidity. This is determined largely by its chemical purity and size of particles. The purity of lime is expressed as calcium carbonate equivalent (CCE). This is a measure of how much of the material can react with the soil to neutralize acidity under ideal conditions compared to pure calcium carbonate. Limestone should have a neutralizing value of at least 90 percent. Even if the CCE of lime is satisfactory, it will not neutralize soil acidity unless the limestone is finely ground. In an attempt to arrive at a more accurate lime rating to measure liming material effectiveness, some states' soil test laboratories have adopted effective calcium carbonate content for rating liming materials. An efficiency rating is arrived at by multiplying the calcium carbonate equivalent times the effective calcium carbonate content, which is based on the fineness of the liming material.

EFFICIENCY FACTORS FOR LIMING MATERIALS

The following example of the "effective neutralizing value" (ENV) calculation, used by the University of Illinois, serves to illustrate the importance of lime particle size in potential soil acidity neutralization. ENV = Total fineness efficiency x (% calcium carbonate equivalent / 100).

Assume that a liming material has a 96 percent calcium carbonate equivalent. After screening, the liming material is found to have the following particle size distribution:

+8 mesh = 4% –8 to +30 = 25% –30 to +60 mesh = 26% –60 mesh = 45%

The total fineness efficiency factor may be calculated as follows for the example material:

+8 mesh efficiency is 5%, so.04 x 5 = 0.20 –8 to 30 mesh efficiency is 20%, so .25 x 20 = 5.00 –30 to +60 mesh efficiency is 50%, so .26 x 50 = 13.00 –60 mesh efficiency is 100%, so .45 x 100 = 45.00

Total Fineness Efficiency for 1st Year = 63.20

Therefore, the effective calcium carbonate content of ENV = 63.20 x (96/100) = 60.67 for this example of liming material for the first year.

These calculations enable a grower to determine the shorter- and longer-term value of the liming material being considered for purchase.

PARTICLE SIZE	WITHIN 1 YEAR OF APPLICATION	AFTER 4 YEARS OF APPLICATION
Greater than 8 mesh	5	15
Between 8 and 30	20	45
Between 30 and 60	50	100
Smaller than 60 mesh	100	100

Most mid-Atlantic and southeastern states use the Mehlich I (double acid) solution to extract P, K, Ca, Mg, Mn and Zn. Most Midwestern states use the Bray I solution for extracting P. For K, Mg and Ca, ammonium acetate is used. In regions having calcareous soils, such as the western Corn Belt and Great Plains, the Olsen test is used to extract P.

EFFICIENCY FACTORS: TIMING, PLACEMENT AND FREQUENCY OF APPLICATION

TIMING

For crop rotations that include legumes like alfalfa or clovers, lime should be applied to allow enough time for reaction with the soil before the legumes are planted. Ideally, lime should be applied three to six months ahead of seeding the targeted crop. Applications as late as just before planting, with good soil incorporation, can still be beneficial on strongly acidic soils. Some reduction in soil acidity will still occur, although maximum pH increases are not normally reached until about one year after application of typical agricultural limestone.

PLACEMENT

Placement is just as important as lime quality. Maximum contact with the soil is essential for neutralization of soil acidity.

