ANNUAL REPORT TO THE ALMOND BOARD OF CALIFORNIA

December 31, 1994

Nitrogen on Drip Irrigated Almonds

by

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Co-Project Leaders: John P. Edstrom, Herbert Schulbach-retired and the Nickels Soil Laboratory (Trustees Michael Murray, Raymond Charter and Greg Ramos)

Objectives: (1) To evaluate the effects of different nitrogen rates applied at two water levels on growth, nutrient concentrations in leaves and twigs, and nut yields of almonds. 2) To assess the extent of soil acidification from urea-nitrogen application under drip emitters and its effect on tree productivity. 3) To evaluate changes in nutrient movement in the drip zone as a result of nutrient uptake, leaching of nitrates and acidification. 4) To evaluate the effects of two rates of potassium on growth, nutrient concentrations in leaves and nut yields. 5) To develop recommendations for nitrogen, irrigation and soil management for use during the establishment and early maturity stages of almond orchards.

Problem and its Significance: Drip and other limited soil area irrigation is a unique method of providing water to trees which makes for a number of challenging management situations. Since water is applied to a more limited soil area, excessive amounts may move and also leach nutrients more rapidly than when other irrigation systems are used. Having a relative small volume of soil being used as the reservoir for water and nutrient uptake which is saturated a high percent of the time during the summer provides a setting for several unusual chemical reactions in the soil. The use of an acidifying nitrogen fertilizer such as urea increases the solubility of toxic elements like manganese and aluminum. Soil sampling of the high nitrogen-high water treatment has indicated nitrates may have been leached below the root zone immediately below the drip emitter. Lower total leaf nitrogen in samples from calcium nitrate treatments would suggest that denitrification may also be occurring at a rather rapid rate which could result in reduced nitrogen efficiency by the crop. Rapid tree growth and higher yields from higher nitrogen rates has reduced leaf potassium levels below the desired range. Treatments where potassium has been added show significant increases in leaf potassium and a trend for increased yield. Because the answers to a number of these questions are still unknown, this project was initiated and the continuing challenges will allow for the development of solutions so that growers can manage fertilizer application through drip irrigation systems to achieve profitable almond production and not adversely affect the environment.

Interpretive Summary: The orchard was planted at the Nickels Soil Laboratory in the spring of 1981 to three almond varieties--Butte, Carmel and Nonpareil on a 12' X 18' spacing (202 trees/A). In the spring of 1982, five-5 tree plots were selected from each of the four-28 tree rows of each variety to which the two replications of the ten treatments were assigned. The ten

treatments included two water levels-0.6 and 1.0 of evapotranspiration (ET) each with five nitrogen rates-0, 0.5, 1.0, 1.5 and 2.0 oz/tree in 1982; 0, 0.8, 1.7, 3.5 and 7.0 oz/tree in 1983; 0, 2, 4, 8 and 16 oz/tree in 1984; 4, 8, 16, 24 and 32 oz/tree in 1985; 6, 12, 24, 36 and 48 oz/tree in 1986; 8, 16, 32, 48 and 64 oz/tree in 1987 and 1988; 6, 12, 24, 36 and 48 oz/tree in 1989; and 4, 8, 16, 24 and 32 oz/tree in 1990, 1991 and 1992. Rates applied in 1993 and 1994 were 0, 4, 8, 16 and 32 oz/tree on two timing schedules; 1) one third each on 4/1, 5/1 and 7/1, and 2) one third each on 6/1, 8/1 and 9/1. Urea is the nitrogen fertilizer source and it was applied on a monthly basis in six equal increments (five in 1990, 1991 and 1992) beginning April 1st. The 1.0 ET irrigation level is based on CIMIS and visual observation to maintain active tree growth. The 0.6 ET treatments receive 60% of the water quantity of the 1.0 ET treatments. In a second experiment, different nitrogen sources have been used since 1986. They are: urea, calcium nitrate, urea and calcium nitrate in alternating years, UN 32, N-phuric and 5 additional urea treatments to which different soil pH amendment materials will be added.

Yields in 1994 were slightly lower than in 1993 with three plots having yields greater than 3000 and 11 plots (out of 60) greater than 2500 meat lbs/A. The lowest plot yield was 973 and the highest was 4233. Average yields for the three varieties Carmel, Butte and NonPareil (20 plots each) were 1757, 2177 and 2174 meat lbs per acre respectively. There was a trend for yields to increase from the lowest nitrogen rate (0 oz/tree) to the fourth rate (16 oz/tree) at the 1.0 ET irrigation level while at the 0.6 ET irrigation level, the increase occurred between the lowest to the intermediate (8 oz/tree) nitrogen rate with no change as the nitrogen rate was increased (Figure 1 and 5). The early application of nitrogen -- one third of total on 4/1, 5/1 and 7/1 resulted in a significantly higher yield (2239 versus 1833 meat lbs/A) than the late timing -- one third each on 6/1, 8/1 and 9/1. A significantly higher yield of 450 meat lbs/A for the higher 1.0 ET irrigation level was consistent across all five nitrogen rates. There was no significant difference between the no potassium treatment and where potassium was applied (1944 versus 2129 meat lbs/A). Meat yield responses for the three varieties to nitrogen rate at the two water levels were as follows: Butte - yield increase at the 0.6 ET water level up to the 16 oz/tree N rate with trend for decline at the 32 oz/tree rate and no yield response at the 1.0 ET water level (Figure 2); Carmel - both water levels gave the same yield and had a similar response to nitrogen rate up to the 16 oz/tree N rate with no change thereafter (Figure 3); NonPareil - decrease in yield at the 0.6 ET water level as N rate increased to 16 oz/tree and then increased, yield increased as N rate increased to 16 oz/tree and then declined slightly at the 1.0 ET water level (Figure 4). Hull, shell and kernel (meat) fractions will also be determined along with the total nitrogen of each fraction for calculating nitrogen removal by the harvested crop.

Tree trunk circumference measurements and twig samples were taken but the analyses have not been completed.

Leaf samples taken on April 1, May 2, June 1, July 1, August 1 and October 3 show a significant continuous decline in total nitrogen throughout the season (Figure 6). Increasing the nitrogen fertilizer rate significantly increased the leaf total nitrogen (Figure 6), sulfur, zinc and manganese (Figure 7) while significantly decreasing potassium (Figure 8), calcium and boron. There was a trend to increase phosphorus on all sample dates as nitrogen rates were increased. The three highest nitrogen rates resulted in leaf total nitrogen levels above 2.3% on July 1st while the highest nitrogen rate also resulted in a leaf potassium level of 1.19% which is slightly above the 1.0% adequacy concentration. No significant water level effect was observed in any of the leaf nutrient concentrations for the growing season. The potassium treatment (1.5 and 2.0 lbs K_2O/tree in 1989 and 1990 respectively plus 2.0 lbs K_2O/tree in 1993 as potassium sulfate) significantly increased leaf total potassium on all of the six sample dates (Figure 8) while increasing total nitrogen on 5 of the 6 sample dates. Leaf sulfur and manganese were increased and leaf calcium was decreased on all three sample dates.

