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Effect of Application Period on the Availability of Fertilizer N to Almond Blossoms and Developing Nuts

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General Summary

Fertilizers have been applied in California without apparent knowledge or consideration for the trees' capacity for nitrogen uptake, its subsequent utilization, or the influence of soil texture on N losses and the availability of fertilizer nitrogen to the developing crop.

In this project the fertilizer used was a special formulation of ammonium sulfate which enabled us to distinguish between fertilizer N in blossoms, fruit and leaves and other N, i.e., the N in these organs derived from other sources. Different N timings were applied to comparable 17-year-old 'Nonpareil' orchards on a sandy soil and a medium-textured soil.

Results and Conclusions

(1) Nitrogen applications either in March or as a March/August split application were most effective.

(2) Nitrogen application during the dormant season should be avoided! Dormant applications resulted in nearly a 30% reductions in the amount of fertilizer N in the combined 1980 and 1981 crops. Trees do not absorb N after leaf fall; therefore, applications should be made not later than the last preharvest irrigation to permit substantial N uptake before leaf fall.

(3) Significantly greater losses of fertilizer N occurred over winter on sandy soils versus the heavier-textured soils. Minimizing the amount of soluble fertilizer N which remains in these soils over winter by early season applications and soil moisture adequate for nutrient uptake should minimize losses.

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Background

The time of year at which nitrogenous fertilizers can be applied to almond trees with greatest benefit has been a subject of considerable question. Fertilizers have been applied without apparent knowledge or consideration for the trees' capacity for nitrogen uptake, its subsequent utilization, or the influence of soil texture on the availability of fertilizer nitrogen to the developing crop. Rational utilization of fertilizer nitrogen requires determination of the relationship between the season of application and its subsequent utilization by the tree.

The isotopic composition ($^{14}N/^{15}N$ ratios) of nitrogenous fertilizers may be altered so that nutrient uptake from the fertilizer applied can be traced and measured within the tree.

This project represents the first work with 'tagged' nitrogen in deciduous fruit trees conducted under actual field conditions. Studies previously completed employed small, potted trees (non-bearing prune and dwarfed apricot trees). Almond conceivably differs from other stone fruits in the depth and duration of its dormant period and, consequently, in its uptake and distribution of nitrogen during late fall and winter.

Procedures

The following applications of ^{15}N-depleted ammonium sulfate (3-1/3 pounds N per tree) were applied in 1980:

Treatment	Application Date of N Tracer in 1980*
1**	March 15, 1980 (post bloom)
2	June 1, 1980
3	August (before last preharvest irrigation)
4**	Split application: March 15, 1980 (1 above) August, 1980 (3 above)
5**	December 15, 1980

*^{15}N-depleted ammonium sulfate applied as 'tracer'.
**Treatments applied in an orchard on a loam soil; all 5 treatments were applied in an orchard on a sandy soil.

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Tagged N applications were made to 17-year-old 'Nonpareil' trees (5 replications per treatment) in two orchards differing in soil texture: a sandy soil (Mr. Y. Asai, Turlock) and a loam (Mr. G. Crum, Winters). The fertilizer (in solution) was poured into trenches dug around each tree. The concentric trenches were 8 inches deep and spaced 4 feet and 6 feet from the trunks. The trenches were immediately refilled with soil and irrigated shortly thereafter to minimize the likelihood of volatilization of fertilizer nitrogen. Nut and leaf samples were collected once or twice a month in 1980 and were collected in 1981 according to the following schedule:

Tissue (Buds, Leaves, Blossoms, Fruit, Nuts) Sampling Periods in 1981
1) Bud swell
2) Mid full bloom
3) Petal fall
4) April 1
5) May 1
6) June 1
7) July 1
8) August 1
9) Harvest

Samples were processed for mass-spectrometric analysis to determine the rate and magnitude of fertilizer N movement to leaves, blossoms, and nuts. Following mass spectrometric analysis we were able to determine (1) how much of the nitrogen in the crop was derived from the fertilizer and (2) whether nitrogen was better utilized by the crop following specific N application periods.

