

PECAN LEAF NUTRITION STATUS

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ABSTRACT

The use of a leaf tissue sampling program is particularly appropriate for pecans, a long-lived perennial tree crop. Such programs are widely used in pecan production in the desert southwest. However, most of the research upon which leaf nutrient standards are based has been conducted in the southeastern U.S. We have conducted field studies to develop standards specifically for southwestern production. We have been conducting a two-year survey of commercially grown pecans in Arizona, collecting leaf nutrient levels and nut yield and quality data. Preliminary leaf nutrient standards based on the first year of that study are presented. We also conducted a two-year study of several varieties of pecans in Arizona and New Mexico for the purpose of determining rates of change of nutrient concentrations during the growing season. These data have been used to develop equations for normalizing early season leaf analyses to the standard late summer sampling period.

OBJECTIVES

Leaf tissue composition is a reflection of the amount of nutrients actually taken up and assimilated by the plant so it provides the most direct means for evaluating plant nutrient status. For this reason leaf tissue analysis has been widely used for nutrient evaluation of a large range of crop species. Leaf analyses are particularly useful for monitoring long-term fertility management in perennial crops such as pecans.

The procedures for collecting, handling, and analyzing pecan leaves are well established and relatively simple. A sample usually consists of 100 middle leaflets of fully mature leaves from new growth collected in late July to early August. To interpret pecan leaf tissue analyses, nutrient levels are compared against standard nutrient values. It is critical that appropriate standards be used for analyses to be valid. Standard pecan values currently in use in Arizona and New Mexico, and in Texas, are shown in Table 1 (Herrera, 1998; Storey, 1997).

Typically, standards are developed through a process that includes using research-based data, calling on practical experience, and “borrowing” values developed in other regions. Using standards developed in other states, however, can be problematic because both soils and climate may affect the relationship between nutrient uptake and crop performance. Therefore, it is desirable to develop standards for the environment where they are to be applied.

Establishment of nutrient standards requires a data base that links crop yield parameters (yield and quality parameters that affect crop value) with leaf nutrient levels. The standard method of collecting this type of data is to set up fertility experiments where the level of at least one nutrient is varied. Crop performance is related to leaf nutrient concentrations to develop a

relationship between these two variables. Unfortunately, this approach is prohibitively expensive and time consuming in a perennial orchard crop such as pecans. An alternative approach was developed by Kenworthy (1973) for use in perennial orchard species using leaf and harvest data collected from commercial orchards. The range of climates, soil types, and management practices (i.e. fertilization, pruning, pest control, irrigation, varieties) assures that a range of leaf nutrient levels and yields will be encountered. Nutrient levels from the better yielding trees are averaged to give optimum nutrient levels, and the standard deviations associated with the means provide a measure of acceptable variation from each mean.

A shortcoming of standard pecan leaf sampling and analysis procedures is that they pertain only to a specific stage of growth. It is well known that nutrient concentrations in leaf tissues change with leaf age. Concentrations of water-soluble nutrients, such as nitrogen, phosphorus, potassium, and magnesium tend to decrease as leaves age. Concentrations of other nutrients, such as calcium, iron, copper, and zinc tend to increase with time. Comparison of nutrient analysis results with incorrect standards can lead to significant errors in interpretation and subsequent fertilization. The standards shown in Table 1 (Herrera, 1998; Storey, 1997) can be applied only to samples collected in the late July to early August time frame. Growers who want to initiate leaf sampling programs earlier in the season can not use these standards for accurate interpretation. Standards must be developed for other stages of growth, or else quantitative descriptions of the rates of change of nutrient concentrations can be used to normalize nutrient concentration data to a standard sampling date.

METHODS

We are completing a commercial pecan orchard survey at 27 locations in Arizona, covering the 2003 and 2004 growing seasons. One hundred thirty-five (135) individual trees of Western Schley pecans were monitored. Data collected for these trees includes: soil properties, leaf nutrient levels, nut yield and quality, and cultural practices.

