

# Soil and lime requirement tests for the 50 states and Puerto Rico<sup>1</sup>

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## ABSTRACT

The purpose for liming acid soils is to adjust their pH to a level where most plant toxic elements are rendered nontoxic and the availability of most essential elements for plants are near maximum. The sources of soil acidity and its development, the predominant cations, and the measurement of soil acidity, as well as soil test procedures used for determining lime requirement, are discussed. The purpose of this paper is to discuss the strengths and weaknesses of soil testing methods for determining lime requirements, their interpretation, and their application, as related to soil properties, tillage systems, and cropping patterns. The soil tests discussed will not include all procedures that have been developed but will include those tests currently being used by 50 states and Puerto Rico.

*Additional index words:* Lime requirement, Soil pH, Soil testing, and Soil acidity.

THE purpose of liming is to adjust soil pH to a level where most plant toxic elements are rendered nontoxic, and the availability of most essential elements for plants is near maximum. Therefore, it is very important to have a test that indicates the amount of lime required to raise the pH of a given acid soil to a selected level. The term pH is used to express the degree of acidity or alkalinity. The numbers used to express pH are negative logarithmic numbers (to the base 10). Therefore,  $\text{pH} = -\log_{10} [\text{H}^+]$ . The entire pH scale ranges from 0 to 14 with pH 7 being neutral. Most agricultural soils range from 4 to 8. The pH of a soil actually expresses that part of acidity that is present in an equilibrated system in the form of hydrogen (H) ions, regardless of their source. Since the reserve acidity of acid-producing ions is not included in pH measurements, as long as the ions stay undissociated, soil pH alone does not reflect the soil's acid-producing potential nor the amount of lime needed for crop production on it (14).

Controlling soil acidity in certain soils may be as important for maximum crop yields as fertilizing, irrigating, and pest control. Soil acidity can be corrected when acidic ions, such as H or Al ions, are replaced with Ca or Mg ions. Of several liming materials (4, 33), finely

ground limestone is one of the most commonly used materials for correcting soil acidity. The lime requirement (LR) is the quantity of agricultural grade lime required to neutralize soil acidity and to increase soil pH from an initial to a final desired value.

## SOURCES OF SOIL ACIDITY

Soil acidity develops over thousands of years in humid regions as precipitation in excess of plant use percolates through the soil and leaches Ca, Mg, and other basic cations from the surface soil. Growing plants also remove Ca and Mg from the soil. The lost Ca and Mg are replaced by H and Al, resulting in increased soil acidity. The use of acid-forming fertilizers also contributes to soil acidity. Soil leaching and the subsequent removal of the basic cations Ca, Mg, and K from the surface of the colloidal particles (clay and organic matter) is enhanced by root activity that generates  $\text{CO}_2$ . Eventually,  $\text{CO}_2$  reacts with water to produce carbonic acid (24),



which then breaks down to release protons or H ions ( $\text{H}^+$ ), thus lowering the soil pH [1 and 2]. The decomposition of organic matter and the release of organic acids in the soil also generates H ions that replace basic cations on the surface of the soil colloids.

For many years, it was assumed that soils with a low pH were primarily H-saturated. However, research has shown that Al was the predominant cation in acid mineral soils with a pH of 5 or lower (6). Aluminum is considered an acidic cation since H ions are released during hydrolysis of the water associated with the Al ions [3].



Although H and Al ions are the two main components of soil acidity in most acid soils, their relationships in soils are certainly more complicated than they are in pure solution, since Al ions may also exist in soil in hydroxy Al forms (42).

Exchangeable Al is generally the predominant cation in the leached soil from the Southeastern USA and from tropical regions when the soil pH is 5 or less (13). In addition to contributing to soil acidity, Al and Mn are toxic to plants and are, thus, important growth-limiting factors in many acid soils of the world. Foy and Fleming (10) indicated that Al toxicity is particularly severe at a

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termining soil pH in 0.01 M CaCl<sub>2</sub>. The pH of a soil measured in 0.01 M CaCl<sub>2</sub> is independent of dilution over a wide range of soil-water ratios. The pH measured at 0.01 M CaCl<sub>2</sub> is about 0.3- to 0.5-pH units lower than that measured in a 1:1 or 1:2 soil-water ratio.