The nitrogen source trial initiated in 1986 has ten treatments: (1) calcium nitrate, (2) calcium nitrate alternated every other year with urea, (3) urea-ammonium nitrate solution 32, (4) N-phuric (urea-sulfuric acid) and (5) through (10) urea to which different soil pH amendment materials will be added. Soil samples taken the summer of 1988 indicated that the degree of soil acidification was nearly the same for all sources of nitrogen fertilizer used. This could be due in part to the earlier use of urea (prior to 1986) which had acidified the soil to a large extent. The soil samples did show that even though considerable acidification had occurred, the $Ca(NO_3)_2$ treatments were showing some ameliorating effect. Complimentary funding from the California Department of Food and Agriculture - Fertilizer Research and Education Program was received and soil samples were taken from plots where several nitrogen fertilizer sources have been applied. Samples were collected from immediately under and at various distances from the emitters to a depth of about ten feet to evaluate pH, nitrate, ammonium and other cation distribution. A trend existed for the average pH for the surface five feet of soil to decrease for the fertilizer sources: calcium nitrate > urea-calcium nitrate alternated > UN32 > Urea > N-phuric (Table 1). This trend is also true but to a lesser degree for the samples taken below five feet. Tables 4 and 5 give the profile pH for the calcium nitrate and N-phuric treatments respectively. Average nitrate-N concentrations in the surface five feet of soil for the six fertilizer treatments sampled are given in Table 2. It can be noted that considerable variation in the nitrate concentration existed as illustrated by the two urea treatments. Perhaps this is most easily explained by the potential for different flow rates from the emitters and subsequent water movement into the soil. However, the two calcium nitrate treatments would seem to show a trend for slightly higher nitrate levels than the N-phuric treatment. Samples from below five feet depth tend to confirm this even to a higher degree (Tables 6 and 7). Average ammonium-N concentrations in the surface five feet of soil for the six fertilizer treatments sampled are given in Table 3. Note again the wide variation between the two urea treatments, but it is confined to immediately under the emitter. A slight trend exists for the N-phuric treatment to have higher levels of ammonium-N and the calcium nitrate treatment to have lower levels (Tables 3, 8 and 9).

Discussion: The results of the soil sampling coupled with the leaf and twig sampling related to yield of almond meats shows that the easiest, most accurate and economical way to assess the nitrogen status of almonds is by the use of leaf analysis with a July (1st week) leaf sampling for total nitrogen concentration. The desirable range is from 2.3 to 2.5% total nitrogen. Rates of nitrogen application should be increased if leaf nitrogen concentrations are below 2.3%. If levels are consistently (for several years) higher than 2.6%, strong consideration should be given to reducing the rate of nitrogen application. July leaf samples can effectively indicate the status of other nutrients required for optimum almond production.

Complimentary support from the California Department of Food and Agriculture-Fertilizer Research and Education Program provided the necessary resources to assess the extent of soil acidification and nitrate leaching for several nitrogen fertilizer sources that have been applied since 1986. A trend existed for the average pH for the surface five feet of soil to decrease for the fertilizer sources: calcium nitrate > urea-calcium nitrate alternated annually > UN32 > Urea > N-phuric. This trend is also true but to a lesser extent for the samples taken from below five feet. The results for the least (calcium nitrate) and most (N-phuric) acidified profiles are given. In general, the nitrate fertilizer sources showed higher soil nitrate levels while ammonium or ammonium forming sources showed the higher ammonium levels in the soil. Considerable variation between the two urea treatments did exist. One possible explanation for this is the potential for different flow rates from the emitters and the resulting water movement into the soil.

Plans for 1995 are to start a new line of research dealing with potassium fertilization and the foliar application of nutrients. Since potassium concentrations in leaf samples of high yielding almonds often decline and fertilization becomes necessary, growers need to determine the most efficient way to apply potassium. The practice of applying potassium fertilizers on the soil surface in bands at the tree drip line is often used while some growers apply potassium through the irrigation system. Several potassium sources and rates will be evaluated in the band versus irrigation system application methods to determine efficiency of tree uptake. Also, growers often observe the large number of nuts dropped, particularly following high winds. If foliar applied nutrients could improve the fertilization, retention and development of these aborted nuts, there is considerable potential for increasing almond yields. Several nitrogen sources, along with phosphorus and potassium will be applied followed by leaf sampling and yield measurements to assess possible yield increases.

Suggestions/Recommendations: The results of soil sampling both the nitrogen rate at two drip irrigation levels experiment and the nitrogen source experiment have confirmed that the rates of nitrogen needed to produce optimum yields at the full water level (1.0 ET) do not result in large amounts of nitrate-nitrogen being leached below the root zone. The rates of applied nitrogen necessary to produce optimum yields and not have excess nitrate leaching can be achieved by monitoring early July leaf total nitrogen concentrations (good range is 2.3 to 2.5%) and applying water at the 1.0 ET level. Either excess water and/or nitrogen may result in excess nitrate nitrogen being leached below the root zone. Sustained high yields and vigorous tree growth require large amounts of nutrients, specially potassium. After observing the large differences in leaf potassium concentrations during the early part of the growing season, followed by nearly the same levels being reached by July 1st, it seems advisable for growers to consider taking leaf samples several times during the year, near April 1 and near July 1 from at least three areas within a field. The three areas should represent low, medium and high producing portions of the field and if leaf analysis indicate large differences in potassium or other nutrients in the early season samples it may indicate an approaching deficient situation.

Another very important point to remember is that higher rates of nitrogen fertilizer will not be effectively utilized unless adequate amounts of irrigation water are applied. Thus if for any reason water supplies are or become limiting, as in a drought year for example, applying a rate slightly below the "full" rate would be advisable. On the other hand, excessive irrigation water applications should be avoided so that nitrogen in the form of nitrate will not be leached below the tree root zone and potentially reach the groundwater. This is particularly important where more limited soil area is wetted with the irrigation delivery system and/or sandy soils are being managed.

Figure 1. Almond meat yields in 1994 as influenced by nitrogen rate and water applied through drip system.

