Adjusting Soil pH for Optimum Nutrient Availability

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Adjusting soil pH before planting and maintaining optimum soil pH after planting are essential for nutrient availability. Most NY soils are too acid (low pH) and need lime before planting. This article explains the steps to calculate the amount of lime needed to bring pH up to 6.5-7.0.

Mineral nutrient availability to fruit trees is dependent on the quantity of each nutrient in the soil, and its availability. Nutrient availability is dependent on soil pH, soil texture and water availability. One of the objectives of orchard nutrient management programs is to improve the availability of nutrients in acid soils that are typical of apple growing regions in New York and the Northeast. In this article, we will introduce a few basic concepts first, then use an apple orchard soil survey to illustrate the effect of pH on soil nutrient availability, and at the end, discuss lime requirement for adjusting soil pH.

Concepts of pH, CEC, Exchange Acidity, and Base Saturation

pH is a measure of soil acidity or alkalinity. It is the concentration of hydrogen ion (H+) in soil solution expressed as the negative logarithm. A pH of 7 indicates neutrality. Although the pH scale is from 0 to 14, soil pH generally ranges from 4 to 9. Since pH is a logarithmic scale, each one unit change indicates a 10-fold change in the concentration of hydrogen ion.

Soil clay particles and humus, collectively called colloids, have negative charges. They adsorb positively charged ions (cations).Cation exchange capacity (CEC) is the sum total of exchangeable cations that are adsorbed on the soil colloids. CEC is expressed as milliequivalents of cations per 100 grams of soil. There are two types of cations on the soil colloids: acid forming cations (H^+, Al^{3+}, Fe^{3+}, Mn^{2+}) and base cations (Ca^{2+}, Mg^{2+}, K^+, and Na^+). The sum of exchangeable acid forming cations is called exchange acidity or reserve acidity. It is expressed as milliequivalents of hydrogen ion per 100 grams of soil. The sum of exchangeable bases and the exchange acidity is equal to CEC. The percentage of CEC that is accounted for by exchangeable bases is base saturation. There is a relationship between soil pH and percent base saturation (Table 1). Extremely coarse-textured sandy soils with low organic matter tend to have a higher percentage base saturation at a given pH.

Soil nutrient availability and pH

The availability of many nutrients is affected by soil pH. A survey of 250 apple orchards on Hilton soils in Western New York showed that as soil pH increases from 4.5 to 7.5, exchange acidity decreases (Figure 1A) whereas exchangeable base cations and base saturation increase (Figure 1B, C). The same soil survey showed that the availability of Ca and Mg decreases with decreasing soil pH (Figure 2A, B). This explains why apple trees often show Ca and Mg deficiencies on soils with a pH lower than 5.5. As soil pH decreases, phosphorus availability also tends to decrease (Figure 2D). Although soil potassium and nitrogen did not exhibit significant trends with changing pH (Fig. 1C, nitrogen data not shown), for a given soil, the availability of both potassium and nitrogen generally decreases with decreasing soil pH. Soils with low pH can not hold potassium and nitrogen very well, resulting in more leaching loss and poor response to potassium and nitrogen fertilizers.

In general, the availability of micronutrients is high in acid soils and low in alkaline soils. As shown in Figure 1E, F, G, aluminum, iron, manganese availability increase with decreasing soil pH. High aluminum and iron availability also reduce the availability of phosphorus by precipitating it out of the soil solution. Although zinc availability did not show a particular trend in this survey, for a given soil, the availability of zinc generally decreases at high soil pH. So does the availability of copper and boron. In addition to soil pH, soil parent material and organic matter content also affect the availability of micronutrients to a great extent.

Lime requirement for adjusting soil pH

In apple growing regions of New York and the Northeast, most soils are acid be-

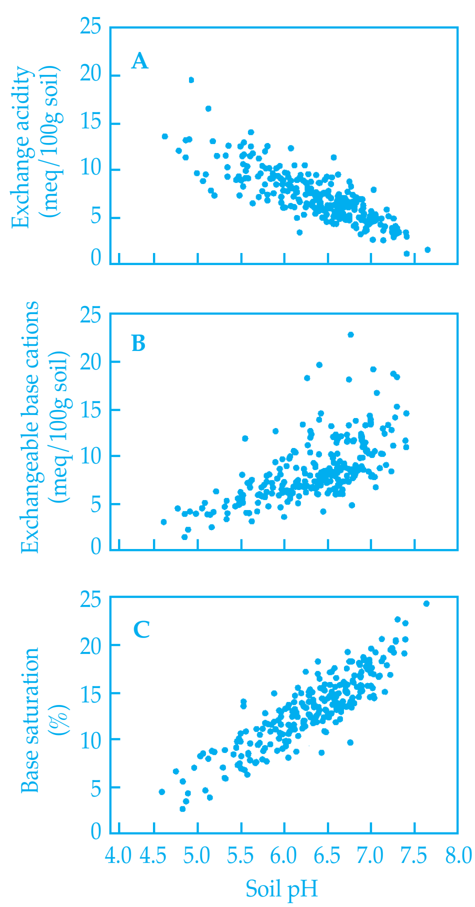

Figure 1. Exchange acidity (A), exchangeable base cations (B), and base saturation (C) in relaiton to soil pH in 250 Hilton soil samples from Western New York apple orchards.

