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FACTORS AFFECTING CROP RESPONSE TO LIMING

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Soil acidity levels directly affect the rate, kinds, and degree of chemical reactions which take place in soil. Crops respond to varying degrees to these chemical reactions. For the most part, these reactions affect the solubility of mineral elements in soil and the activity of the soil's biological processes. As a result, the availability of many plant nutrient elements is regulated by soil acidity. The level of availability of plant required nutrients can be adequate, deficient, or toxic to the plant, depending on the nutrient, soil acidity, and the crop. That is why measurement of soil acidity is regarded by many to be the single most important chemical test for use in determining how well plants are likely to grow in soil. Acidity in soil is best controlled by proper applications of agricultural limestone.

Effective Lime Applications

Application Timing - Since aglime is in its primary mineral form (usually calcite or dolomite or some mixture of the two), it's solubility of calcium or magnesium is relatively low. This means that some time lag after spreading will be required for dissolution of enough calcium and/or magnesium to materially change soil pH.

This implies that *planning ahead* is an important consideration in the timing of lime application. Since *lime effectiveness may be considered as the potential for some amount of a liming material to result in a desired pH change within a desired span of time,* it is important to know what factors may be used to shorten the time-span for lime to become effective. A more direct way to express this is to ask, "What can be substituted for time in the dissolution of lime?" Here are some factors which may be considered to hasten the dissolution of lime, thereby changing soil pH faster.

Fineness - The more finely ground the lime, the faster it dissolves. This simply reflects that a given amount of finely ground lime has more surface area exposed to react with soil acids than the same amount

of a more coarsely ground lime. As a consequence, aglime laws contain minimum specifications for fineness. It is considered that 60-mesh sized lime will dissolve within 2 or 3 years, while 100-mesh material will dissolve within a year. The principle to remember is that the finer the lime, the faster it dissolves.

Purity - Lime purity, which is expressed as % Calcium Carbonate Equivalent, is the amount of "active ingredient" per given amount of lime, and is regulated by lime laws. The point of interest with purity and time is that a high purity lime should be used since this will increase the effectiveness of the material applied.

Degree of Mixing - The more uniformly a given amount of lime is mixed into a given volume of soil, the faster it will dissolve and change pH within that volume. So, if a fast change of pH is needed, it can more likely be attained by spreading it uniformly on a horizontal basis and uniformly incorporating it vertically throughout the desired volume of soil by use of appropriate tillage tools.

Use of More Soluble Liming Materials Soluble liming materials can be used to substitute for time. The most common of these would be calcium oxide (burned lime) and calcium hydroxide, both of which have neutralizing values much greater than calcite. Both are of very fine particle size and dissolve readily in the soil, although both have limited agronomic usefulness due to physical characteristics and cost.

All the factors mentioned above (fineness, purity, degree of mixing, and solubility) can be manipulated to varying degree as a means of decreasing the time required for the applied lime to dissolve and provide the desired pH change. Fields should be sampled every 3 or 4 years so that soils do not become so acid that crop response is likely to be affected before lime is applied. This is more important for the legume crops since their performance is more affected by acid soil than non-legumes.

Uniformity of Lime Applications

Uniformity of application should be considered in terms of horizontal and vertical distribution. Horizontal distribution is determined largely by spread pattern and vertical distribution is determined largely by tillage system used.

Horizontal Distribution. - Type of spreader, how well it is calibrated, and capability of the operator to follow the correct spread pattern are factors of concern in applying lime evenly across the surface of a field. The very nature of solid aglime results in a product of wide variation in particle size. When applied with the commonly used spinner-type spreaders, the finer sized materials are not thrown as far by the spinner as are the coarser ones. This can result in "streaking" of fields unless the spreader has been calibrated to determine the swath width necessary to eliminate or minimize this source of rate variation.

Another technique which can be used with spinner-type spreaders to minimize rate variation is to spread half the lime in one direction and half in a direction 90^{o} from the first half. Auger type spreaders will minimize much of the rate variation swath in a boom before it is dropped onto the field. Even so, auger spreaders should also be calibrated to determine rate accuracy across the swath.

Use of pelleted lime (finely ground lime which has been granulated), even through expensive, will also minimize rate variation across the spreader swath. Suspension limes offer another way for improvement of horizontal spreader accuracy since the physical nature of the product and the use of fluid application equipment will provide for improved horizontal uniformity.

