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Leaf Tissue Analysis Review

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Background

Plant analysis as a method to diagnose plant health, dates back to the early 1900's (Reuter & Robinson 1997). Plant analysis has been developed to provide information on the nutrient status of plants as a guide to nutrient management for optimal plant production whilst also minimising the risk of environmental and economic cost of over-fertilisation (Reuter & Robinson 1997).

There have been two approaches to using plant analysis. One is as a diagnostic tool where critical values are defined which allow the user to show whether the plant is deficient in a particular micro- or macro- nutrient, or affected by a toxic concentration of something like chloride or boron. The second method is as a monitoring tool where the nutrient concentrations in the leaves are compared with standard ranges and growers can assess the nutrient status of their crop and make informed decisions on how appropriate their fertiliser program might be. Critical values have most commonly been derived from experimentally determined relationships between plant yield and associated nutrient concentration. The relationship tends to form a curve of the kind shown in Figure 1 with increasing yields occurring with increasing nutrient levels (i.e. deficient to marginal levels), with a short or long plateau where yields don't change with increasing nutrient levels (i.e. adequate levels) and finally yields decreasing with increasing nutrient levels (i.e. toxicity). The commonly used standard nutrient ranges are more usually determined from a mixture of experiments and field surveys which allow the agronomist to sketch in parts of the curve. (It is usually easy to see when a crop is severely deficient or showing toxicity. The uncertain areas are often described as "low" or "high", or "marginal" as shown in the diagram.

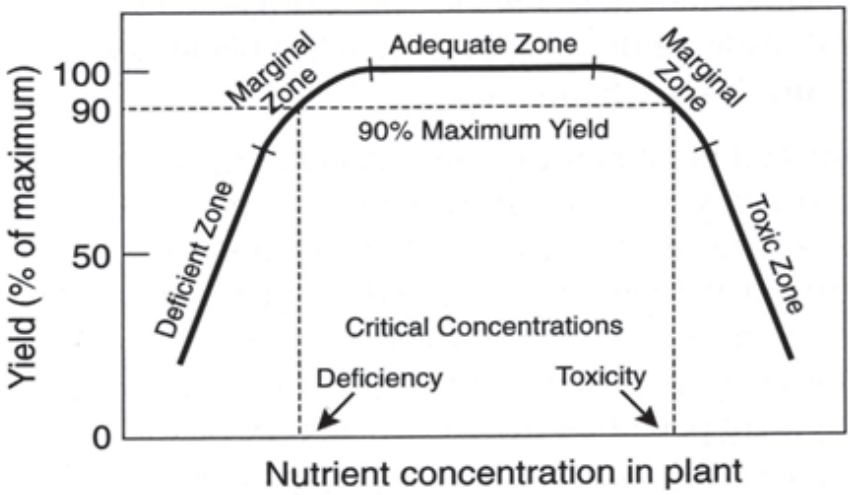

Figure 1: Derivation of critical concentrations for diagnosing nutrient deficiency and toxicity in plants (Reuter & Robinson 1997).

To be useful, leaf analysis is dependent on proper sampling both in terms of leaf choice and timing. If a diagnostic sample is taken it often represents only a few trees. If a monitoring sample is taken it often represents a complete block. Either way, the sampling program should be repeatable so results can be objectively compared from one year to the next. For monitoring, samples should be collected from all four quadrants of the tree and in a pattern that best reflects the variability of the orchard. Leaf sampling should also occur at the correct time during the growing cycle to allow valid comparison with the standards. In the CT Trial, leaf samples were taken during October, November, and December as well as the traditional January timing.

Leaf analysis values over a few seasons can show a trend of plant nutrient levels from one sampling event to another. Results can't be used to determine actual rates of nutrient to apply in a fertigation program because of the uncertainties that exist within any one orchard. Soil type can influence nutrient availability. Some nutrients are easily leached away from the roots below the root zone etc.

Calculations of crop nutrient removal can help growers understand the sorts of fertiliser rates that might be required. Leaf analysis can help show if these calculations have been appropriate and help fine tune them.