Another factor influencing the soil pH measurement is the suspension effect (6). When soil particles settle from an unstirred suspension, the pH measured by inserting electrodes into the layer of sediment differs from (and is usually lower) that measured in the supernatant liquid. The magnitude of the suspension effect depends upon the nature of the soil and its salt concentration. High CEC, loosely bound exchangeable ions, and low electrolyte concentrations favor a large suspension effect. To minimize the suspension effect, most soil-testing laboratories stir the soil-water suspension just before taking a pH reading.

**LIME REQUIREMENT**

The term lime requirement is somewhat ambiguous. It is simply the amount of lime that must be applied to the soil to grow a certain crop. More often, however, it is the amount of CaCO<sub>3</sub>, or its equivalent, that must be applied to a soil to increase its pH to 6.5 or to some other desired value. The LR is affected by soil acidity and several other factors, including soil texture, type of clay mineral, amount of acidity, including extractable Al, CEC, and amount of organic matter. These factors influence the capacity of a soil to remain at a relatively constant pH level, known as its buffering capacity.

Soil serves as a reservoir of nutrients and water for plant growth. In addition, the soil solids are a reservoir of basic or acidic materials that regulate soil pH (buffering capacity). In spite of large annual additions of ferti-

lizer materials and minerals removed during crop production, this buffering capacity makes soil resistant to rapid pH change. All recognized forms of soil acidity must be considered when one is estimating the LR of soils that differ widely in their chemical and cation exchange characteristics (22). In addition, soil texture and organic matter can influence this buffering capacity (11) as is shown in Fig. 2. The pH of both of the soils is 5, which is too acidic for optimum production of most crops. The soil on the bottom will have a larger lime requirement because of a greater buffering capacity.

Many qualitative and quantitative methods have been used for determining suitable lime applications for acid soils. Different rapid LR methods can give widely divergent results (29). Certain methods are better suited to specific soil conditions (22). Although a field study would be ideal for determining LR, because of its cost and time required, the CaCO<sub>3</sub>-moisture-incubation method has been considered as a standard for comparative purposes (13, 18, 21, 34, 43). Another widely accepted reference method is a Ca(OH)<sub>2</sub> equilibration, fol-

Table 1. Lime requirement test used in each state and Puerto Rico†

State(s)	Lime requirement test	Abbreviation on Fig. 3	Reference	
Colorado	Rhode Island	None offered	No	--
Hawaii	South Dakota			
Illinois	Tennessee			
New Hampshire	Utah			
New Mexico	Virginia			
Nevada	Wyoming			
North Dakota				
Alaska	Minnesota	Shoemaker,	SMP	19, 34
Arizona	Montana	McLean, and		
California	Nebraska‡	Pratt Buffer		
Indiana	Ohio			
Iowa	Oklahoma			
Kansas	Oregon			
Kentucky	Pennsylvania§			
Maine§	Wisconsin			
Michigan				
Mississippi				
Idaho	Missouri	Woodruff	W	41
Massachusetts	Nebraska‡			
Alabama	Georgia	Adams and Evans	A&E	1
Florida	South Carolina	Buffer		
Louiana		Dunn-titration curve with Ca(OH) <sub>2</sub>	Dunn	8
New York		BaCl <sub>2</sub> -TEA titration method	BaCl <sub>2</sub> -TEA	29
North Carolina	West Virginia	Mehlich buffer method	Meh.	21
New Jersey	Texas	Water pH plus soil texture	pH-T	--
Maryland		Water pH-texture-organic matter	pH-T-O	--
Conneticut				
Delaware				
Washington		Base saturation test	base saturation	38
Arkansas		Water pH and exchangeable Ca	pH-Ca	--
Vermont		Active aluminum and salt pH (0.1 M CaCl <sub>2</sub> )	Al and salt pH	39
Puerto Rico		CaCO <sub>3</sub> Buffer	CaCO <sub>3</sub> buffer	26

† Summarized from a questionnaire sent to all 50 states and Puerto Rico.  
 ‡ Nebraska uses the Woodruff test, but does the SMP buffer test on request.  
 § Maine changed from Woodruff to SMP in January 1980, and Pennsylvania changed from Woodruff to SMP in July 1980.

