EVALUATION OF PEAR TISSUE SAMPLING PROTOCOLS FOR IMPROVING NUTRIENT MANAGEMENT

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ABSTRACT

The standard method of nutrient sampling in California is to collect non-fruiting spur leaves in mid-summer. But shoot leaves are used in all pear-producing areas of the world, and spring analyses can be used to make in-season adjustments for the current anticipated crop load. Three Bartlett pear blocks were used in this study, each with distinct characteristics. Leaves and fruit were sampled and analyzed for nutrient content in late April and July. Significant differences were found among the blocks in leaf and fruit nutrient content, but there was little correlation between April and July sampling timings. N and P were significantly higher in shoot leaves, and K and Ca were higher in spur leaves. In a newly developed model, spring leaf sampling combined with yield estimations have been shown to accurately predict July leaf N levels in almonds and pistachios to allow for in-season fertilizer adjustments. We applied early-season pear leaf analyses to that model and contrasted the predicted July leaf values with actual measured values. The use of the prediction model resulted in a good fit.

INTRODUCTION

Current California recommendations for tissue nutrient sampling are to collect mid-summer non-bearing spur leaves, which mature soon after bloom and leaf-out. These leaves are about 3 months old at sampling and are not acting as a strong “sink” for nutrients, as are leaves on extension shoots or leaves on bearing spurs (bourse). It is likely that leaves collected from vegetative extension shoots, as is common outside of California, or from fruit-bearing spurs, where demand is likely to be highest for fruit growth and bourse shoot growth, may prove to be a better indicator of nutrient status for cropping and overall tree nutrient status. Fruit quality is dependent on N, Ca, K, Mg and P, particularly the 'balance' of N, K, P, and Mg to Ca, and optimum levels of these nutrients should reflect the current strategy of maximum yield and fruit size. High nitrogen is considered detrimental to fruit quality, particularly its balance with Ca, and K. Not all nutrient status in leaves is indicative of nutrient status of fruits, especially Ca, which moves only in the xylem and not readily to fruits.

Shoot leaves have been used in all pear-producing areas of the world, and while current UC recommendations apply to nutrient levels in non-bearing spur leaves, virtually all of the underlying research conducted in California prior to 1983 depended on nutrient values from shoot leaves. Research findings from outside of California amount to a considerable volume of information and it would prove valuable to be able to utilize this information more fully if nutrient standards for California could be compared with those developed elsewhere.

Below is a discussion of why researchers have concentrated on shoot leaves.

- Most deficiency symptoms for nutrients are seen in shoot leaves, both for nonbearing and bearing trees. For example, K deficiency shows first in shoot basal leaves and is most pronounced in mid-shoot leaves, and N deficiency shows first in older shoot leaves when N is mobilized to younger, actively-growing leaves. As shoots grow, shoot leaves are the most likely to be diagnostic of toxicity and deficiency symptoms.
- Terminal, extension shoots grow throughout the season, thus providing a source of older (basal) leaves and newer, mid-shoot leaves for comparison.
- Shoot leaves may be sampled from young and mature trees for comparison.
- Non-bearing spur leaves complete growth shortly after bloom and no additional leaves arise on these spurs in the current year. By using these leaves only, it may be more difficult to determine 'real-time' status of nutrient mobilization due to seasonal fertilizer applications, growing fruit, or fruit removal.
- Although fruiting spur leaves also represent a relatively static 'older' population of leaves, these leaves are still part of a more dynamic tissue 'unit' including growing fruits and bourse shoots. Dynamic tissue units may be more representative of changing nutrient status than the relatively non-dynamic, nonfruiting spur.
- Comparisons to nutrient levels or recommendations developed for pear outside of California are difficult, since non-bearing spur leaf sampling doesn't appear to be used for nutrient profiling elsewhere. For example, pear leaves sampled in Washington are mid-shoot (Whitney, 1996), as are those in Oregon (OSU ref.) Labeled N studies of N cycling (Sanchez et al., 1990-92) included shoot and bearing spur leaves. These are the most definitive studies of pear N use to-date.