A leaf analysis will give a rough average of the plant nutrient status in the orchard. This means that when levels for a particular nutrient are at a marginal to adequate level, then it's possible for 50% of the orchard to be below adequate or even deficient.

In a nutrition survey by Brown, 2009 it was found that Californian almond growers were aiming for higher values than those set by the University of California (UC). Infield testing showed when growers achieved a higher level of leaf nutrition, for

example 2% K compared to the traditional UC recommendation of 1.4% K, yields were maintained at a highly productive level. If the average nutrition level of K was allowed to fall to 1.4%, then 50% of the orchard could be deficient and therefore yields could drop accordingly.

Brown, 2009 has also noted there could be a difference in sampling fruiting spurs compared to the traditional method of non fruiting spurs. If fruiting spurs were sampled, the likely result would be lower nutrient concentrations as fruiting spurs have a greater nutritional demand. In the CT Trial we sampled fruiting spurs.

Average Australian almond industry yields have increased by approximately 30% in the last 8-9 years from 2.5T/Ha to 3.2T/Ha. This increase is largely attributed to increased and more efficient use of inputs (mainly water and fertiliser) as a response to the data collected in the CT Trial. The increase in average yields would suggest the traditional leaf analysis standard ranges which were last reviewed in California and Australia in 1976 and 1981 respectively, may not be appropriate for the sorts of yields now being obtained.

Grower Survey

In early 2010 a survey of past leaf analysis results from a range of growers was undertaken across the Australian almond industry. It aimed to statistically analyse the data and propose new working leaf analysis standards. We hoped the review would provide some insight into the range of levels of leaf nutrient concentrations now being achieved and how they related to the current Australian leaf analysis standards. The growers' results were also compared to the CT Trial leaf analysis records.

The survey collected data from orchards with the following characteristics:

- Mature almond trees, generally greater than 5 year old.
- Predominantly Nemaguard rootstock.
- Nonpareil only.
- Traditional spacings of approximately 280-300 trees/ha.
- Mid to late January leaf samples from non-fruiting spurs.
- Irrigation and yield records from which leaves were sampled.

This Fact Sheet proposes new standards for nutrient concentrations in leaves sampled in October, November, December and the traditional January timing.

Figure 2: Photo from 2006 (Top) Improved almond leaf size - CT Trial; (Bottom) Smaller almond leaf size - Conventional nutrition program

Current Standards

The current range of values for leaf analysis is shown in Table 1. Leaf analysis data were collected from 12 participating properties for 2002 to 2009. The average and range of values for each nutrient are compared with data from the CT Trial and the traditional leaf standards of Robinson and Glenn, 1981. A full summary of results are available in the Leaf Analysis Review Background Paper which is available for download from the Almond Board website.

Proposed New Standards from the CT Trial & Grower Survey

Working standards for October, November and December sampling

The combined average leaf analysis results for Treatment 1 and Treatment 2 (the higher yielding plots in the CT Trial) are shown in Table 2. These data are from leaves collected from fruiting spurs on one year old wood. These data may be helpful for growers who would like to monitor nutrient levels through the growing season.

Working standards for January sampling

In Table 3 we proposed some new working standards for leaf analysis in Australian almond orchards. These are presented along with those currently used and results from the CT Trial to allow growers to compare them. The higher nutrient levels obtained from the CT Trial are likely to be a result of a more intensive foliar nutrient program and more generous fertigation programs than are likely to be economic in commercial orchards. These nutrients include Nitrogen, Potassium, Zinc and Boron. The standards have been modified to reflect the current standards of industry practice and the results of the CT Trial. While some of the changes only seem small, it must be remembered that the proposed new standards refer to leaves that are sampled from fruiting spurs.

Standards for the macro nutrients are proposed to be slightly higher than the current standards. Standards for the micro nutrients are similar to previous standards or have been increased only a little. For those nutrients that had no previous standards, new ones have been proposed based on the CT Trial data.