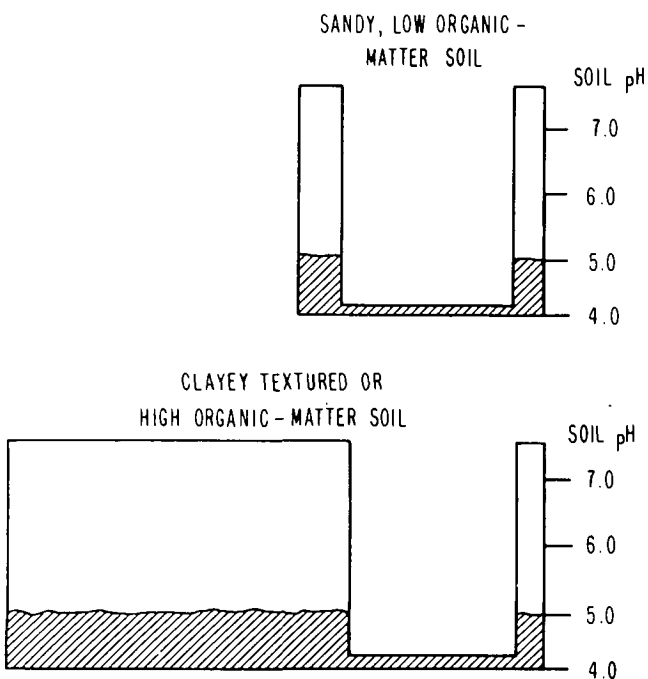


Fig. 2. Reservoirs of cation exchange capacity in clayey vs. sandy soils.

lowed by carbonation (14, 18). As conditions vary from location to location, the method that is best suited for determining LR may also change. Fortunately, for most agronomic crops, plant response is favorable within a pH range (33) not critically dependent upon obtaining an exact soil pH. For example, a specific crop may yield nearly as well at pH 6.2 as at pH 6.5, or at pH 7.0. Thus, the purpose of using a well-adapted, lime-requirement test that can be adapted to a routine soil-testing program is to improve the prediction capability for making LR recommendations, rather than to predict an exact amount of lime required for each specific soil to reach an exact final pH.

Most of the more rapid LR methods involve an equilibrium extraction of the soil with a buffered salt solution, followed by determination of the exchange acidity in the extract, either by direct titration, or by measuring the pH change of the extract. All of these methods are subject to the same error because of incomplete extraction of the exchange acidity (28, 34).

### COMPARISON OF (LR) TESTS USED BY THE 50 STATES

The various methods used by soil-testing laboratories in 50 states and Puerto Rico, to determine LR, are summarized in Table 1 and Fig. 3. Thirteen states do not offer a LR test; several, such as Colorado, Nevada, New Mexico, Utah, and Wyoming have soils that are pre-

dominantly high in  $\text{CaCO}_3$ , where pH seldom decreases below pH 6.5. Although it was not reported in the survey questionnaire, states that do not offer a LR test may use water pH or some other criteria for making lime requirements. Several states responded to the questions regarding what they thought were the strengths and weaknesses for the particular tests that they use for lime requirements. Many of their responses were similar to comments found in the literature relative to the various LR methods. Their comments are summarized in Table 2.