Pecans are an alternate-bearing species, with yields from “on” years greatly exceeding those from “off” years. 2003 was the “on” year for the trees selected for this study so the preliminary leaf standards presented here are based on “on” year data only. These will be updated when 2004 data are completed by combining 2003 and 2004 yields for each tree. This way, each data point will represent a complete two-year yield cycle.

To evaluate the rates of change of nutrient concentrations, five trees each of Bradley, Cheyenne, Sioux, Western Schley, and Wichita pecans at Picacho, Arizona (on Denure sandy loam: coarse-loamy, mixed, hyperthermic Typic Camorthids and Mohall sandy loam: fine-loamy, mixed, hyperthermic Typic Haplargids) and five trees each of Bradley, Western Schley, and Wichita pecans at Las Cruces, New Mexico (Harkey loam: coarse-silty, mixed [calcareous], thermic Typic Torrifluvents) were monitored in 2000 and 2001. Leaf tissue samples were collected at two-week intervals, beginning in early May, and continuing until the end of the growing season, in mid-October. Nut yield and quality were also monitored.

RESULTS AND DISCUSSION

Leaf Nutrient Standards

Average nutrient concentrations plus or minus the standard deviation were used to define a “normal” nutrient range. These values were calculated for trees that yielded at least 2,000 lbs/a in 2003. This yield cutoff represents what is generally considered to be a “good” yield; however the selection of the cutoff is arbitrary. Previous studies (Letzsch and Sumner, 1984) have

demonstrated that yield cutoff selection is relatively unimportant for nutrient standard development. Resulting ranges are shown, along with currently used ranges (Herrera, 1998; Storey, 1997) in Table 1. Values in the right-hand column of Table 1 represent data collected in 2003 only; these values will change when additional data are added and should be considered preliminary.

A comparison with current values indicates good agreement in general, although there are some important differences. For example, current nitrogen standards may be too high. An appropriate range for our area may be 2.3 to 2.7% rather than 2.5 to 3.0 or 4.0%. This does not necessarily mean that leaf nitrogen levels greater than 2.7 represent a problem. In fact, the highest level of leaf tissue nitrogen encountered in our survey was 2.9%, so we have no data indicating that higher levels are deleterious. On the other hand, our data do not suggest that increasing nitrogen to higher levels will increase yield. Our data simply indicate the range of leaf nitrogen levels found in trees with yields greater than 2,000 lb/a, and that maintaining nitrogen in this range should ensure that nitrogen nutrition is adequate to maintain yields above 2,000 lb/a..

Survey results generally support current phosphorous levels of Herrera (1998), although they are lower than those of Storey (1997), or those used in the southeastern U.S.

Our lower limit for calcium (1.9%) is considerably higher than that of either Herrera (1998) or Storey (1997), 0.9 and 0.7, respectively. The minimum calcium level we observed among all our samples was 1.2%, so we have no data from trees in the lower part of the published ranges. These low levels may not be deleterious. Instead, the higher values we found are probably reflective of the levels of these nutrients found in Arizona soils, whereas the published standards may reflect soil conditions in pecan producing areas in lower pH soils.

Table 1. Currently recommended pecan leaf tissue nutrient levels and values from the 2003 Arizona survey.

Nutrient	Herrera, 1998	Storey, 1997	2003 Survey
Nitrogen	2.5 – 3.0	2.5 – 4.0	2.3 – 2.7
Phosphorus	0.12 – 0.19	0.15 – 0.30	0.12 – 0.15
Potassium	0.90 – 1.20	0.75 – 1.25	1.01 – 1.51
Calcium	0.9 – 1.8	0.7 – 3.0	1.9 – 2.7
Magnesium	0.30 – 0.60	0.30 – 0.60	0.43 – 0.63
Sulfur	0.10 – 0.15	0.20 – 0.25	0.13 – 0.20
Boron	50 - 200	20 - 45	61 - 141
Copper	8 - 30	10 - 30	4 - 16
Iron	50 - 250	50 - 300	40 - 68
Manganese	100 - 600	40 - 300	237 - 638
Nickel	N.A. ¹	N.A. ¹	10 - 16
Zinc	50 - 100	80 - 500	115 - 354

¹N.A. - Standards not available.