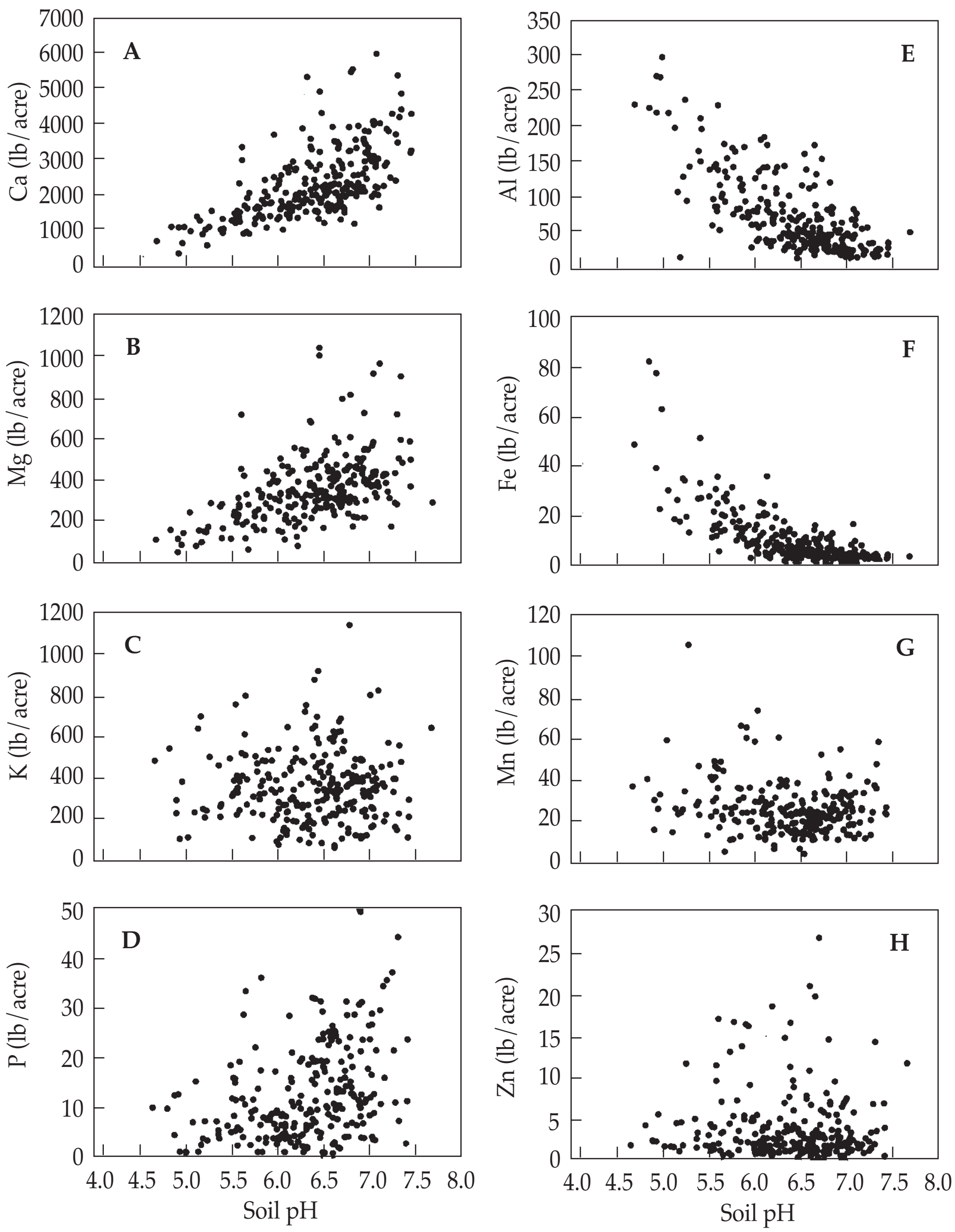

Figure 2. Availability of soil mineral nutrients in relaiton to soil pH in 250 Hilton soil samples from Western New York apple orchards.

TABLE 1

Relationship Between Soil ph And Percentage Base Saturation, 200 New York Soils (from Lathwell and Peech, 1964)

	Approximate % Base Saturation	
pH*	200 soils	"Sandy" soils**
8.2	100	—
8.1	98	—
8.0	96	—
7.9	94	—
7.8	92	—
7.7	90	—
7.6	88	—
7.5	86	100
7.4	85	99
7.3	83	99
7.2	82	98
7.1	81	97
7.0	80	96
6.9	78	95
6.8	76	94
6.7	74	93
6.6	73	92
6.5	71	90
6.4	70	88
6.3	68	86
6.2	66	84
6.1	64	82
6.0	62	80
5.9	60	74
5.8	57	68
5.7	54	62
5.6	52	56
5.5	48	50
5.4	42	45
5.3	32	40
5.2	23	33
5.1	17	27
5.0	14	22
4.9	10	19
4.8	7	16
4.7	6	12
4.6	4	9
4.5	2	6