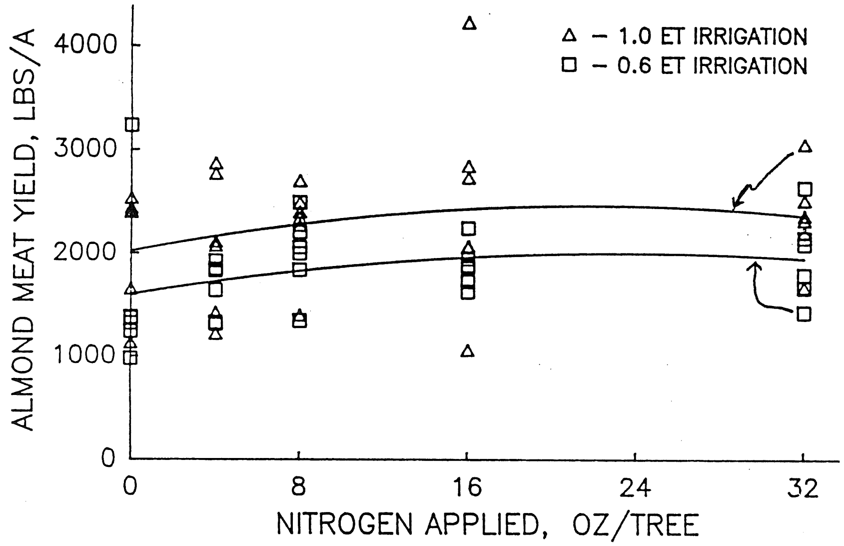

Figure 2. Butte almond meat yields in 1994 as influenced by nitrogen rate and water applied through drip system.

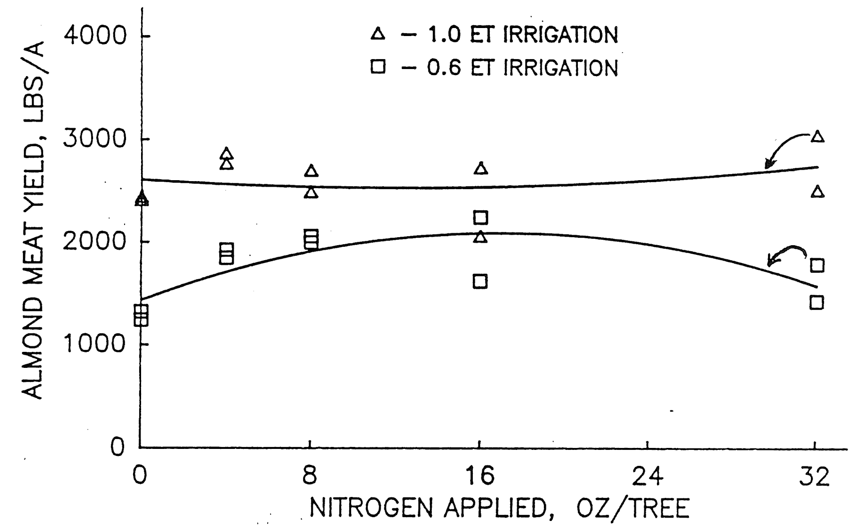

Figure 3. Carmel almond meat yields in 1994 as influenced by nitrogen rate and water applied through drip system.

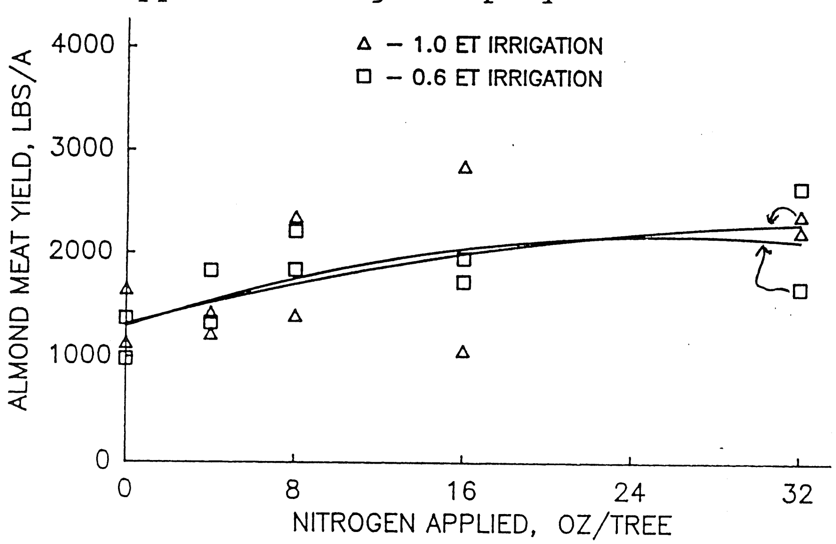

Figure 4. NonPareil almond meat yields in 1994 as influenced by nitrogen rate and water applied through drip system.

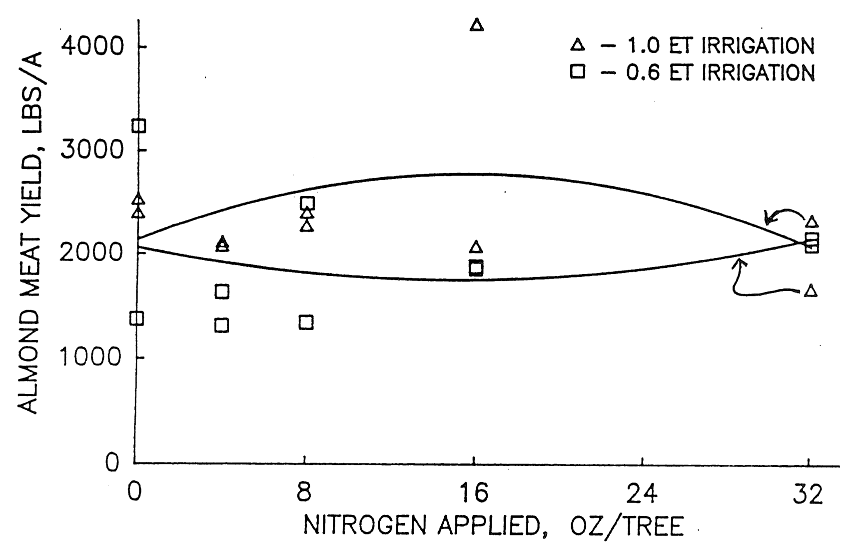

Figure 5. Almond meat yields in 1994 as influenced by nitrogen rate and water applied through drip system.

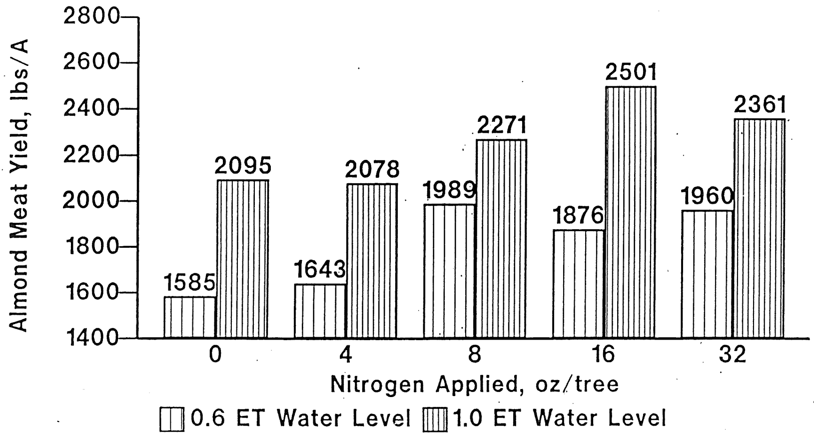

Figure 6. Almond leaf total nitrogen throughout 1994 for five rates of drip irrigation applied nitrogen.