The adequate sulfur range of Storey (1997), 0.20 to 0.25%, is higher than that of Herrera (1998), 0.10 to 0.15%. Our survey data range of 0.13 to 0.20% generally supports the lower

range of Herrera (1998). Conversely, Storey (1997) recommends a relatively low level of boron (20 to 45 ppm) compared to Herrera (1998) who gives a boron range of 50 to 200. Our range of 61 to 141 is close to that of Herrera (1998).

Our copper range is substantially lower than the current standards. Our lower limit is 4 ppm versus the current 8 or 10 ppm. However, our lower figure is in line with standards published elsewhere. Jones (1991) suggest a minimum adequate level of 6 ppm, and Robinson et al. (1997) a minimum of 5 ppm.

Leaf tissue manganese levels in our study were somewhat higher than the current range (237 to 638 versus 100 to 600 or 40 to 300). We have noted that manganese levels in pecans grown in Arizona have considerably higher manganese levels than those in Las Cruces. Manganese levels in the Las Cruces area, in turn, tend to be higher than those in Texas or in eastern New Mexico (Dr. Michael Kilby and Mr. Philip Messick, personal communications). The reason for this is not well understood. However, the values from our survey represent manganese levels for pecans grown in Arizona, and may not be appropriate for pecans from other areas. In Arizona, we have seen leaf manganese levels substantially higher than the top of this range (well over 1,000 ppm) without apparent negative effects. Personal observations suggest that manganese levels can reach approximately 2,500 ppm before the crop is adversely affected.

We have determined a preliminary leaf nickel standard. There are no existing standards with which to compare our range (10 to 16 ppm), and we have no definitive data suggesting that nickel deficiency occurs in the southwestern U.S. However, nickel deficiency has been identified in the southeastern U.S. in commercial pecan orchards (Wood et al, 2004). They observed nickel deficiency in trees with less than 0.5 ppm nickel in sampled leaf tissue, but not in trees with 4 to 7 ppm. The lowest value we observed in Arizona pecans was 5.2 ppm.

Zinc was applied to all but a few of the pecan trees we monitored as a series of foliar sprays. Leaves were washed prior to analysis to remove any zinc spray residues. Leaf zinc levels ranged from 16 to 490 ppm among all samples we collected; the lowest values were from trees that were not sprayed with zinc. Our data resulted in a range of 115 to 354 ppm, which is considerably higher than Herrera's (1998) range of 50 to 100 ppm, but more in line with that of Storey (1997) which is 80 to 500 ppm. The lower range is in agreement with numbers based on zinc application studies and is more typical of published values (Jones et al., 1991; Robinson et al. 1997).