Possible change in leaf sampling method

The method of leaf sampling may need to be altered to give a better indication of nutrient demand when yields vary. The current method of sampling leaves from a non-fruiting spur from last year's growth may not give an accurate indication of the current crop's nutrient demand. We propose that sampling fruiting spurs on last year's growth may give a better indication of the status of the trees. If a large crop is present then it seems logical that a nutrient deficiency would be visible first in fruiting spurs, rather than non-fruiting spurs. The CT Trial used leaves from fruiting spurs on one year old wood.

This logic is supported by preliminary research work from UC Davis (Brown, 2011) which suggests the leaves on fruiting spurs may show nutrient deficiencies while non fruiting spur leaves on the same tree may have adequate nutrition levels. The implication from this observation is that while leaf analysis of non-fruiting spur leaves may show adequate nutrition levels, the tree may have a nutritional deficiency depending on the crop load. Further work here and collaboration with UC Davis is needed to verify this.

Growers may like to compare values from the same blocks by sampling both ways for two or three years to gain some familiarity with the proposed revised working standards and changed sampling method in their orchards. This will be necessary to gain an appreciation of how much the standards may vary before making major changes to nutrition programs.

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Table 1: Almond leaf standards for January sampling – South Australian survey work by Robinson and Glenn (1981) based on the Californian method (e.g. Beutel et al 1976).

NUTRIENT	Deficient (D)	Marginal (M)	Adequate (A)	Toxic / Excessive (T)
N (%)	< 1.8	1.8-1.9	2.0-2.5	
P (%)	< 0.1		>0.1	
K (%)	< 1.0	1.0-1.3	1.4-1.7	
S (%)				
Ca (%)			>2.0	
Mg (%)			>0.25	
Na (%)			<0.25	>0.25
Cl (%)			<0.3	>0.3
Cu (mg/kg)			>4	
Zn (mg/kg)	<15	15-24	25-30	
Mn (mg/kg)			>20	
Fe (mg/kg)				
B (mg/kg)	<12	12-24	25-65	>85

Table 2: CT Trial (Average of Treatment 1 & Treatment 2) leaf analysis results for October, November, December & January

Nutrient		October	November	December	January
N	%	4.07	3.51	3.05	2.99
P	%	0.20	0.16	0.14	0.14
K	%	3.13	2.76	3.32	2.76
Ca	%	1.49	1.82	2.44	2.42
Mg	%	0.40	0.40	0.47	0.46
Na	%	0.07	0.07	0.08	0.07
Cl	%	0.35	0.35	0.51	0.41
Zn	mg/kg	266.09	361.88	410.48	335.20
Mn	mg/kg	158.05	158.98	149.25	162.83
Fe	mg/kg	85.54	87.45	105.28	88.76
Cu	mg/kg	8.12	5.91	5.42	5.65
B	mg/kg	50.82	39.91	41.40	40.25
S	%	0.23	0.20	0.19	0.17

Table 3: Current and proposed leaf analysis standards for January sampling

Nutrient		Current Australian	Current Californian	CT Trial Averages (T1,T2)	Grower Survey Averages	Proposed New Australian
N	%	2.0 - 2.5	2.2 - 2.5	2.99	2.71	2.5 - 2.7
P	%	> 0.1	0.1 - 0.3	0.14	0.14	> 0.1
K	%	1.4 - 1.7	> 1.4	2.76	2.47	2.2 - 2.5
Ca	%	> 2.0	> 2.0	2.42	3.23	> 2.0
Mg	%	> 0.25	> 0.25	0.46	0.68	> 0.40
Na	%	< 0.25	< 0.25	0.07	0.04	< 0.25
Cl	%	< 0.3	< 0.3	0.41	0.31	< 0.40
Zn	mg/kg	25 - 30	> 15	335.20	144.23	> 30
Mn	mg/kg	> 20	> 20	162.83	347.16	> 20
Fe	mg/kg	-	-	88.76	183.88	> 50
Cu	mg/kg	> 4	> 4	5.65	18.72	> 4
B	mg/kg	25 - 65	30 - 65	40.25	36.54	30 - 65
S	%	-	-	0.17	0.21	> 0.15

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