*pH measured in water using 1 part soil to 1 part water. If pH is measured in 0.01 M $CaCl_2$ (1 part soil : 2 parts $CaCl_2$ solution) measured values will be 0.6 pH units lower, i.e. at pH 6.4 base saturation would approximate that at pH 7.0 measured in water.
**Extremely coarse-textured sandy soils with low organic matter content tend to have a higher percentage of base saturation at a given pH.

cause of the high rainfall which has leached base forming cations from the soil over the years. Liming benefits apple growth and development by (1) increasing the availability of calcium and magnesium; (2) reducing the availability of aluminum and manganese; (3) promoting microbial activity in the soil and improving soil structure; and (4) improving root growth and efficient uptake of nitrogen and potassium and other fertilizers.

pH values of orchard soils should be maintained in the range of 6.0 to 6.5 throughout the soil profile to optimize nutrient availability. For preplant soil preparation, we recommend the pH of topsoil (0-8 inch depth) be adjusted to 7.0 and that of subsoil to 6.5. The amount of lime required to adjust topsoil pH to 7.0 and subsoil pH to 6.5 is determined by the current pH values of the topsoil and subsoil (determined from a soil analysis) and the buffering capacity of the soil, i.e. exchange acidity or cation exchange capacity, (CEC), of topsoil and subsoil (also determined from a soil analysis).

There are several ways to estimate the lime requirement. They generally fall into two categories: estimating lime requirement with, or without consideration of Ca and Mg requirements.

1. *Estimating lime requirement without consideration of Ca and Mg requirements.* Based on the current pH and exchange acidity of topsoil and subsoil, one can read the corresponding amount of lime required to adjust pH of topsoil and subsoil to 7.0 and 6.5 directly from lime tables published in the *Cornell Recommends for Tree Fruits*. The total lime requirement is the sum of topsoil and subsoil requirements.
2. *Estimating lime requirement with consideration of Ca and Mg requirements.* This method is based on CEC, base saturation at target pH, and the desired ratio of Ca to Mg ratio (5 to 1) to ensure adequate Ca and Mg supply in the soil while adjusting soil pH.

(1) Calculate exchangeable base cations from soil test report: Based on 1meq Ca/100 g = 400 lbs/acre; 1 meq Mg/100 g = 243 lbs/acre; 1meq K/100

g = 782 lbs/acre and soil test result, exchangeable base cations are calculated. For example, a soil test shows that there are 2400 lb Ca/acre 6" depth, 200 lb Mg/acre 6" depth, and 360 lb K/acre 6" depth with a pH of 5.5, the exchangeable base cations are calculated as:

(2400/400 + 200/243 + 360/782)/0.9 =7.28 meq/100 g soil

Where 0.9 is the extraction efficiency of the chemical soil test for these exchangeable base cations.

(2) Estimate CEC: When exchange acidity is available in the soil test, CEC can be easily calculated as the sum of exchangeable base cations and exchange acidity. When exchange acidity is not known, CEC can be estimated from the sum of exchangeable base cations and the relationship between soil pH and base saturation (Table 1). In this case, the base saturation of a soil with a pH of 5.5 is 48%. Therefore, CEC is 7.28/0.48 = 15.17 meq/100 g soil.

(3) Determine Ca and Mg requirements: If the soil sample is taken from 0 to 8 inches, the target pH for preplant preparation is 7.0, which has a base saturation of 80 percent. The combined requirements for Ca and Mg are 15.17 X 0.8 = 12.14 meq/100 g soil. The desired ratio of Ca to Mg is 5 to 1. The requirement for Mg is 12.14/(5 + 1) = 2.02 meq/100 g soil. The requirement for Ca is 2.02 X 5 = 10.1 meq/100 g soil. Convert these requirements from meq to lbs/acre:

Ca: 10.1 X 400 = 4040 lbs per acre 6-inch depth

Mg: 2.02 X 243 = 490.9 lbs per acre 6-inch depth

If the soil sample is taken from 8 to 16 inches, calculate the Ca and Mg requirements similarly using a base saturation of 71 percent at a target pH of 6.5.

(4) Determine the amount of Ca and Mg needed to reach these targets. Subtract the values for calcium and magnesium reported in the soil test results from the calculated requirement to determine the amounts of calcium and magnesium needed to reach desired levels per 6-inch depth of soil:

Ca: 4040 – 2400 = 1640 lbs per acre 6-inch depth

Mg: 490.9 – 200 = 290.9 lbs per acre 6-inch depth

Increasing these values by one/third (multiply the above numbers by 1.33) shows the amounts needed per 8-inch depth of soil. Adding the amount of Ca needed for topsoil and subsoil together gives the total amount of Ca per acre 16 inches. The total amount of Mg needed can be calculated similarly. The actual pounds of lime product required is calculated as the total amount of Ca needed per acre 16 inch divided by the Ca content of the product. The Mg content of the lime required is the total amount of Mg needed divided by the actual pounds of lime product.

References

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