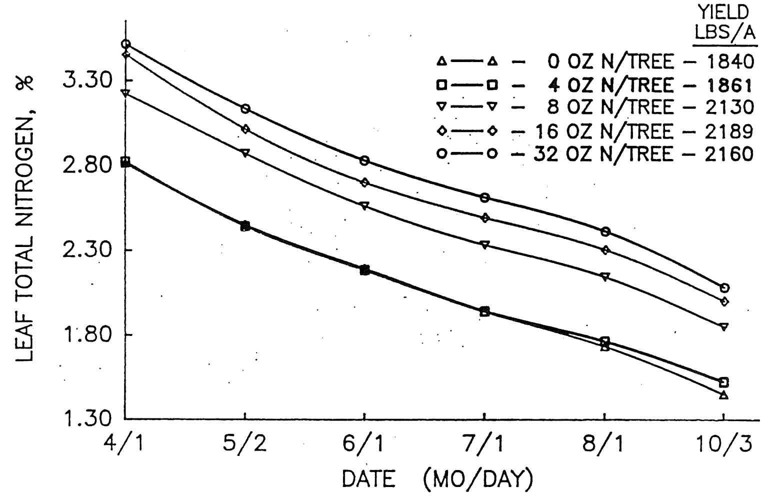

Figure 7. Almond leaf total manganese throughout 1994 for five rates of drip irrigation applied nitrogen.

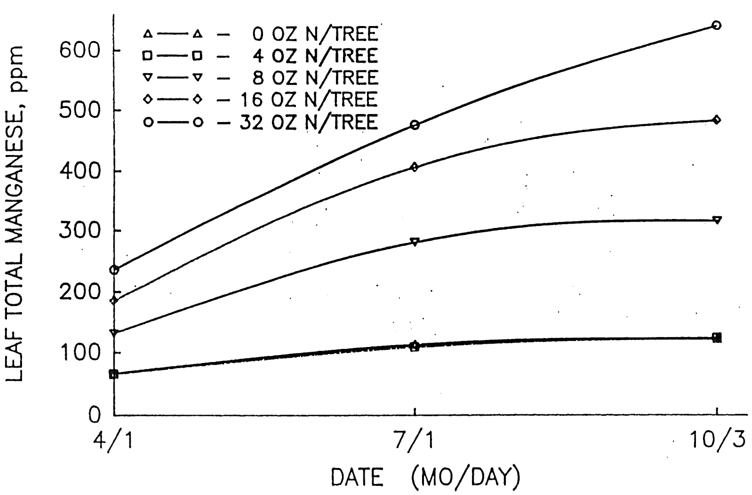

Figure 8. Almond leaf total potassium throughout 1994 for four drip irrigation applied potassium and nitrogen treatments.

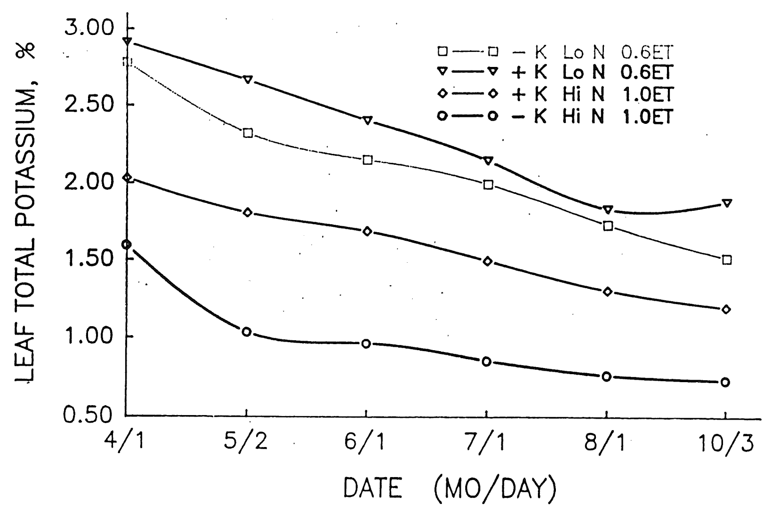

Table 1. Average pH for the surface five feet of soil at different distances from the emitter for six nitrogen fertilizer treatments.

Trt.#	Fertilizer	Distance from emitter, inches				
		0	8	16	24	32
1	$Ca(NO_3)_2$	5.32	6.26	6.89	7.01	6.85
9	Urea-$Ca(NO_3)_2$	4.95	5.26	5.88	6.28	6.28
3	UN 32	4.85	5.00	5.35	6.13	6.34
2	Urea	4.91	4.69	5.02	5.84	6.14
6	Urea	4.53	4.85	5.36	6.12	6.14
10	N-phuric	4.52	4.74	4.98	5.07	5.08

Table 2. Average nitrate-N concentration (ppm) in the surface five feet of soil at different distances from the emitter for six nitrogen fertilizer treatments.

Trt.#	Fertilizer	Distance from emitter, inches				
		0	8	16	24	32
1	$Ca(NO_3)_2$	37.9	15.9	4.9	4.6	2.6
9	Urea-$Ca(NO_3)_2$	13.6	13.6	9.5	7.1	4.1
3	UN 32	16.5	6.5	3.7	3.4	0.9
2	Urea	17.1	27.4	22.3	14.1	6.9
6	Urea	13.6	8.0	6.9	7.8	7.2
10	N-phuric	6.2	4.9	5.1	2.6	6.3

Table 3. Average ammonium-N concentration (ppm) in the surface five feet of soil at different distances from the emitter for six nitrogen fertilizer treatments.

Trt.#	Fertilizer	Distance from emitter, inches				
		0	8	16	24	32
1	$Ca(NO_3)_2$	10.5	3.8	3.0	2.8	2.5
9	Urea-$Ca(NO_3)_2$	15.4	6.5	4.9	3.5	3.7
3	UN 32	19.4	10.7	3.7	2.8	2.3
2	Urea	9.0	9.7	7.4	4.9	2.7
6	Urea	48.8	10.7	10.4	4.1	2.8
10	N-phuric	17.7	12.4	8.1	6.4	7.2

Table 4. Soil Profile pH -- Winter 1993

Fertilizer Source - Calcium Nitrate

Depth, in	Distance from emitter, in: 0	8	16	24	32
0 - 6	5.6	6.8	7.2	7.2	6.9
6 - 12	4.6	5.9	7.0	7.0	7.0
12 - 18	4.2	5.9	6.9	6.9	7.0
18 - 24	4.3	6.0	6.8	7.2	6.7
24 - 30	4.8	5.5	7.0	7.4	6.8
30 - 36	5.1	6.5	7.0	7.1	7.0
36 - 42	5.8	6.6	6.9	7.0	7.0
42 - 48	6.4	6.6	6.8	6.9	6.9
48 - 54	6.2	6.6	6.7	6.8	6.6
54 - 60	6.3	6.4	6.6	6.6	6.6
60 - 66	6.3	6.3	6.4		
66 - 72	6.3	6.4	6.4		
72 - 78	6.4	6.4			
78 - 84	6.5	6.5			
84 - 90	6.4	6.5			
90 - 96	6.5	6.5			
96 -102	6.5				
102-108	6.5				
108-114	6.4				
114-120	6.4				

