Almond Productivity as Related to Tissue Potassium

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Synopsis: Heavy crop removal and inadequate soil K availability could limit almond production in California. This research suggests that K-deficiency is associated with higher mortality rates for fruiting spurs. Leaf K concentration from samples taken in July were found to be moderately correlated with yields in the following year. Leaf K concentration below 0.8% in July was associated with K deficiency and we observed no yield benefit associated with leaf K concentrations greater than 1.4%. Almond fruit (kernel, shell and hull) is a major K sink containing the equivalent of approximately 55 lb K_2O/1,000 lb meats (kernels).

Yield is the product of fruit number and fruit size, but fruit number is arguably the most important yield determinant. There is evidence, from other fleshy *Prunus* species, that K-deficiency limits fruit size. Almond flowers are differentiated during the summer prior to anthesis, and almost all fruit are borne laterally on relatively long-lived spurs. Therefore, a nutrient deficiency may conceivably reduce potential future yields (in terms of flower/fruit number) by limiting growth of new shoots and spurs, by reducing the productivity of existing spurs, and by reducing the quality or quantity of floral differentiation.

Potassium fertilizer was applied to drip irrigated 'Nonpareil' almond trees in a Modesto, California orchard at the rates of 0, 240, 600, and 960 lbs K_2O/A/year as K_2SO_4, beginning in 1998. The fertilizer was applied directly beneath six drip emitters per tree, split 3 times (May 23, June 17, and July 3) in 1998 and 2 times (Feb. 26 and April 29) in 1999. Forty individual branch units from trees in the control (0 K) and 960 lbs K_2O/A rates ("low-K" and "high-K", respectively) were selected to monitor yield determinants and individual spur longevity over several years. Yield and leaf K concentrations were also measured.

Differential K application rates were initiated during the summer of year 1 (i.e., 1998), July leaf K concentrations indicative of K deficiency were established during year 2 (i.e., 1999, and a statistically significant yield response to K fertilizer occurred in year 3 (i.e., 2000) (Table 1). Our data indicate a time lag between establishment of K deficiency and yield reduction, that yield is a multi-component process and these components vary both in sensitivity to K deficiency and the time frame over which they contribute to the yield reduction.

The lack of a yield reduction in 1999, despite K deficiency, as indicated by leaf K concentration, indicate that some of the parameters influencing yield, namely percentage fruit set (which influences the percentage of flowers which develop until fruit maturity) and, therefore, the number of fruit, and almond fruit growth (which influences the weight per fruit) and, therefore, total crop weight are relatively insensitive to limited soil K availability. The insensitivity of percentage fruit set and fruit growth to low K availability was demonstrated in both 1999 and 2000 (Table 2).

Although overall percentage fruit set was not different among low- and high-K trees in 2000, the return bloom (flower number in 2000 divided by flower number in 1999) was markedly lower on unfertilized trees (Table 2). The lower return bloom in low-K trees might have been caused by the death of existing spurs, decreased initiation of new spurs within the canopy, and/or a reduced number of flowers per spur. Our data from monitoring individual spurs from the low- and high-K trees suggest that the 27% increase in mortality of fruiting spurs in 1999 (Table 3a) was a major factor in the lower return bloom and reduced yields of low-K trees in 2000. Tree K status did not influence the mortality of spurs that were non-fruiting in 1999 (Table 3b), meaning that this effect of K-deficiency was localized to fruiting spurs.

Leaf K Critical Value: The concept of a leaf K critical value implies the existence of a relationship between leaf K concentration and yield. As noted above, we believe that the lower yields for untreated trees in 2000 was due to the persisting or carry-over effects of K deficiency in 1999, while we expect that tree K status in 2000 would have no relationship to the crop harvested in 2000. Therefore, we correlated 2000 yield with the 1999 leaf K concentration. This analysis indicated a moderate (60%), but significant relationship between leaf K concentration and future productivity. The relatively low variability in leaf K concentration and yield for untreated trees suggests leaf K concentrations are diagnostic for potassium deficiency (Figure 1). The highest yields among plots receiving fertilizer had leaf K concentrations ranging from 1.4 to 1.7% (Figure 1). There were also, however, plots within the latter leaf K concentration range that yielded no better than the controls. This suggests that factors other than K were limiting yield when K concentration in leaves exceeded 1.4% .

Removal of K in the Crop: Most of the additional K in the fruit resulting from fertilization was found in the hull and shell (Table 4) that constitute part of the harvested crop along with the meats (kernels). We also determined the quantity of K removed per acre in the almond crop so that growers and consultants can better estimate the amount of K fertilizer required to avoid deficiency (Table 5). Based on 1999 data, the kernel contains the equivalent of about 8 lb K_2O/1,000 lb. The shell contains slightly more than the kernal and the largest K sink is the hull that contained the equivalent of about 37 lb K_2O (high K treatment). Since kernel, shell and hull are all removed from the field at harvest, the equivalent of approximately 55 lb K_2O was removed/1,000 lbs of harvested kernels. Thus a 3,000 lb crop would remove on the order of 165 lb K_2O/A.