### SMP Buffer (34)

Eighteen states used the Shoemaker, McLean, and Pratt Method (SMP) buffer for determining LR. The buffer solution consists of a combination of p-nitrophenol, triethanolamine, potassium chromate, calcium acetate, and calcium chloride. The buffer reagent is adjusted to pH 7.5 with sodium hydroxide. Because the nature of soil acidity, whether predominantly H or Al, may affect buffer pH's, Shoemaker, McLean, and Pratt (34) indicated that the SMP buffer method would predict more LR if the amount of acidity was large and H ions predominated rather than Al. Extensive investigation has shown that the method, based on the average buffer capacity of a broad group of soils, is reasonably accurate for a wide range in LR. Recently, McLean et al. (19) have indicated that the SMP method is most accurate for soils that have a LR > 4 meq/100 g, pH

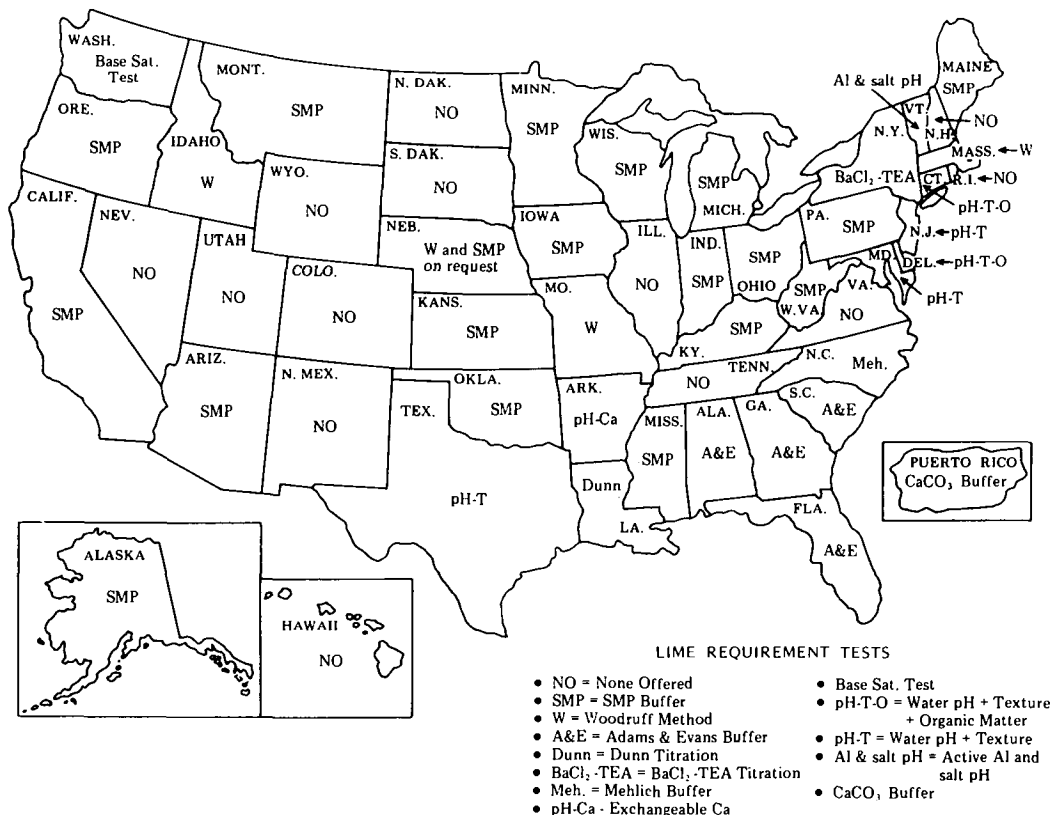


Fig. 3. Lime requirement test used in each state and Puerto Rico.

< 5.8, OM < 10%, and soluble (extractable) Al in appreciable quantities (18). However, shortcomings of the SMP method have been apparent for some time. One reason for generally satisfactory LR measurements of medium to high LR soils by the SMP buffer method likely results from the tendency for the pH vs. CaCO<sub>3</sub> applied curves to be linear and, hence, easily extrapolated in the range pH 4.5 to 7.5 (15, 16).