Table 5. Soil Profile pH -- Winter 1993

Fertilizer Source - N-phuric

Depth, in	Distance from emitter, in: 0	8	16	24	32
0 - 6	4.5	4.9	5.7	5.7	5.4
6 - 12	3.7	4.0	4.3	4.5	4.0
12 - 18	3.5	3.9	3.8	3.7	3.8
18 - 24	3.5	3.6	3.8	3.8	4.1
24 - 30	3.8	3.8	4.2	4.3	4.7
30 - 36	4.4	4.5	5.0	5.0	5.4
36 - 42	4.8	5.2	5.3	5.7	5.6
42 - 48	5.4	5.8	5.9	6.0	5.9
48 - 54	5.8	5.9	5.9	6.1	5.9
54 - 60	5.8	5.9	6.0	5.9	5.9
60 - 66	6.0	5.8	6.3		
66 - 72	6.1	6.1	6.2		
72 - 78	6.2	6.2			
78 - 84	6.2	6.2			
84 - 90	5.5	6.2			
90 - 96	5.8	6.3			
96 -102	5.7				
102-108	5.5				
108-114	5.9				
114-120	6.0				

Table 6. Soil Nitrate-N Levels -- Winter 1993

Fertilizer Source - Calcium Nitrate

Depth, in	Distance from emitter, in: 0	8	16	24	32
0 - 6	4	1	1	1	2
6 - 12	6	1	0	11	3
12 - 18	27	6	2	13	9
18 - 24	95	31	18	5	0
24 - 30	71	64	7	1	0
30 - 36	66	12	2	2	2
36 - 42	27	4	2	2	1
42 - 48	13	5	3	1	1
48 - 54	25	6	3	3	2
54 - 60	45	29	10	7	6
60 - 66	42	34	25		
66 - 72	36	30	21		
72 - 78	23	22			
78 - 84	21	17			
84 - 90	20	17			
90 - 96	18	13			
96 -102	22				
102-108	19				
108-114	24				
114-120	26				

Table 7. Soil Nitrate-N Levels -- Winter 1993

Fertilizer Source - N-phuric

Depth, in	Distance from emitter, in: 0	8	16	24	32
0 - 6	3	1	1	1	5
6 - 12	1	1	0	1	17
12 - 18	2	1	1	0	6
18 - 24	3	2	2	2	7
24 - 30	2	3	2	2	5
30 - 36	3	8	8	1	3
36 - 42	9	3	9	2	3
42 - 48	14	7	9	3	4
48 - 54	12	10	9	4	5
54 - 60	13	13	10	10	8
60 - 66	8	7	6		
66 - 72	8	7	4		
72 - 78	6	4			
78 - 84	6	5			
84 - 90	12	9			
90 - 96	15	11			
96 -102	13				
102-108	15				
108-114	15				
114-120	15				

Table 8. Soil Ammonium-N Levels -- Winter 1993

Fertilizer Source - Calcium Nitrate

Depth, in	Distance from emitter, in: 0	8	16	24	32
0 - 6	25	19	8	9	7
6 - 12	37	6	7	5	4
12 - 18	17	3	3	4	3
18 - 24	13	3	5	3	3
24 - 30	3	2	1	3	3
30 - 36	3	1	2	1	1
36 - 42	2	1	1	1	1
42 - 48	1	1	1	0	1
48 - 54	2	1	1	1	1
54 - 60	2	1	1	1	1
60 - 66	1	1	0		
66 - 72	1	1	1		
72 - 78	0	0			
78 - 84	1	1			
84 - 90	1	1			
90 - 96	1	0			
96 -102	1				
102-108	1				
108-114	1				
114-120	1				

Table 9. Soil Ammonium-N Levels -- Winter 1993

Fertilizer Source - N-phuric

Depth, in	Distance from emitter, in: 0	8	16	24	32
0 - 6	56	19	16	15	16
6 - 12	33	17	7	16	16
12 - 18	12	26	16	8	12
18 - 24	25	22	19	10	13
24 - 30	27	30	12	7	6
30 - 36	4	4	4	3	4
36 - 42	4	3	2	2	2
42 - 48	8	1	1	1	1
48 - 54	2	1	2	1	1
54 - 60	6	1	2	1	1
60 - 66	1	1	1		
66 - 72	2	1	1		
72 - 78	1	1			
78 - 84	1	1			
84 - 90	4	2			
90 - 96	2	1			
96 -102	3				
102-108	5				
108-114	1				
114-120	5				

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Effect of Nitrogen Rate and Drip Irrigation on Almond Production

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Robert J. Zasoski and Herbert Schulbach

Drip and other limited soil volume irrigation is a unique method of providing water to trees which makes for a number of challenging management situations. Since water is applied to a more limited soil area, excessive amounts may move and also leach nutrients more rapidly than when other irrigation systems are used. Having a relative small volume of soil being used as the reservoir for water and nutrient uptake which is near saturation a high percent of the time during the summer provides a setting for several unusual chemical reactions in the soil. The use of an acidifying nitrogen fertilizer such as urea increases the solubility of toxic elements like manganese and aluminum. Soil sampling of the high nitrogen-high water treatment has indicated nitrates may have been leached below the root zone immediately below the drip emitter. Lower total leaf nitrogen in samples from calcium nitrate treatments would suggest that denitrification may also be occurring at a rather rapid rate which could result in reduced nitrogen efficiency by the crop. Rapid tree growth and higher yields from higher nitrogen rates has reduced leaf potassium levels below the desired range. Treatments where potassium has been added show significant increases in leaf potassium and a trend for increased yield. Because the answers to a number of these questions are still unknown, this project was initiated and the continuing challenges will allow for the development of solutions so that growers can manage fertilizer application through drip irrigation systems to achieve profitable almond production and not adversely affect the environment.

<u>Objectives</u>: (1) To evaluate the effects of different nitrogen rates applied at two water levels on growth, nutrient concentrations in leaves, and nut yields of almonds. 2) To assess the

small) leaves were collected from each of 5 trees per individual plot, dried, ground and mixed thoroughly. Total nitrogen and potassium analysis were run on all samples with phosphorus, calcium, sulfur, zinc, manganese, copper and boron run on the samples collected in April, July and October.