The reason for the departure from the use of shoot leaves in California's historic pear research is not clear. It may have been the choice of those writing the recommendations for California fruit trees in 1983 (Beutel et al., 1983) as a whole to apply a single standard to as many species as seemed appropriate, since this publication was comprehensive for temperate tree fruit species grown in California at the time. In the 1983 recommended practices for leaf analysis spur leaves were to be used for pear and all stone fruit species but peach. Other than stating that 'Leaves from non-fruiting spurs are easiest to collect and give the most consistent results', these authors did not cite past research or other justifications for this choice, nor did they provide a review of California pear nutrient research.

Tissue analyses conducted only shortly before harvest do not allow in-season fertilizer adjustment for current season yields and quality, although they do aid in fertilizer scheduling for postharvest applications, which are important for return bloom nutrition and adjustment for heavy crop drain of nutrients. Spring analyses made before fertilizer applications typically begin can be used to make in-season adjustments for the current anticipated crop load. Spring analyses can also be made to judge whether or not to forgo or reduce early nutrient applications to reduce vigor (where possible) or anticipate potential fruit quality problems due to nutrient imbalances. Spring-applied nutrients support vegetative and fruit growth in-season and floral initiation for the next year's crop.

Spring sampling and analysis utilizing a newly developed model (Silva, 2014) has been demonstrated to be effective in almonds, however its potential for pears is unexplored.

Below are nutrient management considerations related to tissue type and timing of sampling, especially for nitrogen.

- Leaf analyses have a limited utility in predicting response of pear trees to fertilization (especially for N), except under nutrient deficient conditions.
- A response could probably be expected with leaf nitrogen below 1.7% for midsummer value for basal shoot leaves. Between 1.7% and 2.2%, local influences would determine whether or not a response to applied N would be obtained, and the rate of application necessary to secure such a response would be uncertain. Above 2.2% *any response to applied N* would be unlikely (Proebsting, 1961). Pear's insensitivity to applied N has been demonstrated numerous times in replicated trials, in California and elsewhere.
- Consider no application of N in the current year if: 1) crop load is at the moderate to low end of historic yield, and 2) N content of any leaf type sampled in <u>spring</u> is 2.6% or greater. When tree N is adequate, additional applied N will be of no benefit and may, in fact, be detrimental to fruit quality and enhance excessive vegetative vigor.

OBJECTIVES

1. To compare the nutrient levels and ratios from different tissues and sampling timings
2. To determine if a more appropriate tissue sampling protocol can better predict fruit quality problems and improve nutrient management
3. To serve as a 'bridging' project in anticipation of a possible FREP project
4. Possible revision of the UC recommendations for sampling and nutrient management

PROCEDURES

Originally, two Bartlett pear blocks were to be used in this study, but three blocks were used. The orchard was the Joe Green Ranch in Courtland. <u>Block D</u> was a highly productive block with well-drained, fertile soil. <u>Block F</u> had struggled for years, with low production from limiting soil conditions including poor drainage and low fertility. <u>Block M</u> was a highly uniform, higher density block but one with low production; it began the transition to organic in early 2013. The soil in blocks D and F is Valpac loam, whereas block M is largely Egbert clay. No foliar nutrients were applied in any block.

In each block, tissue samples were collected from each of four separate groups of four rows (each group had a harvest row in the middle) each. Leaves and fruit were washed and rinsed before drying. In each of the three blocks, the following sampling regime was used. In late April, 75 young fruits and 125 fully expanded mid-shoot leaves from each of the four sampling sections were collected from the southwest sides of trees for nutrient analysis (N, P, K, Ca, and Mg). In early July, 125 mid-shoot leaves and 125 non-bearing spur leaves were collected for nutrient analysis. Just prior to the first harvest, 200 randomly chosen fruits from each sampling section were harvested and weighed; wedges of 50 of these fruits were removed and dried for nutrient analysis and 50 fruits were taken to the lab, where 25 were tested for firmness at harvest and 25 were tested for firmness after 1 week of ripening.

Soil samples (0-12”) from each of the three blocks were taken in mid-July and analyzed for total N, NO3-N, exchangeable P and K, Mg, Ca, texture, organic matter, and pH.

Results were statistically analyzed to determine if early-season tissue analyses predicts mid-summer deficiencies or imbalances.