To help overcome weaknesses of the SMP-single buffer (SB) method (Table 2), McLean et al. (19, 20) have recently identified that considerable improvement is obtained by using the double-buffer (DB) feature of the Yuan method (43, 44). The questionnaire returned by the 18 states, using the SMP buffer, did not indicate

**Table 2. Summary of comments on the strengths and weaknesses of the various lime requirement (LR) tests used by the states and Puerto Rico†**

LR test	Strengths	Weaknesses
SMP Buffer	High correlation on soils with high requirement Best on medium and fine-textured soils Best for low pH situations	Low correlation on soils with low lime requirement Overestimates LR on sandy soils Cannot be used to adjust soil pH to levels greater than 7.0 for disease control
	Best for a wide range of acid mineral soils Accurate, reliable, and fast	Not accurate for muck or peat soils Underestimates LR for some soils
	More accurate on soils with high extractable	Less sensitive as pH approaches 7.0
Woodruff	Best for sandy soils	Overestimates LR for low lime needs Underestimates LR for high lime needs Not accurate on soils that have high extractable Al Not related to exchangeable calcium
Adams and Evans	Sensitive on low CEC soils (1-10 meq/100 g) Good on kaolinitic soils	Underestimates LR on high CEC soils Not suited for organic soils or mineral soils high in clay or organic matter Not suited on soils high in montmorillonitic type clays
Dunn BaCl <sub>2</sub> -TEA	Reliable Consistent results; good correlation	Time consuming procedure Less sensitive on soils with low LR (pH 6.0) Not fast enough
Mehlich	Rapid estimation of salt-exchangeable acidity and LR	Must be tempered according to the ratio of toxic elements, particularly organic soils
Water pH + texture and pH + texture and O.M.	Fast, easy, and adequate for 85% of the samples	Tends to overestimate Requires texture estimate Not reliable for sandy soils
Base saturation test	Inexpensive or low CEC soils	Not accurate for highly buffered soils
pH and exchangeable Ca	Reliable	Long, drawn-out procedure
Active Al + salt pH	Correlated in 95% of soils	Not reliable if soil contains extractable Al
CaCO <sub>3</sub> Buffer	Takes Al as well as H ion activity into account Consistent results	Time consuming procedure tends to overestimate LR

† Comments were summarized from a questionnaire sent to all 50 states and Puerto Rico.

whether any had started to use this improved double-buffer method. However, the improved double-buffer method is being included in the 1980 draft revisions of Recommended Chemical Soil Test Procedures for the North Central Region (17). The SMP-DB method takes into consideration both the acidity and buffering property of individual acid soils, and it has the advantage that it is relatively rapid. The improvement is particularly good for soils with low lime requirement.

Results reported by McLean et al. (19, 20) indicate that the double-buffer feature decreased the uncertainty of estimate for the SMP method in all soil tested with the greatest improvement in soils of low LR. Regression values obtained for the SMP-DB method were somewhat better than for the Yuan-DB method (43), and considerably better than the new Mehlich method (21) for the soils tested.

### Woodruff (41)

The Woodruff test is best for sandy soils according to the survey comments. It was not accurate on soils that have high extractable Al. Loynachan (14) found that for soils of Alaska, both CaCO<sub>3</sub> incubation and the Woodruff buffer were measuring similar components of soil acidity. However, at low lime requirements, the Woodruff buffer overestimated lime requirement. The Woodruff buffer solution consists of a combination of p-nitrophenol, calcium acetate, and magnesium oxide adjusted to a pH of 7.0 with HCl or MgO as required.