Soil samples were taken during the October through December 1992 period from several of the nitrogen rate-water level treatments. Samples were taken immediately under and at 12, 24, 36 and 48 inch distances from the emitter all at equal distance from the tree trunk. Soil was sampled at six inch increments to depths down to ten feet under the emitter and analyzed for nitrate, ammonium, calcium and magnesium in a one molar KCl extract. Soil pH and electrical conductivity was determined on a saturated paste.

Results: Yields in 1994 were slightly lower than in 1993 with three plots having yields greater than 3000 and 11 plots (out of 60) greater than 2500 meat lbs/A. The lowest plot yield was 973 and the highest was 4233. Average yields for the three varieties Carmel, Butte and NonPareil (20 plots each) were 1757, 2177 and 2174 meat lbs per acre respectively. There was a trend for yields to increase from the lowest nitrogen rate (0 oz/tree) to the fourth rate (16 oz/tree) at the 1.0 ET water level while at the 0.6 ET water level, the increase occurred between the lowest to the intermediate (8 oz/tree) nitrogen rate (Figure 1). The early application of nitrogen -- one third of total on 4/1, 5/1 and 7/1 resulted in a significantly higher yield (2239 versus 1833 meat lbs/A) than the late timing -- one third each on 6/1, 8/1 and 9/1. A significantly higher yield of 450 meat lbs/A for the higher 1.0 ET irrigation level was consistent across all five nitrogen rates. There was no significant difference between the no potassium treatment and where potassium was applied (1944 versus 2129 meat lbs/A).

Leaf samples taken on April 1, May 2, June 1, July 1, August versus 8). At the present the only observed effect of the soil acidification has been the increasingly higher leaf manganese levels (Figure 4). No effect on leaf, bark or tree growth has been observed.

Discussion: Although earlier years' data are not presented, the 1994 research results continue to show (for the 11th year) that the easiest, most accurate and economical way to assess the nitrogen status of almonds for optimum production is by the use of leaf analysis with a July (1st week) leaf sampling for total nitrogen concentration. The desirable range is from 2.2 to 2.5% total nitrogen. Rates of nitrogen application should be increased if leaf nitrogen concentrations are below 2.2%. If levels are consistently (for several years) higher than 2.6%, strong consideration should be given to reducing the rate of nitrogen application. July leaf samples can effectively indicate the status of other nutrients required for optimum almond production. Sustained high yields and vigorous tree growth require large amounts of nutrients, specially potassium. After observing the large differences in leaf potassium concentrations during the early part of the growing season, followed by nearly the same levels being reached by July 1st, it seems advisable for growers to consider taking leaf samples several times during the year, near April 1 and near July 1 from at least three areas within a field. The three areas should represent low, medium and high producing portions of the field and if leaf analysis indicate large differences in potassium or other nutrients in the early season samples it may indicate an approaching deficient situation.

Soil sampling in 1985 and 1989 of the lowest nitrogen rate-low water level treatment revealed very little, if any nitrate movement below the root zone. Nitrate concentrations in the soil under the emitter of the highest nitrogen rate-high water level were quite high (>50 ppm at 6.0-6.5 ft depth) in 1989, suggesting considerable nitrate movement below the root zone.

Figure 1. Almond meat yields in 1994 as influenced by nitrogen rate and water applied through drip system.

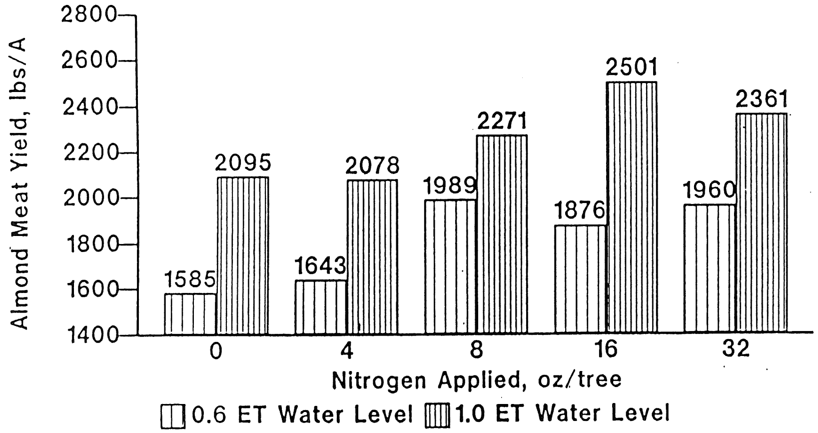

Figure 2. Almond leaf total nitrogen throughout 1994 for five rates of drip irrigation applied nitrogen.

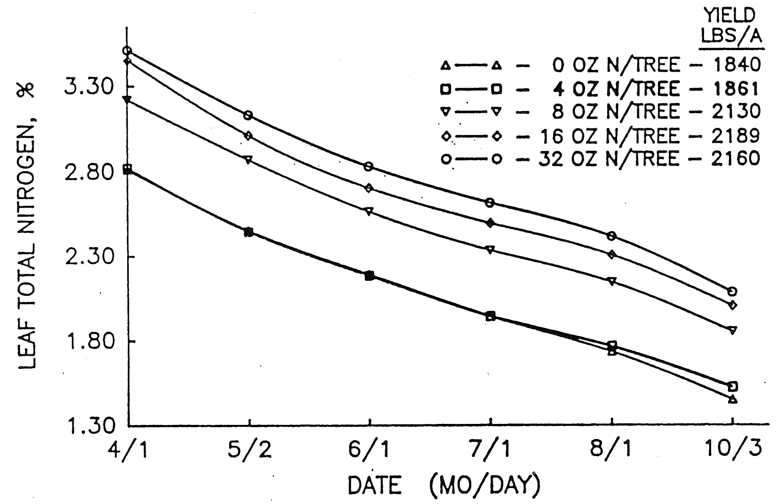

Figure 3. Almond leaf total manganese throughout 1994 for five rates of drip irrigation applied nitrogen.

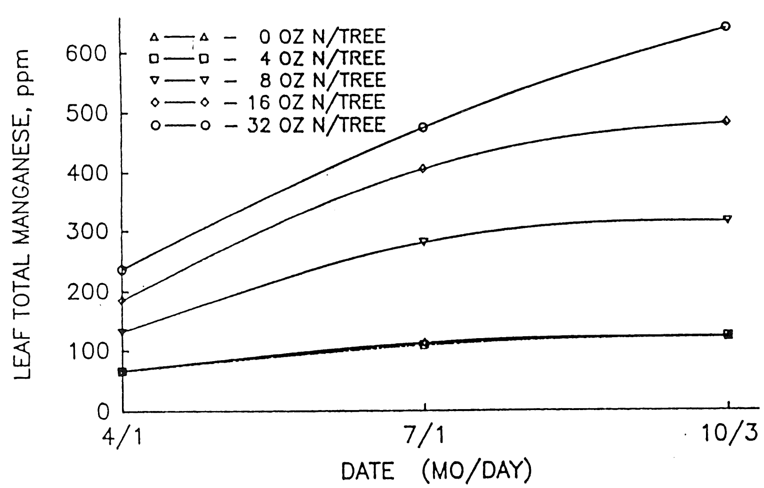

Figure 4. Almond leaf total potassium throughout 1994 for four drip irrigation applied potassium and nitrogen treatments.