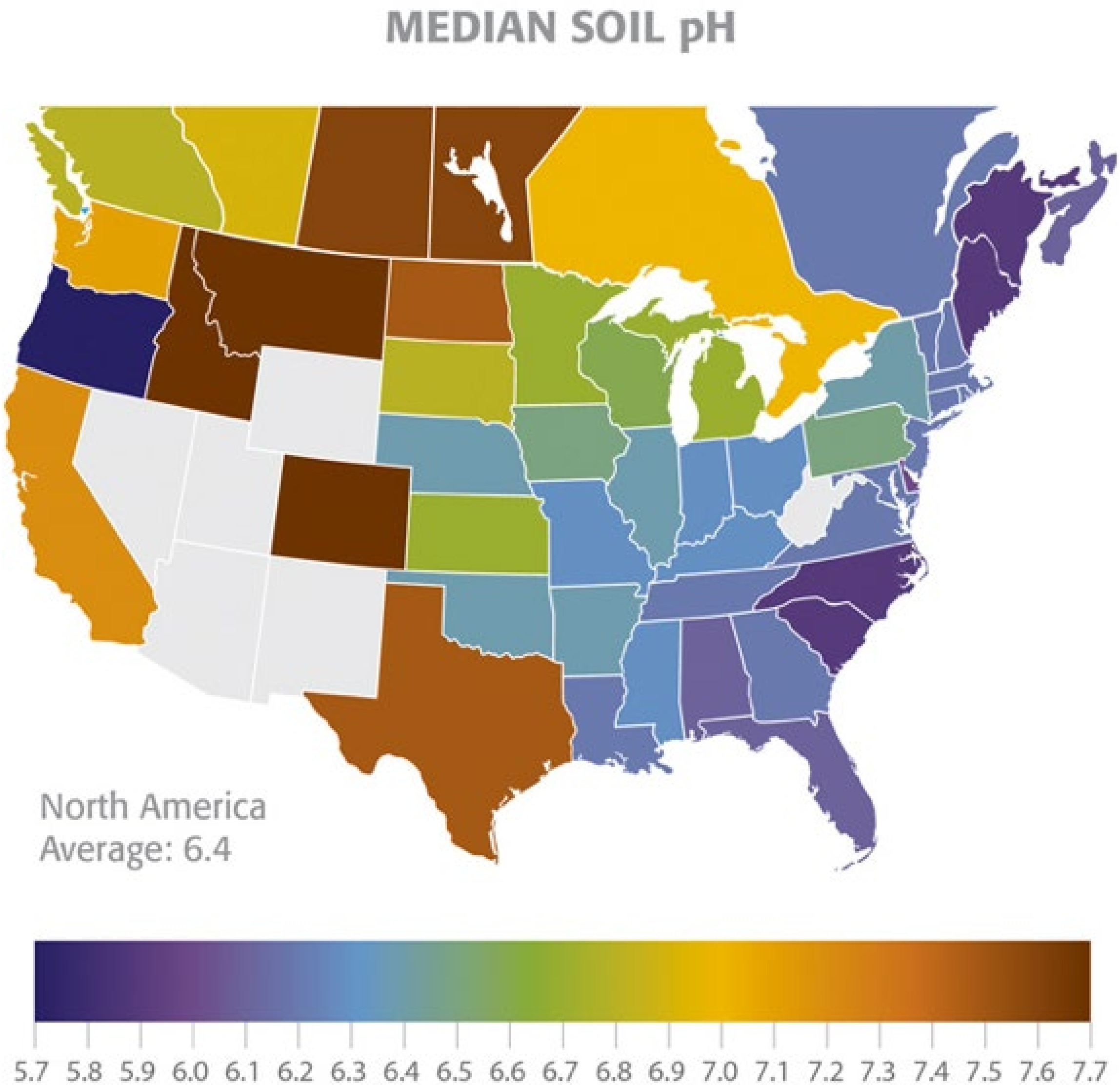
Most common liming materials are only sparingly soluble in water. For example, ammonium nitrate is about 84,000 times more soluble than pure calcium carbonate. Even if lime is properly mixed into the plow layer, it will have little reaction if the soil is dry. Moisture must be available for the lime-soil reaction to occur. Perhaps the best way to incorporate lime or any other material with the plow layer is to use two perpendicular passes of a combination disc, followed by a chisel plow. Deep plowing of lime does not achieve desirable mixing in the upper 6 to 8 inches of soil. However, because the plow or a heavy breaking disc inverts the lime, it can help to distribute the lime in the upper portion of the subsoil. Choice of tillage equipment will depend on the depth at which soil acidity neutralization is most needed. Good horizontal and vertical mixing of the lime provides the best results. In some cropping systems, like established perennial sods or established no-till crop production, mixing lime with the plow layer is not possible. Lime should be incorporated to adjust the pH in the plow layer before the establishment of these cropping systems. Once the desired pH is reached, it can be maintained by surface applications in these no-tillage systems. Surface-applied lime reacts more slowly than lime that is mixed with the soil, and usually only affects pH in the upper 2 to 3 inches of soil. Research at Pennsylvania State University indicated that surface applications of limestone in no-till crop production can begin to influence soil pH below the 2-inch depth after the fourth year, if lime is applied about every third year. Surface liming every third year with 6,000 pounds of lime/A was just as beneficial as annual lime applications of 3,000 pounds/A.

FREQUENCY

The more intensive the crop production, the higher the nitrogen fertilizer or manure use, and the greater the crop yields (and nutrient removal), the greater and more frequent the need will be for lime. Soil sampling is the best way to evaluate soil pH levels and the need for lime.