### Adams and Evans (1)

Reported strengths and weaknesses of this method are shown in Table 2. The buffer reagent for the Adams-Evans method consists of a combination of p-nitrophenol, boric acid, potassium chloride, and potassium hydroxide adjusted to a pH of 8.0. The Adams and Evans method was developed because it was felt that such a method was especially needed for Red-Yellow Podzolic soils (Ultisols) where amounts of lime needed may be small, and the possibility of damage from over-liming exists (1). The present classification for Red-Yellow Podzolic soils would mostly include thermic families of Fragiudults, Hapludults, and Paleudults (36). The pH range of the Adams-Evans buffer is between 7 and 8, and the SMP buffer between pH 4.8 and 7.0 (21). It is probably due to this difference in the respective pH ranges of the two buffers that the results have been observed with the Adams-Evans method that were more highly correlated with total soil acidity, while results with the SMP method were also correlated with unbuffered salt-exchangeable acidity (21).

### Dunn Titration Method (8)

This method was reported to be reliable but a time consuming procedure (Table 2). Soil-water suspensions are allowed to come to equilibrium pH values with different amounts of 0.04 N Ca(OH)<sub>2</sub>.

### **BaCl<sub>2</sub>-TEA Method (29, 30)**

This method is used by New York State. The extracting solution (0.5 *N* BaCl<sub>2</sub>-0.055 *N* triethanolamine) is added to the soil (75 ml to 3 g soil) and then allowed to equilibrate over night. The supernatant liquid is titrated with 0.1 *N* HCl to a pH of 5.1. Suggested strengths and weaknesses of this method are documented in Table 2.

### **Mehlich Buffer Method (21)**

This is a relatively new buffer pH method used by North Carolina and West Virginia for the rapid estimation of unbuffered salt-exchangeable acidity and lime requirement. The buffer reagent consists of a combination of sodium glycerophosphate, acetic acid, triethanolamine, ammonium chloride, and barium chloride. In view of the importance of exchangeable acidity, and particularly exchangeable Al, Mehlich determined that there was a need for a buffer primarily calibrated against salt-exchangeable acidity for lime requirement determinations. The method gives a quantitative measure of exchangeable acidity; however, the results must be tempered depending on the ratio of toxic elements, particularly in organic soils.

### **Water pH and Texture**

States which used this method thought it was a fast, easy, and adequate method for the majority of their samples. The method requires a texture estimate and tends to overestimate LR, particularly on sandy soils and low CEC soils. It was also not considered accurate on highly buffered soils. The same comments were made about the soil pH-texture-organic matter method of estimating LR.

### **Base Saturation Test (37)**

This test is used by Washington State and is considered to be reliable. It is, however, time consuming.

### **Water pH and Exchangeable Ca**

This test is used in Arkansas to estimate LR needs. It has a good correlation for 95% of the soil samples tested in Arkansas.

### **Active Al and Salt (0.1 *M* CaCl<sub>2</sub>, pH (39)**

This test is used in Vermont, and works quite well for their soils. The test is based on active aluminum moderated by salt pH. The well-known effect of the variation of the soluble salt content of a soil on soil pH, as measured in aqueous suspensions, may introduce a serious error in the estimation of LR of a soil from its pH value. For this reason, the pH value of a soil, as measured in 0.01 *M* CaCl<sub>2</sub>, should reflect more accurately the base status and the LR of the soil. It will be noted that the pH value measured in 0.01 *M* CaCl<sub>2</sub> is

about 0.6 pH lower than that measured in water. Also, the pH of a soil containing an excess of CaCO<sub>3</sub> in equilibrium with the partial pressure of CO<sub>2</sub> of the air, as measured in 0.01 *M* CaCl<sub>2</sub>, is very nearly equal to the value of 7.7 predicted by the equation  $\text{pH} - \frac{1}{2}\text{pCa} = 6.60$  (29).

The active Al and salt method has recently been suggested as possibly important where lime must be transported long distances, such as for northern Alberta and northeastern British Columbia, Canada, and it is important that lime be used as economically as possible (40). The principle would be to add just enough lime to reduce soluble Al below the toxic level for the crop being produced, based upon determination of 0.01 *M* CaCl<sub>2</sub>-soluble Al.