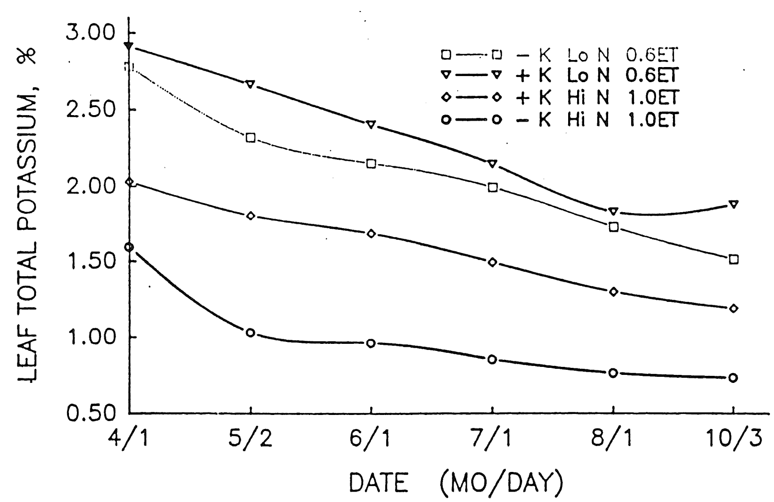

Table 5. Soil Profile pH -- Fall 1992
Treatment No. 8

	Distance from emitter, in				
Depth, in	0	12	24	36	48
0 - 6	6.6	5.7	6.7	6.3	6.5
6 - 12	4.6	5.2	6.3	6.0	6.1
12 - 18	4.0	4.2	6.0	6.0	5.9
18 - 24	4.2	4.7	5.9	6.0	6.1
24 - 30	4.9	5.3	6.5	6.3	6.2
30 - 36	5.3	5.8	6.6	6.4	6.4
36 - 42	5.5	6.3	6.6	6.6	6.5
42 - 48	5.8	6.3	6.7	6.6	6.5
48 - 54	6.0	6.5	6.7	6.5	6.5
54 - 60	6.1	6.7	6.8	6.5	6.6
60 - 66	6.4	6.7	6.7		
66 - 72	6.4	6.4	6.6		
72 - 78	6.5	6.6			
78 - 84	6.6	6.5			
84 - 90	6.6				
90 - 96	6.7				
96 -102	6.8				
102-108	6.8				

Table 6. Soil Profile pH -- Fall 1992
Treatment No. 10

	Distance from emitter, in				
Depth, in	0	12	24	36	48
0 - 6	6.5	6.5	6.0	6.4	6.5
6 - 12	5.0	5.5	5.7	5.6	5.3
12 - 18	4.4	4.4	5.7	5.5	5.6
18 - 24	3.9	4.1	5.5	5.6	5.7
24 - 30	4.0	4.2	5.2	5.8	5.8
30 - 36	3.8	4.1	5.4	5.7	5.7
36 - 42	4.1	4.1	5.5	5.8	5.9
42 - 48	4.1	4.1	5.9	5.9	5.9
48 - 54	4.2	4.5	5.7	5.9	6.0
54 - 60	4.3	4.8	5.6	5.9	6.0
60 - 66	4.6	5.0	5.9		
66 - 72	5.1	5.2	5.8		
72 - 78	5.6	5.3	5.6		
78 - 84	5.9	5.5	5.6		
84 - 90	6.2	6.0	5.7		
90 - 96	6.3	6.4	5.8		
96 -102	6.5	6.5	5.6		
102-108	6.4	6.5			
108-114	6.4	6.4			
114-120	6.1				

Table 7. Profile Calcium Levels -- Fall 1992
Treatment No. 8, ppm

	Distance from emitter, in				
Depth, in	0	12	24	36	48
0 - 6	915	810	749	687	696
6 - 12	423	564	532	681	657
12 - 18	142	218	801	789	822
18 - 24	863	584	1364	1208	1521
24 - 30	1133	1527	1536	1543	1678
30 - 36	1001	1569	1527	1430	1456
36 - 42	960	1403	1356	1460	1346
42 - 48	1214	1489	1360	1462	1126
48 - 54	1398	1493	1469-	1505	1075
54 - 60	1405	1649	1462	1509	1396
60 - 66	1617	1765	1649		
66 - 72	1492	1402	1225		
72 - 78	1131	1176			
78 - 84	1234	1130			
84 - 90	1218				
90 - 96	1235				
96 -102	1040				
102-108	1148				

Table 8. Profile Calcium Levels -- Fall 1992
Treatment No. 10, ppm

	Distance from emitter, in				
Depth, in	0	12	24	36	48
0 - 6	787	680	528	496	566
6 - 12	333	601	502	521	629
12 - 18	149	100	612	640	774
18 - 24	58	43	717	711	892
24 - 30	168	136	665	839	1022
30 - 36	49	81	729	1000	1182
36 - 42	79	101	938	1112	1126
42 - 48	306	418	1105	1429	1296
48 - 54	671	931	1067	1453	1393
54 - 60	927	1019	1324	1618	1544
60 - 66	1366	1313	1524		
66 - 72	1462	1479	1479		
72 - 78	1547	1444	1284		
78 - 84	1203	1358	1098		
84 - 90	1212	1163	969		
90 - 96	1096	1077	1080		
96 -102	1110	1133	887		
102-108	1068	920			
108-114	914	878			
114-120	989				

New advice for applying nitrogen to drip-irrigated orchards aims for maximum yields and minimum nitrate leaching.

A Fine Line

Best N rates for drip irrigation

Can almond growers maximize yields and at the same time be politically correct on the nitrates-in-groundwater issue? "Impossible!" you say? Then take heart. Roland Meyer of UC Davis' Department of Land, Air and Water Resources and associates John Edstrom, Herb Schulbach and the Nickels Soil Laboratory have uncovered the means of walking that fine line.

In the Almond Board research project, *Nitrogen on Drip Irrigated Orchards*, they have found that, for best yields without adding to the groundwater nitrate problem, growers should aim for an early-July leaf N concentration of 2.2 percent to 2.5 percent with water applied at 1.0 of ET (evapotranspiration rate). In their tests, the optimum N application rate in terms of yield has been 16 ounces per tree per year at 1.0 ET. At that rate, significant amounts of nitrates did not leach below the root zone.

Predictably, yields increased as the amount of N applied increased from zero. However, production levelled off at 16 ounces of N per tree and did not rise as the amount of N was increased beyond that point. At the higher levels (above 16 ounces N per tree) nitrates leached below the root zone

In the study, irrigation water was applied at 60 percent and 100 percent of ET. Yields peaked at 16 ounces of N at both 60 percent and 100 percent ET.