Nutrient Concentration Changes

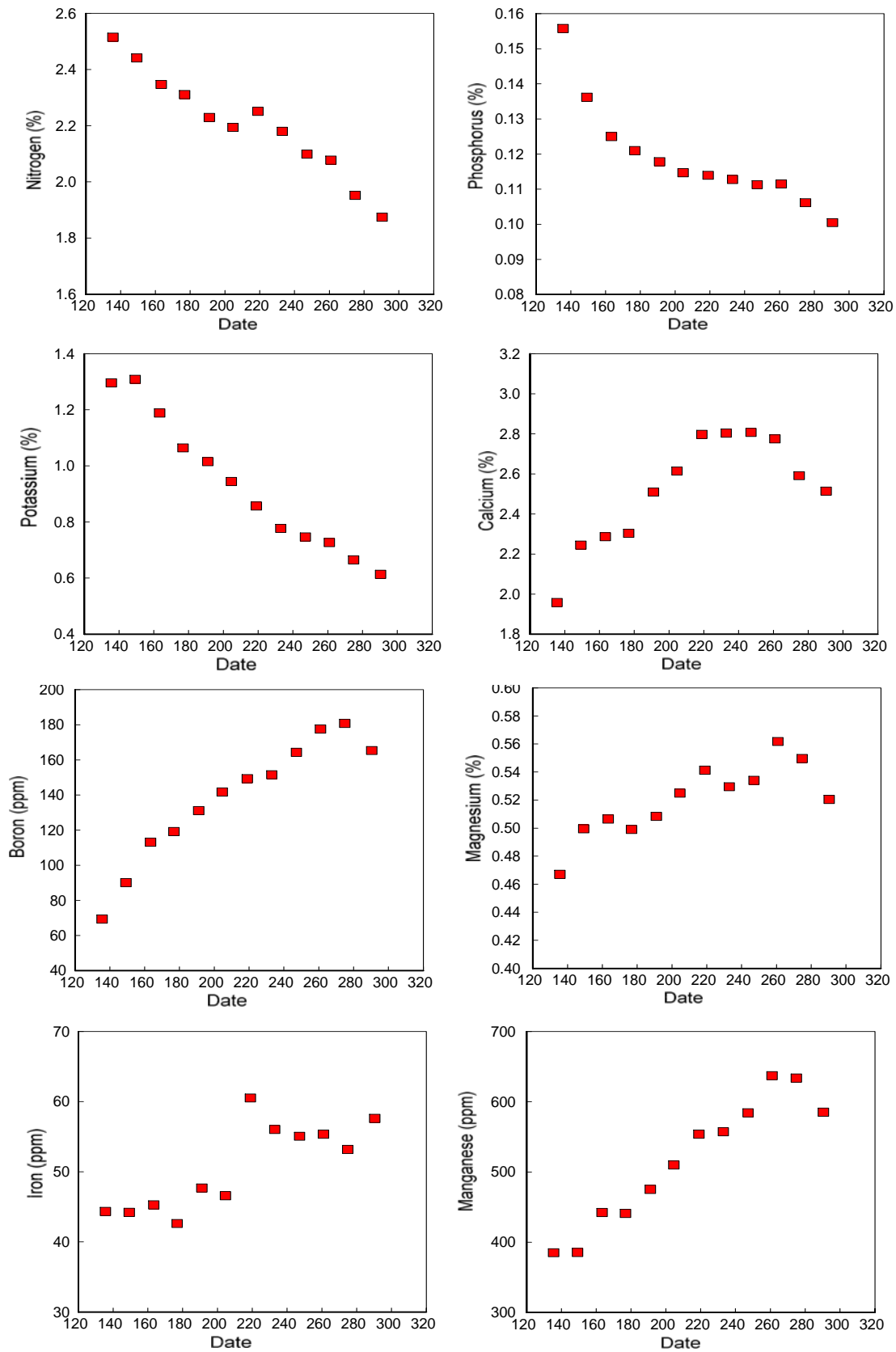
We have also studied how pecan leaf nutrient levels change during the growing season. Consistent with observations in other crops, pecan leaf nitrogen, phosphorus, and potassium levels decreased as the growing season progressed. Calcium, magnesium, boron, iron, and manganese levels increased; and copper and zinc levels remained largely unchanged. Graphs of nutrients with relatively consistent patterns of concentration change with time (nitrogen, potassium, phosphorus, calcium, magnesium, boron, iron, and manganese) are shown in Figure 1.