### **CaCO<sub>3</sub> Buffer (26)**

The test is used by Puerto Rico. A series of soil samples are incubated for 3 h with increased levels of chemically pure CaCO<sub>3</sub> and then pH is determined. From a buffer curve (pH vs. tons of CaCO<sub>3</sub> added), the quantity of lime required to raise the soil pH to the desired range is estimated. The procedure gives consistent results but is time consuming. The use of room temperature incubation of incremental mixtures of CaCO<sub>3</sub> and soil tends to overestimate the actual lime requirement. According to Baker and Chae (3), this occurs because soil acidity increases under room temperature incubation.

## **RESEARCH NEEDS**

A great deal of effort has been expended on developing soil-testing methods for determining LR. The soil tests discussed here have not included all procedures, but have concentrated primarily upon those tests currently being used by U.S. soil-testing laboratories. Considerable progress has been made in developing soil-testing procedures for lime. However, even if we assume that each state is using the best soil-test procedures for its soil conditions, a continuing research challenge exists as new technology and improved farming systems are developed, and how the interpretation of these or other soil tests can be improved, extended, or adapted to new or additional needs.

### **Liming for Conservation Tillage**

Perhaps one of the most important recent changes in farming systems that may affect soil test interpretations is the increasing shift to conservation tillage. During the past 15 years, the use of conservation tillage systems has increased rapidly. Estimates are reported that by the year 2000 the amount of cropland under no-till (conservation tillage) cultivation will be about 45% of the total U.S. cropland (31). The amount of lime estimated by soil test is usually for the surface 15 cm of soil. In cases where tillage practices are used that do not incorporate added lime (25), research is needed and care

should be taken to make soil test recommendations that do not lead to overliming. This may be particularly important for sandy soils or soils of low buffering capacity.

Factors needing more understanding include soil tests for lime and their interpretation for conservation tillage systems, as affected by conditions such as the evenness and depth with which lime is incorporated into the soil, the rate at which it dissolves in the soil solution and reacts with the soil particles, its neutralizing value, fineness of grind, and its use to adjust soil pH for optimum efficacy of pesticides.

#### **Liming for Nutrient Availability and Use**

Although the purpose for liming is to adjust soil pH within a given depth of the root zone, to a pH at which most plant toxic elements are rendered nontoxic and most plant essential elements are at near maximum availability, included in this concept is optimizing a balance between nutrient elements to improve their availability. However, additions of lime can sometimes aggravate nutrient balance. For example, research from Georgia (12), for soils low in Mg, showed that Mg-deficiency can be intensified by applying low-Mg lime since the gap between available Ca and Mg in the soil is widened.

When legumes are grown, the fixation of N is important to supply their needs as well as to potentially supply N to crops grown after the legumes. Currently, more information is needed about the interpretation of soil-tests for LR as they might relate to nutrient availability for symbiotic N<sub>2</sub>-fixation, or as they might relate to the interactions of nutrients (such as molybdenum (Mo), P, or other nutrients) with lime for optimum nutrient availability for the growth of either legume or nonlegume crops.

#### **Evaluation of the Effectiveness of Liming Materials**

Liming recommendations for a specific soil usually take into consideration such factors as the purity and fineness of the lime used. However, some soils do not respond as expected. An explanation may be that the lime particles react with some constituents to form a surface coating that reduces particle-dissolution rates. Research by Barrows et al. (5) indicated that, for coarser lime particles (12 to 14 mesh), reduced efficiencies of up to 8.5% were observed, with addition of P, because of surface coating of the lime particles. Thus, the availability of both nutrients and the reactivity of the lime particles are influenced by surface coatings may be factors requiring additional research. Little geological research of the physical and chemical characteristics of limestone has been done. Additional research is needed to help identify the effectiveness of different limestone sources in different soils. Limestone sources, used or recommended, should likely be based on laboratory tests for the chemical and physical properties of both the limestone sources and the soils.