RESULTS

Yields and Fruit Weight. Not surprisingly, block D had the highest yields overall at 24 tons/acre, block F was lowest at 16 tons/acre, and block M was intermediate at 19 tons/acre. However, block F had far more missing or declining trees and block M had very few, so after all trees in each block were rated for health, block D was still highest yield per tree and block M had slightly lower yield per tree than block F. Average fruit weight in the four rows each of blocks D and F were 0.41 and 0.40 lb. per fruit, and block M had the largest fruit at 0.47 per fruit.

Soil Analyses. There were large differences in the nitrate-nitrogen levels among the blocks; block M had the highest level, block D the lowest, and block F was intermediate (Table 1). A similar trend was seen with Ca and Mg, as well as cation exchange capacity and organic matter. Phosphorus and potassium differences were less pronounced, with block D being highest in phosphorus and block F the highest in potassium.

Leaf Analyses. Analyses of mid-shoot leaves in April showed significant differences among blocks for all nutrients tested except phosphorus (Table 2). The nitrogen, calcium, and magnesium content of leaves in block F were significantly higher than those of blocks D and M, but the reverse was true for potassium.

In July, nitrogen levels in mid-shoot leaves in block F were still somewhat higher than those in blocks D and M, but phosphorus and potassium were highest and magnesium lowest in block M (Table 3). Non-bearing spur leaves showed no consistencies with mid-shoot leaves among the blocks except that potassium levels in block M were higher than those in blocks D and F for both leaf types. A comparison of shoot vs. spur leaves across all blocks in July showed that nitrogen and phosphorus were significantly higher in shoots, and potassium and calcium were higher in the spurs (Table 2). A comparison of mid-shoot leaves collected in April vs. those collected in July showed no similarities (Tables 2 and 3).

Fruit Analyses. In the April fruit sampling, block M had the highest phosphorus, potassium, calcium, and magnesium, and block D had the lowest phosphorus, potassium, and calcium (Table 4). In the July fruit sampling, block D had significantly higher nitrogen than block F, and block D had the highest calcium content. There were no similarities among the blocks in fruit nutrition between the April and July timings. Likewise, there were no similarities in nutrient content among the blocks between the April leaf and April fruit analyses (Tables 2 and 4), nor between the July leaf and July fruit analyses (Tables 3 and 4).

DISCUSSION

It was challenging to draw conclusions about this study, which was conducted as a preliminary comparison of plant tissues and time of sampling. The sampling size was small, consisting of three blocks of different production characteristics, and no treatments were applied.

The organic block (block M) had relatively low yield per tree but it had soil with the greatest fertility in the top 12”. The high-production block (block D) had the lowest nitrate-nitrogen. Yet in the low-producing block (block F), both leaves and fruit were highest in several key nutrients in April.

There were few consistencies between non-bearing spur leaves and mid-shoot leaves among the blocks. Also, April sampling was generally not a good predictor of July nutrient levels, with either leaves or fruit.

Old pear blocks often contain trees that are highly variable in tissue nutrient content. In this project, approx. 1 leaf per healthy tree was used in the sampling for each of the four rows in each block. Approx. 1 fruit per 1.5 trees were sampled in April, and approx. 2 fruits per tree were sampled in July. Sampling from nearly all healthy trees should have eliminated this variability. The standard method is to collect non-fruiting spur leaves from each of 10-20 trees per block as one sample (Brown and Niederholzer, 2007).

Early Season Leaf Sampling Model. Spring leaf sampling combined with yield estimations have been shown to accurately predict July leaf nitrogen levels in almonds and pistachios to allow for in-season fertilizer adjustments (FNRIC, 2014). At 6 weeks after full bloom (mid-April in almonds), 5-8 leaves per tree are sampled from non-bearing spurs on 18-28 trees per block, and a full nutrient analysis is performed. The fertilization strategy for the remainder of year is adjusted to reflect April leaf and yield estimates.

Though we did not conduct sampling according to the methods defined in the early season sampling protocols for Almond (Silva, 2014), we nevertheless applied early-season leaf samples to that model and contrasted the predicted July leaf values with actual measured values. The use of the prediction model resulted in a remarkably good fit, especially considering that samples were not collected according to protocol and that we did not obtain data on all required nutrients used in the almond model. Predicted leaf

N values were 2.41%, 2.45%, and 2.44% vs. actual July shoot leaf values of 2.43%, 2.51%, and 2.40% for blocks D, F, and M, respectively. July non-bearing leaf values were lower, at 1.98%, 1.95%, and 2.03%, respectively.