Vertical Distribution. - As lime dissolves in soil, the soluble calcium and/or

magnesium does not move very far from its point of dissolution until it reacts with other soluble components or with the cation exchange complex of the soil. The net result is that it doesn't move downward through the soil very fast. Thus, if pH of the plow layer needs adjusting, a surface application of lime will not change the pH of the plow layer below the soil surface very rapidly. In fact, past research on the rate at which surface applied lime moved downward into pasturefields indicated it took 10 years for pH to equilibrate to a depth of 6 inches.

Another similar study on several acid, coarse textured soils indicated that surface applied lime took 6 months to change pH in the top inch of soil and 30 months to change pH to a depth of 4 inches. The implication from this is that even though lime cannot be mechanically mixed vertically through the plow layer in established pasture and hay fields, they still should be limed if they become too acid. However, it will take much longer for the lime to have an effect throughout the plow layer than if it could be mixed in. Continuous no-till fields also fall into this category.

No-till - Since no-tillage of corn and soybeans is now an important production system in several important grain producing areas and likely will be adapted even more widely because of its distinct advantages in sediment control, soil moisture conservation, and energy savings, liming strategies for this system of tillage are important. One of the distinct characteristics of continuous corn production using no-till techniques, is the development of an extremely acid layer of 1-2 inches thickness at the soil surface. Since this surface layer remains intact each successive year as compared to organic residues being mechanically mixed throughout the plow layer in the conventional tillage, soil acidity at the surface increases faster under no-tillage. In a Kentucky study, an application of lime after 3 years neutralized this surface acidity, resulting in surface pH being similar to that of limed conventionally tilled plots, and alleviated the negative effect of surface acidity on no-till corn yields.

Conventional till - For acid fields which can be tilled, the practical question is *how deeply does lime need to be incorporated* so as not to limit economic crop production. Several studies have been conducted to make this determination. Most of these have shown that incorporation of lime to the six inch depth produced near maximum growth as compared to incorporating lime to greater depths.

Mixing Lime Into The Plow Layer - Another question which often arises is what method to use to incorporate lime as uniformly as possible within the plow layer. One study was reported on the effectiveness of several implements on degree of mixing obtained. A spring-tooth harrow or a disk harrow mixed only the upper part of the plow layer. All the shallow tillage implements tested mixed only to a depth of less than one inch. Use of the disk harrow also gave non-uniform horizontal mixing. Deep tillage implements varied greatly. Moldboard plowing placed most surface-applied lime in the lower part of the plow layer. Best vertical mixing was obtained by applying half and plowing it under and then applying the remaining half after plowing and before final harrowing. Cross disking with a spring-tooth harrow improved horizontal mixing in the top part of the plow layer. Two operations with a rotary tiller mixed the 0-6 inch layer uniformly.

Summary of Need for Vertical Mixing

The acid neutralization reaction resulting from lime dissolution in soil is very localized, taking place very near the surface of individual lime particles. Because of this, the degree to which soil acidity is

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neutralized in a given volume of soil is directly related to mixing the liming material as thoroughly as possible within that volume.

Two important production systems exist in which lime cannot be mixed into the soil...perennial sodland used for pasture or hay, and continuous no-till production of row crops. For both situations, studies have shown that topdress application of lime onto the surface is effective in terms of crop yield response compared to not liming.

Furthermore, application to the surface in normal amounts every 4 or 5 years was as effective as more frequent applications at low rates. From a practical viewpoint, it would seem appropriate for many situations in which fields are used in long-term rotations, that adjusting soil pH could best be accomplished by applying lime and thoroughly mixing it into the soil during the time a major tillage operation is performed during the change of crops on the field. Some such fields may rarely if ever be plowed, but when they are, this presents the best time to effectively adjust soil acidity of a large volume of soil in a fairly short period of time.

In crop production systems involving tillage operations in seedbed preparation, soil acidity can be more uniformly changed throughout the plow layer by roto tilling or by applying half the lime before plowing followed by application of the remaining half after plowing but before final disking of the seedbed. Cross disking assures more uniform mixing of lime in the surface 3-4 inches. Any mechanical tillage procedure which will result in a thorough mixing of the liming material within the plow layer will increase the rate at which soil acidity will be neutralized within the volume of the plow layer. This appears to be more important for strongly acid plow layers since field studies in such instances showed mixing to be better than either all plow down or all broadcast and disked after plowing. Mixing lime into the surface six inches appears to be deep enough for near maximum yields. With only a few exceptions, results from field studies have shown little yield benefit to placing lime deeper than 6 inches.

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