EXCESS ALKALINITY - NATURAL AND INDUCED

Many soils in the semi-arid and arid regions of the United States have a naturally high pH. They may contain significant quantities of "free calcium carbonate." However, these areas are not the only ones with problems associated with high pH. Irrigation well water may contain significant quantities of calcium and/or magnesium carbonate in certain regions of the United States. In areas of the mid-South for example, some irrigation well water contains in excess of 3 to 5 milliequivalents of bicarbonate per liter and 3 to 5 milliequivalents of calcium. An acre-foot of water or more per year can deliver more than 300 to 600 pounds of calcium and/or magnesium carbonate (lime) per acre. Sprinkler irrigation systems tend to deliver the lime in the water uniformly across the field. If "flood" or furrow irrigation systems are used, much of the lime from the water may precipitate in the upper regions of fields nearest the water delivery inlets and in the water flow path. In effect, the soil is limed by the irrigation water. If the water distribution and delivery are the same over several years, the soil may become alkaline, with soil pH levels rising to 7.0 and above. Soil pH increases may approach 0.2 pH units per year, until equilibrium is reached with atmospheric carbon dioxide levels. Such soil pH increase will occur more rapidly on coarse and medium-textured soils than on clays, which are more highly buffered.



Values calculated in 2010 from 4.3 million samples.

If the well water contains significantly more sodium compared to calcium or magnesium, there may be a risk of sodium buildup on soils that do not readily leach. This is more often a greater concern in arid regions than in humid regions. Soils with naturally high sodium levels, or those that have received large quantities of sodium bicarbonate through irrigation, may have pH levels as great as 8.5 or higher. Theoretically, if sodium is not a factor, even if large quantities of calcium or magnesium carbonate are applied, the soil pH will not exceed 8.2 to 8.3. At pH 8.2, the soil carbonate reaches an equilibrium with the carbon dioxide level in the atmosphere. If irrigation water is suspected or known to deliver significant amounts of lime salts and/or soluble salts, soil samples should be collected more frequently to better monitor soil pH, salinity and cation balance. Irrigation water quality should also be periodically monitored.

CORRECTION OF EXCESS ALKALINITY BY SOIL ACIDULATION

Elemental sulfur may be used to acidify alkaline soil to the desirable pH range. It may also be used to maintain pH in the desirable range, on soils that tend to become alkaline with management. When elemental sulfur is applied to soil, it combines with oxygen and water to form sulfuric acid. This oxidation of sulfur is brought about by certain microorganisms, and it may take from three to six weeks or longer, depending on the soil conditions. The finer the sulfur is ground, the more rapid the conversion to sulfate and dilute sulfuric acid. The rate of decrease in pH with elemental sulfur may be similar to the rate of pH increase brought about by liming. The more free calcium carbonate present and the more buffered the soil, the longer it will take to acidify the soil. More sulfur will also be needed on soils with free carbonates present. Aluminum sulfate is another amendment often used in ornamental horticulture to acidify soil in plant beds. However, more of it is needed to produce the same acidification as elemental sulfur, even though it offers the advantage of a faster reaction. Compared to elemental sulfur, the rate may need to be two to seven times greater. Little of this amendment is used in commercial agriculture.

Approximate Amount of Elemental Sulfur Needed to Increase Acidity (Reduce pH) of a Carbonate-Free Soil

CHANGE IN PH DESIRED	POUNDS OF SULFUR PER ACRE		
	SAND	SILT LOAM	CLAY
8.5 to 6.5	2,000	2,500	3,000
8.0 to 6.5	1,200	1,500	2,000
7.5 to 6.5	500	800	1,000
7.0 to 6.5	100	150	300

NOTE: If free carbonates are present, higher rates than those shown will be required. Reference: "Western Fertilizer Handbook," eighth edition. California Fertilizer Association

PROCEDURES

As with soil testing, an important phase of plant analysis is sample collection. Plant composition varies with age, the portion of the plant sampled, the condition of the plant, the variety, the weather and other factors. Therefore, it is necessary to follow proven sampling instructions. Most laboratories provide instruction sheets for sampling various crops, plus information sheets and directions for preparing and submitting samples. It is usually suggested that samples from both good and problem areas be submitted for comparison when diagnosis is the goal. Because experience and knowledge are vital in sampling plants correctly, agricultural advisors or consultants often do the job.

The Four Basic Steps in Plant Analysis

- Sampling
- Sample Preparation
- Laboratory analysis

- Interpretation