Based upon this result there appears to be considerable potential for the development of a pear-specific early-season sampling and prediction protocol.

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Table 1. Analyses of soil, 0-12 in. depth.

	NO_3-N	**Olsen-P**	**X-K**		**X-Ca**	**X-Mg**	**CEC**	**OM**	**pH**
Block	ppm	ppm	ppm	meq/ 100g	meq/ 100g	meq/ 100g	meq/ 100g	%	
D	5.3	54.3	591	1.5	7.4	3.5	12.5	2.0	6.1
F	10.7	40.9	707	1.8	17.6	6.2	26.7	3.5	6.9
M	19.8	46.5	506	1.3	21.7	9.5	33.0	4.9	6.6

NO3-N = nitrate-nitrogen, X = exchangeable, CEC = cation exchange capacity, and OM = organic matter

Table 2. Nutrient analysis of mid-shoot leaves collected on 24 April.

Block	**N (%)**		**P (%)**		**K (%)**		**Ca (%)**		**Mg (%)**	
D	2.86	b	0.241	ns	1.44	a	0.757	b	0.274	b
F	3.14	a	0.249	ns	1.33	b	1.111	a	0.319	a
M	2.95	b	0.258	ns	1.47	a	0.854	b	0.238	c
Trt		**		*ns*		*		**		**
Rep		*ns*		*ns*		*ns*		*ns*		*ns*

Means separation within columns by Duncan's Multiple Range Test,
** = 0.05 level, ** = 0.01 level, and *** = 0.001 level*

Table 3. Nutrient analysis of mid-shoot and non-bearing leaves collected on 2 July, and mid-shoot vs. spur means of all three blocks.

Block	**N (%)**		**P (%)**		**K (%)**		**Ca (%)**		**Mg (%)**	
Mid-shoot leaves										
D	2.43	ab	0.155	b	1.005	b	1.17	ns	0.338	a
F	2.52	a	0.151	b	0.978	b	1.19	ns	0.324	a
M	2.40	b	0.166	a	1.260	a	1.13	ns	0.270	b
Trt		*		**		***		*ns*		**
Rep		*		*ns*		**		*ns*		*ns*
Non-bearing spur leaves										
D	1.98	ns	0.134	ns	1.65	b	1.66	a	0.365	a
F	1.95	ns	0.140	ns	1.73	b	1.60	ab	0.264	c
M	2.03	ns	0.135	ns	2.16	a	1.50	b	0.295	b
Trt		*ns*		*ns*		**		*		***
Rep		*ns*		*ns*		*ns*		*ns*		**
Shoot vs. Spur Leaves										
Shoot	2.45	a	0.157	a	1.08	b	1.16	b	0.311	ns
Spur	1.98	b	0.136	b	1.85	a	1.59	a	0.308	ns
Trt		***		***		***		***		*ns*
Rep		*ns*		*ns*		**		*ns*		*

Means separation within columns (by leaf type) by Duncan's Multiple Range Test,
** = 0.05 level, ** = 0.01 level, and *** = 0.001 level*

Table 4. Nutrient analysis of fruit collected on 24 April (immediately after the fruit drop period), and fruit wedges on 14 July (preharvest).

Block	N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
24-Apr										
D	2.19	ns	0.28	c	1.84	c	0.129	c	0.157	b
F	2.35	ns	0.30	b	1.93	b	0.142	b	0.163	b
M	2.52	ns	0.32	a	2.05	a	0.172	a	0.182	a
Trt		*ns*		**		***		***		***
Rep		*ns*		*ns*		*ns*		*ns*		*ns*
14-Jul										
D	0.39	a	0.07	ns	0.70	ns	0.030	a	0.040	ns
F	0.32	b	0.07	ns	0.69	ns	0.021	b	0.037	ns
M	0.36	ab	0.07	ns	0.73	ns	0.023	b	0.039	ns
Trt		*		*ns*		*ns*		***		*ns*
Rep		*ns*		*ns*		*ns*		*ns*		*ns*

Means separation within columns (by date) by Duncan's Multiple Range Test,
** = 0.05 level, ** = 0.01 level, and *** = 0.001 level*