From Figure 1 it can be easily seen that nitrogen, phosphorus, and potassium in pecan leaves decrease rapidly during the growing season and that the time of sample collection is critical for accurate nutrient diagnosis. For example, a leaf sample collected at the end of May (date = 150) and containing 2.6% nitrogen would be considered in the sufficient or acceptable range based on the values in Table 1. If the nitrogen concentration declined at the rate indicated in Figure 1, a

sample collected at the beginning of August (date = 215) from the same tree would only contain about 2.2% nitrogen, and would indicate that the tree is deficient in nitrogen.

The converse would be true of nutrients with increasing concentrations, such as calcium, magnesium, boron, iron, or manganese, where early season samples would tend to be diagnosed as deficient, even if leaf concentrations are adequate. Of course, nutrient levels can be adjusted during the growing season, and the trends shown in Figure 1 will change depending on fertilizer application practices. Foliar nutrient applications, particularly, can rapidly change leaf nutrient levels.

Figure 1. Pecan leaf tissue nutrient concentration changes during the growing season. Dates are presented as Julian Date (day of the year).



It may be possible to correct or adjust results from leaf samples collected outside the standard sampling window back to the standard sampling time for nutrients that behave in a predictable, consistent manner. To do this, regression equations were developed for nutrients with consistent patterns of change with time. These are shown in Table 2.

Table 2. Regression equations for nutrient concentrations versus time and r^2 values.

Nutrient		Regression Equation	r^2	Line Slope
Nitrogen		$N = 2.97 - (0.0036 \times \text{Date})$	0.94	-0.0036
Phosphorus	%	$P = 0.174 - (0.00026 \times \text{Date})$	0.78	-0.00026
Potassium		$K = 1.93 - (0.0047 \times \text{Date})$	0.97	-0.0047
Calcium¹		$Ca = 0.88 + (0.0085 \times \text{Date})$	0.96	0.0085
Magnesium²		$Mg = 0.40 + 0.00059 \times \text{Date}$	0.86	0.00059
Sulfur		$S = 0.19 - (0.000082 \times \text{Date})$	0.40	-0.000082
Boron³		$B = -17.3 + (0.74 \times \text{Date})$	0.96	0.74
Copper		$Cu = 7.16 + (0.0027 \times \text{Date})$	0.06	0.0027
Iron	ppm	$Fe = 29.6 + (0.099 \times \text{Date})$	0.66	0.099
Manganese³		$Mn = 110 + (1.95 \times \text{Date})$	0.98	1.95
Zinc		$Zn = 143 - (0.11 \times \text{Date})$	0.11	-0.11

¹Only dates 136 to 233 were used in this regression.

²Only dates 136 to 261 were used in this regression.

³Date 290 was omitted from these regressions.

Regressions for calcium, magnesium, boron, and manganese were conducted on partial data, as noted in Table 2. In each case some late-season data was omitted from the regressions. Regressions for nitrogen, phosphorus, potassium, calcium, magnesium, boron, copper, iron, and manganese all had r^2 values greater than 0.65. Therefore, we believe that the equations from Table 2 for these nutrients can reasonably be used to correct early-season analyses to the standard sampling time.

The following formula is used:

$$\text{actual analysis} + [\text{line slope} \times (213 - \text{sampling date})] = \text{corrected analysis}$$

This formula adjusts values to date 213 (August 1). Any other date can be substituted into the formula if desired.

For example, if a leaf sample collected On May 30 (date = 150) had a phosphorus concentration of 0.15%, the phosphorus concentration on August 1 would be estimated as follows:

$$0.15 + [-0.00026 \times (213-150)] = 0.15 - 0.016 = 0.134\%$$

Thus we would expect that leaves from this same tree, sampled on August 1, will contain approximately 0.134%. The corrected value, 0.134%, can then be compared to the standard ranges in Table 1. Based on the sufficient range of Herrera (1998) or that from our survey, the

sampled tree contains a sufficient level of phosphorus. This interpretation is not as accurate as one based on a sample collected at the standard sampling time, but it should provide a good estimate for interpreting early season leaf sample analyses.

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