Conclusions:

1) July leaf K concentration is moderately associated with future productivity. Maximum yields were correlated with leaf K values equal to or greater than 1.4%, but due to the lack of data points between 0.9% and 1.4%, we cannot clearly delineate the zone of sufficiency from that of deficiency.
2) Potassium deficiency will not affect yield in the year it is indicated by leaf testing, since percentage fruit set and fruit size are not influenced by K status in the current year. Very low July leaf K concentrations in a heavy-cropping year (below 0.7 to 0.8% for non-fruiting spurs) are associated with a K limitation to tree productivity which will result in decreased yields in subsequent years as a result of decreased overall flower number due to increased spur mortality.
3) The effects of K application on leaf K concentration observed in this study are site- and cultivar specific and may vary according to soil type, application technique, and irrigation method. However, since most of the fruit K is contained in the hull, and because 'Nonpareil' almond has a relatively large hull compared to other cultivars, it should be possible to match K fertilizer application to the predicted crop size. Also, growers and

consultants should consider whether the soils in their area are likely to fix significant quantities of applied K and adjust fertilizer recommendations accordingly.

4) Although the data are not presented here, early spring is likely to be the most critical period for K availability because this is the period of rapid vegetative growth and fruit development. It makes sense to apply K so that it will be available at this time.

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Table 1. Effects of K applications on leaf K concentrations and yields

Treatment	Leaf K (% dry wt.)[x]			Nut yield (meats, lb/A)		
(lb K_2O/A)	1998	1999	2000	1998	1999	2000
0	1.1	0.7	0.7	780	3930	2410
240	1.3	1.3	1.2	890	3840	2860
600	1.3	1.6	1.4	830	4380	2860
960	1.3	1.7	1.7	1070	4020	2770
	**	**	**	ns	ns	*

*,** Significant differences among treatment means at $p<0.05$ and $p<0.01$, respectively.

[x]Samples taken in the last week of July.

Table 2. Effect of tree K status on yield determinants measured on individual branches, beginning eight months after differential K fertilization was initiated[z]

Level of treatment	**Fruit set (%)**		**Nodes/ shoot**	**Weight -- 1999 (g)**		**Return bloom (%)**
lb K_2O/A	1999	2000	1999	Embryo	Whole fruit	2000
0	27 ± 2.4	21 ± 2.2	11.1 ± 0.86	0.95 ± 0.04	2.76 ± 0.05	23 ± 3.2
960	26 ± 1.8	25 ± 2.2	11.6 ± 0.43	1.01 ± 0.01	2.78 ± 0.09	33 ± 4.6 *

[z] means ± SE..
* Denotes means which differ at $p<0.10$.

Table 3a. Effect of tree K status on subsequent productivity of *fruiting* spurs tagged in 1999

Level of treatment		**Spur status in 2000** (% of total sample)		
(lb K_2O/A)	N=	Vegetative	Fruiting	Dead
0	133	26	18	56
960	172	31	27	42 *

[*] *Denotes means which are significantly different at $p < 0.05$.*

Table 3b. Effect of tree K status on subsequent productivity of *vegetative* spurs tagged in 1999

Level of treatment		**Spur status in 2000** **(% of total sample)**		
(lb K_2O/A)	N=	Vegetative	Fruiting	Dead
0	113	21	77	2
960	138	16	77	7

Table 4.Fruit K content at 1999 harvest (August 26)[z]

Level of treatment	K content (mg K / fruit)[y]			
(lb K_2O/A)	Hull	Shell	Kernel	Total
0	23[a]	7.0[a]	6.3[a]	36.3[a]
960	33[b]	9.2[b]	6.7[a]	48.9[b]

[z]Data represent means of 10 fruit per tree subjected to high- and low-K availability, respectively.
[y]Significantly different means at $p < 0.01$ denoted by different letters within columns.

Table 5. Total fruit K removed in 1999 per 1000 lb of 'Nonpareil' almond kernels (meats)[z]

		Low K		High K	
Fraction	Weight (lbs)[y]	K conc. (%)	K removed (lbs K_2O)	K conc. (%)	K removed (lbs K_2O)
Kernel	1000	0.7	8.4	0.7	8.4
Shell	400	1.5	7.2	2.0	9.6
Hull[y]	1200	1.7	24.0	2.6	37.2
Total			39.6		55.2

[z]Includes the mesocarp plus exocarp.
[y]Kernel/shell/hull ratio data (not presented) indicated no yield differences among treatments in 1999.

Figure 1. Plot yields as measured in August 2000 versus their leaf K concentration measured in July 1999.