Results --- 1980

The nitrogen derived from the 'tagged' fertilizer (applied in mid-March) was detected in the young leaves and immature nuts within two weeks after application. This rapid uptake and transport of fertilizer N to the crop in the spring is consistent with previous work we have done with prunes. Fertilizer applied in March, 1980, contributed 19% of the nitrogen in the crop at harvest (1980). Nitrogen applied later during the 1980 season was utilized by the 1980 crop to a lesser extent, with correspondingly greater carryover of the 1980 applied fertilizer in the 1981 crop (Table 1). The fertilizer contributed N to the crop in 1980 if applied as late as June (Table 1); whereas N applied in August was not detected in the 1980 crop, and the December N application obviously occurred after harvest. Because of this carryover of fertilizer N in crops over successive years, quantitative comparisons among treatments are somewhat complicated. Nevertheless, we have based our evaluation on the amount of fertilizer N in the combined 1980 plus 1981 crops (Table 2). The least effective treatment was clearly the dormant application, and the amount of fertilizer - derived N in the 1980 plus 1981 crops was nearly 30% lower if N was applied during dormancy than if application was made in March or as a March/August split.

Table 1. Utilization of Fertilizer N (% N in Crop Derived from 1980 Fertilizations) by the 1980 and 1981 Crops - Sandy Soil

Fertilizer Application Period	% N Derived from Fertilizer	
	1980 Crop	1981 Crop
(1) March, 1980	19.0%	12.8%
(2) Split: March/August, 1980	13.9%	19.9%
(3) June, 1980	6.22%	16.9%
(4) August, 1980	0.00%	28.3%
(5) December, 1980	-	24.5%

Table 2.

Period of Fertilizer N Application	Sandy Soil: Amount of Fertilizer N in Blossoms & Crop Relative to March Application	
	In Blossoms at FB, 1981	In Crop at Harvest (Combined 1980 plus 1981 Crops)
(1) March, 1980*	100%	100%
(2) Split: March/Aug, 1980*	80%	102%
(3) June, 1980*	96%	81%
(4) August, 1980**	78%	85%
(5) December, 1980**	6%	73%

*Fertilizer N appeared in crop both in 1980 and 1981.
**Fertilizer N appeared in crop in 1981 but not 1980.

We believe the reduced availability of dormant-applied N (particularly in sandy soils) is a result of its enhanced loss from the soil profile. This conclusion is supported by several lines of evidence:

(1) Reduced uptake during dormancy - The minimal capacity for N uptake by fruit trees occurred during dormancy; thus, soluble fertilizer N in the soil remains vulnerable to losses (leaching, denitrification) over extended periods during winter (a time when environmental conditions typically favor such losses).

(2) Soil texture effect - Evidence of reduced fertilizer N availability on sandy soils the year subsequent to application. Comparison of fertilizer N applied in August vs. December 1980 (Table 3). Neither treatment supplied fertilizer N to the 1980 crop. However, there was nearly 15 times more fertilizer N in the blossoms (spring, 1981) if application was made in August rather than delayed until December (Table 3).

Table 3.

Period of Fertilizer N Application	N Timing Experiment in Almond		
	% N Derived from Fertilizer in Blossoms & Crop		
	1980 Crop	Blossoms (Full Bloom, 1981)	1981 Crop
August, 1980	0.00%	21%	28.3%
		difference equals 1500%	difference equals 15%
December, 1980	-	1.70%	24.5%

These data support previous work with apricot in which we found that nitrogen applied to apricot trees during August contained 34 times more fertilizer N in their blossoms at anthesis than N applied during dormancy (Table 4).

Table 4. % Blossom N Derived from Labeled Fertilizer

	Fertilizer Application Period			
	March	June-July	Aug	Dormant (Dec-Jan)
10-year apricot* (potted)	11%	14%	16%	0.48%
17-year almond** (field)	27%	26%	21%	1.70%

* Study employed ^{15}N-enriched KNO_3.
**Study employed ^{15}N-depleted $(NH_4)_2SO_4$

Interestingly, although the availability of dormant-applied fertilizer N to the 1981 bloom was greatly reduced relative to the other application periods, total blossom N (% dry weight) did not differ statistically among treatments (Table 5). Thus, blossoms were apparently sufficiently strong metabolic sinks for nitrogen that their N demands were satisfied with N mobilized from other internal N pools.

At harvest, 1981, there was 15% more fertilizer N in the crop if application was made in August (vs. the December dormant application).

