Primary Plant Nutrients: Nitrogen, Phosphorus, and Potassium

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Part 1 of this series (April 2010) emphasized that soil testing is complementary to plant tissue testing and not a substitute in orchard management. Considerations to ensure soil testing provides representative and useful information and interpretation of two common soil test parameters: 1) Saturation Percentage (SP); and 2) pH were also discussed. This article will focus on the nutrients nitrogen (N), phosphorus (P), and potassium (K).

Nitrogen

Nitrogen occurs in soils as organic and inorganic forms and soil testing may be performed to measure levels of either. Nitrate nitrogen (NO_3-N) is most commonly measured in standard soil tests because it is the primary form of nitrogen available to trees and, therefore, an indicator of nitrogen soil fertility. However, soil concentrations of NO_3-N depend upon the biological activity and may fluctuate with changes in soil temperature, soil moisture, and other conditions. Nitrate is also easily leached with rainfall or irrigation so current soil tests may not reflect future levels of nitrogen soil fertility. Table 1 provides guidelines for evaluating NO_3-N soil fertility levels.

Table 1. Guidelines for interpreting nitrate nitrogen (NO_3-N) levels in soil test results.

Fertility Level	ppm	lbs/acre[1]
Low	<10	<36
Medium	10-20	36-72
High	20-30	72-108
Excessive	>30	>108

[1] Some laboratories report NO_3-N as lbs/ac rather than as a concentration (ppm). A soil bulk density is assumed in this calculation so the NO_3-N fertility levels should be considered an estimate rather than an absolute level.

Ammonium nitrogen (NH_4-N) is also a plant available form of nitrogen in orchard soils and it can be determined with soil testing upon request. In general, NH_4-N is not determined and reported with a standard soil test. Ammonium nitrogen does not usually accumulate in soil because soil temperature and moisture conditions that are suitable for tree growth are also ideal for conversion of NH_4-N to NO_3-N. Ammonium nitrogen concentrations of 2-10 ppm are common. Levels above 10 ppm NH_4-N may occur in cold, wet soils or in soils irrigated with a water supply that is high in ammonium nitrogen.

Total nitrogen which is a measure of all organic and inorganic forms of nitrogen in soil can be determined with soil testing. However, it is not included in standard soil testing.

Phosphorus

Soil tests are performed to determine the concentrations of plant available phosphorus in soil. The Bray P1 Test is used for neutral and acid soils (pH 7.0 and lower) and the Olsen sodium bicarbonate test is used primarily for alkaline soils (pH>7.0) but can be used on soils with pH >6.5. These phosphorus soil tests measure ortho-phosphate (PO_4-P) and provide an index of the phosphorus availability. Table 2 provides guidelines for evaluating phosphorus soil fertility.

Table 2. Guidelines for interpreting phosphorus (PO_4) levels in soil test results.

Fertility Level	Bray P1 method PO_4 Concentration (ppm)	Olsen method PO_4 Concentration (ppm)
Low	<20	<10
Medium	20-40	10-20
High	40-100	20-40
Excessive	>100	>40

Depending on soil pH, the availability of phosphorus to trees is influenced by two processes in the soil: 1) specific adsorption to iron and aluminum minerals; and 2) the precipitation or dissolution of calcium phosphate compounds. Both the Bray and Olsen methods of analyzing phosphorus fertility recognize these processes by providing an index of the phosphorus availability. However, neither method simulates the exact soil reactions that occur so the soil test values cannot be used to calculate available phosphorus in absolute terms as lbs P_2O_5 /acre. If soil test levels are reported in units expressed as lbs/acre rather than concentration, they should also be viewed as estimates or relative indicators. Lastly, phosphorus deficiency has not been common in California orchards, so if soil tests suggest low phosphorus fertility the possibility of a deficiency should be confirmed with plant tissue testing.

Potassium

Potassium undergoes exchange reactions with other cations in the soil such as calcium, magnesium, sodium, and hydrogen and this affects the plant available potassium. Therefore, an ammonium acetate extraction method is the most common method to model these soil reactions and analyze for potassium fertility. Less commonly, a sodium bicarbonate extraction method may be used to analyze potassium fertility. When the sodium bicarbonate method is used the soil test results might indicate slightly lower values. Table 3 provides guidelines to interpret potassium soil test results.

Table 3. Guidelines for interpreting potassium (K) soil test results using the ammonium acetate method.

Fertility Level	Extractable K (ppm)
Very Low	< 75
Low	75 -150
Medium	150 - 250
High	250 -800
Very High	> 800

Orchards growing on soils with extractable potassium concentrations less than 150 ppm in the root zone are most likely to respond to potassium fertilization. Soils with extractable potassium levels between 150 and 250 ppm are not as likely to respond as lower levels but they could be signaling a decline in fertility and a trend toward future deficiencies. Combining soil and plant tissue testing is preferred to monitor trends in potassium nutrition and guide management.