#### **Evaluation and Management of the Causes of Acid-Soil Infertility**

Soil test interpretation for use of lime to correct soil acidity must continue to rely upon and be improved by research to determine the specific underlying causes of acid-soil infertility. These causes often differ among broad groups of soils. However, the specific soil properties causing these differences need to be better defined. Poor growth of plants on acid soils is often related to the toxic effect of Al and Mn (2), or because Ca, Mg, and other nutrients may be seriously deficient. In soils where organic matter is an important contributor to the CEC, the exchangeable acidity is H (42). Salts may also influence soil acidity (42); Al is held quite tightly to the soil exchange compared with other cations, and in some soils with low salt contents, appreciable amounts of Al are not found in the soil solution until the Al saturation is greater than 60% (42). However, as the salt content increases, the amount of Al in the soil solution increases (10). Frequency of liming will depend upon how quickly Ca and other basic cations are removed by leaching, and how soon exchangeable Al reappears on the exchange sites. Long-term studies and a better understanding of the effects of climate, management, and soil characteristics are needed to answer these questions. Where economic considerations are likely to override other considerations, soil tests are needed that will provide recommendations that can reduce the source of soil acidity or toxicity (like that from soluble Al) below levels for sensitive crops without requiring the soil pH to be raised to the level normally recommended. Soil tests and liming practices are needed to extend liming experience gained in temperate zones to acid soils of tropical regions.

Research from Puerto Rico (27) suggests that liming experience gained in temperate zones can be used with caution for acid soils in tropical regions. Also, their results supported the concept that plant growth can be satisfactory on acid soils of tropical regions at somewhat lower pH levels than that on soils of temperate regions. The extension of soil testing for lime requirement to tropical soils seems a reasonable goal, since of all the soil orders, only Oxisols are restricted to the tropics (45).

#### **Liming for Acid Topsoil and Subsoil Conditions**

Because of topsoil loss, the surface or near surface soils of many southeastern states are acid and low in fertility, and the crop yields in extensive areas could probably be improved by correcting soil acidity. Presently, mechanical incorporation is the only effective method available for correcting subsoil acidity because lime moves so slowly in the soil profile (23). Therefore, of particular benefit would be an understanding of how the rates of Ca and Mg migration might be increased to provide for a deeper root zone. The benefits of mechanical incorporation for correction of subsoil acidity has recently been demonstrated by Doss et al.

(7). However, improved soil tests and their interpretations are needed to more adequately provide recommendations for liming where acid subsoil conditions exist.

Another problem related to subsoil pH is the development of an acid topsoil over a calcareous subsoil. The use of acid-forming fertilizers over a period of several years can slowly change a neutral or slightly alkaline topsoil to a soil that requires from 2 to 8 t of limestone/acre. Soil samples taken from the topsoil can indicate a need for lime in the surface soil; however, the subsoil below 20 to 25 cm may be calcareous. Thus, a deep-rooted crop will not respond to the application of lime. Again, improved soil tests and their interpretations are needed to more adequately provide recommendations for liming where neutral to alkaline subsoil conditions exist.

### Liming for the Maintenance of Long-Term Soil Productivity

An issue that is becoming of increased concern is the importance of maintaining the productivity of soils of the USA. Recently, a report (38) evaluated the influence of soil erosion on soil productivity. Primarily, the physical losses of topsoil resulting from erosion are discussed. The importance of the loss of plant nutrients, acid subsoil conditions, and the characteristics of soil productivity loss are also included. In addition to factors discussed in this report, research is needed on the role of lime in the protection of soil productivity under long-term N-fertilization and soil management systems.

### SUMMARY

The survey and literature review reported herein was used to identify the soil tests currently being used by the 50-state soil testing laboratories and Puerto Rico for determining soil pH and lime requirement tests. The survey revealed that soil pH determinations and LR tests among the 50 states are not uniform. Several states responded to questions regarding what they thought the strengths and weaknesses were for the particular test that they use for determining LR. Soil testing research needs of liming for conservation tillage, liming for nutrient availability and use, evaluation of the effectiveness of liming materials, evaluation and management of the causes of acid-soil infertility, liming for acid topsoil, or subsoil conditions, and liming for the maintenance of long-term soil productivity are discussed.

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