Table 5. N Timing Expt. on Almond - Sandy Soil

Period of Fertilizer Application	(FB) Blossom Samples	
	N Derived from Fertilizer (%)	Total N (% D.W.)
March, 1980	27%	2.86
Split: March/August, 1980	22%	2.83
June, 1980	26%	2.92
August, 1980	21%	2.95
December, 1980	1.7%	2.77

*3-1/3 lbs ^{15}N-depleted $(NH_4)_2SO_4$ applied/tree.

Evidence we have accumulated working with several deciduous fruit tree species besides almonds indicates the following:

1) The relative N absorption capacity (i.e., uptake per day) during dormancy is only about one tenth as great as the absorption capacity during the growing season (Table 6; data obtained with prune trees). The absorption and movement of dormant-applied fertilizer nitrogen to the developing crop is therefore, delayed relative to other N application periods.

2) Nitrogen applied in August is absorbed efficiently before leaf fall (Table 6), and much of this N is stored in the roots and rootstock over winter. Seventy-four percent of the fertilizer N absorbed by prune trees in early September was stored over winter in roots and rootstock (Table 6). This stored nitrogen represents a nitrogen pool which is much more accessible to the developing blossoms and young fruit than the N applied during dormancy which remained in the soil over winter.

3) Not only is dormant-applied N poorly absorbed during winter, this nitrogen is particularly predisposed to loss mechanisms (i.e., leaching, denitrification) which are more serious during winter. The potential for loss appears to be accentuated on lighter-textured soils.

Table 6. Non Bearing Prune Trees

^{15}N Application Period	Distribution of Absorbed Fertilizer N (%) Within the Tree			Fertilizer Uptake Capacity over 10-day Period (% of N Applied)
	Current Growth	1 & 2 YR Wood	Roots & Rootstock	
Dormant	<1%	<1%	99%	4%
Spring Growth Flush	71%	7%	22%	31%
Terminal Bud Formation	37%	10%	53%	39%
Early September	20%	5%	74%	33%

The comparison between N applications during the growing season vs. N applied during the dormant period is summarized in Table 7.

Table 7. Greater Fertilizer N Availability to Crop When Fertilizer Applied During Growing Season

Fertilizer Application Period	Comment
March through August	Significant fertilizer N absorbed before leaf fall stored in roots during winter & transported to blossoms in spring.
Dormant period	Fertilizer N not absorbed by tree until spring (post bloom); enhanced N losses (leaching, denitrification) from soil during winter.

Soil texture effect - evidence for enhanced N losses (presumably occurring over winter) on light-textured soils. The contribution to the 1980 crop of fertilizer nitrogen, applied in March, 1980 or as a March/August split, was similar on the sandy soil and the loam in 1980 (Table 8). In 1981, however, the availability of that same N applied in 1980 was 50% to 100% greater on the heavier textured soil than the sandy soil (Table 8). Presumably the lower sorbtive capacity of the sandy soil was responsible for the smaller retention of the fertilizer N.

Table 8. % Fertilizer Nitrogen in Crop as Influenced by Soil Texture

Period of N Fertilizer Application	1980 Crop		1981 Crop	
	Light Soil	Heavy Soil	Light Soil	Heavy Soil
March, 1980	19.9%	20.2%	12.8%	23.8%
Split: March/August 1980	13.9%	15.4%	19.9%	27.8%

Horticultural differences among treatments (yield, kernel size, kernel weight, etc.) were not detected over the brief course of this experiment. Confirmation of the findings reported here should be further evaluated in the field (preferably on a sandy soil), by conducting a longer term experiment (e.g., 5 years) and critically evaluating the effects of N timing on yield and yield components.

Conclusions

(1) Nitrogen applications either in March or as a March/August split application were most effective.

(2) Nitrogen applied during the dormant season should be avoided! Dormant applications resulted in almost a 30% reduction in the amount of fertilizer N in the combined 1980 and 1981 crops. Trees do not absorb N after leaf fall; therefore, applications should be made not later than the last preharvest irrigation to permit substantial N uptake before leaf fall.

(3) Significantly, greater losses of fertilizer N occurred over winter on sandy soils versus the heavier-textured soils. An objective of nitrogen management on these soils would appear to be the minimization of the amount of soluble fertilizer N remaining in the soil over winter. Split applications, application in July or earlier in the season, and maintenance of soil moisture adequate for nutrient uptake throughout the autumn would appear to advance those ends.