Better Early Than Late

Timing of N applications has a major impact on yields, too, notes Meyer. In their tests, the researchers compared two application schedules in which one-third of the annual amount of N was applied on each of three dates. They discovered that early application of N is better by far than a later schedule. When applications of N were made on April 1, May 1 and July 1, the test orchard yielded 2,239 meat pounds per acre. Applications made on June 1, August 1 and September 1 produced 1,833 meat pounds per acre.

Everyone knows that the amount of water applied also affects yields, but Meyer's team found that water application rates affect yields without regard for N levels. When full water (1.0 ET) was applied to each of the N application rates being tested, yields rose 450 meat pounds in every case.

The varieties used in the study are Butte, Carmel and Nonpareil.

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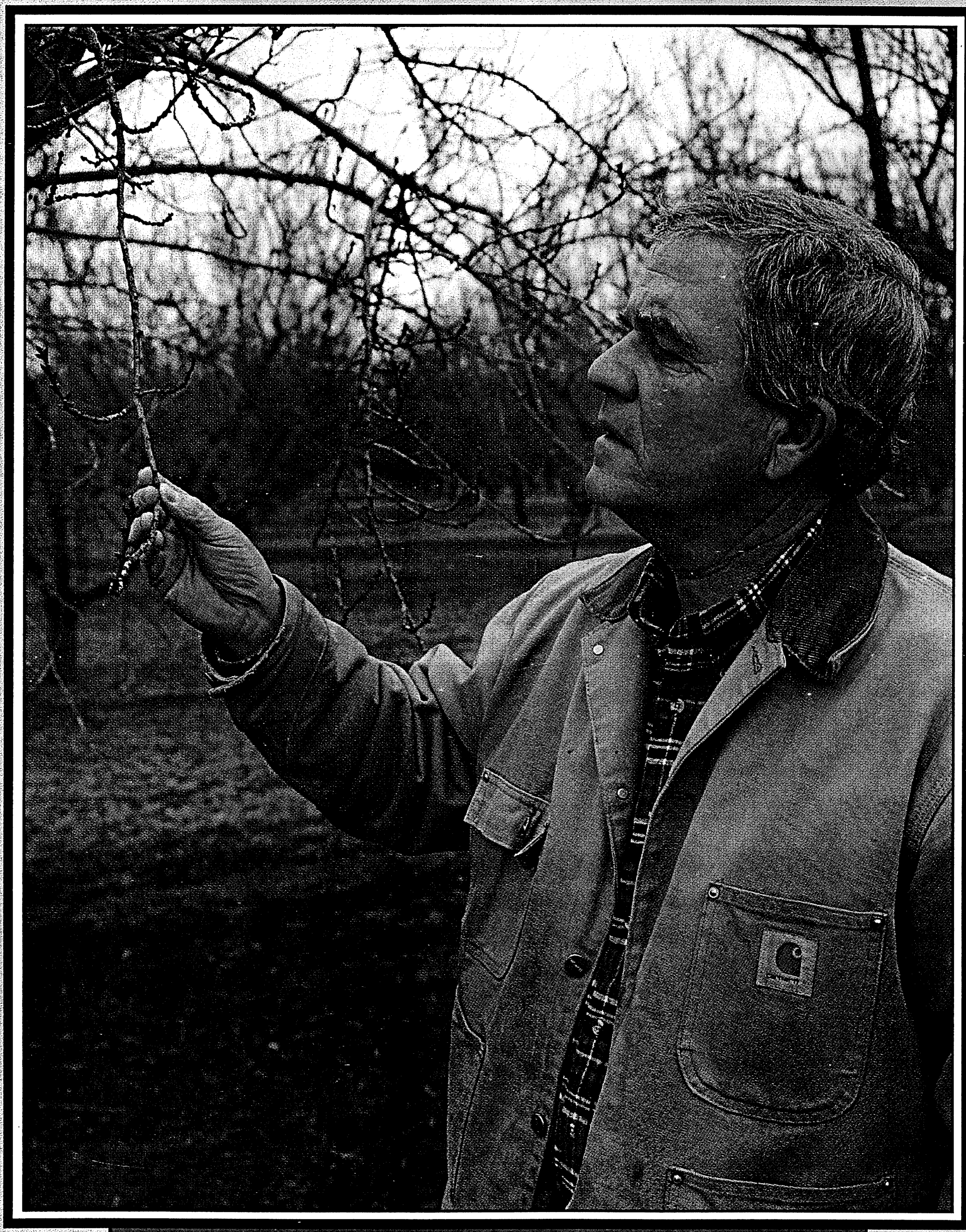


Bloom Protection

Almond Ads Canceled!

GATT Tariffs

Nitrogen Management in Drip Irrigated Almonds

By Dr. Roland D. Meyer
UC Extension Soils Specialist

The easiest, most effective and economical way for growers to assess the nitrogen status of almonds is by the use of leaf analysis with a July first-leaf sampling for total nitrogen (N) concentration. Leaf samples were taken the first week in July and analyzed for total nitrogen from a drip-irrigated nitrogen rate trial beginning in 1984. The were related to almond meat yields from three varieties: nonpareil, butte and carmel.

In 1984, of the five nitrogen rates applied, only the highest rate of 16 ounces N per tree resulted in a leaf nitrogen concentration above the recommended 2.2-percent nitrogen level on July 6. The meat yields increased with more applied N and were the highest at the 16-ounces-per-tree nitrogen rate.

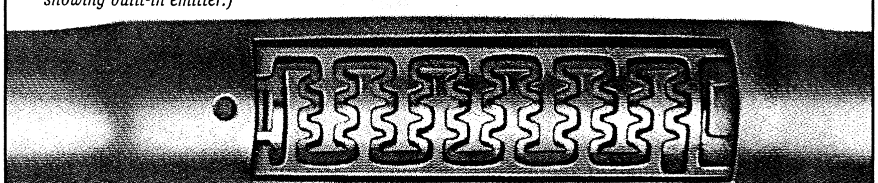
The leaf nitrogen levels for 1985 indicated that only the highest applied nitrogen rate (32 ounces per tree) was above 2.2 percent on July 3. It should be noted however that both the 16 and 24 ounces N per tree applied nitrogen rates had very close to the 2.2-percent level, but had significantly lower meat yields.

The 1986 leaf nitrogen levels on July 7 for the 24, 36 and 48 ounces per tree nitrogen rates were all near or just slightly above 2.2 percent and the meat yields are likewise very similar.

In 1987, the leaf nitrogen levels for the three higher nitrogen rates were again nearly the same and all three had significantly greater yields than the two lower-applied nitrogen rates (8 and 16 ounces N per tree) which had less than 2.2 percent leaf N levels. Almost the same situation occurred in 1988 as was observed in 1987.

The leaf nitrogen levels were similar for the three higher nitrogen rates in early July, whereas the yields in 1989 were similar for the four highest applied nitrogen rates. The three highest nitrogen rates had leaf levels above 2.3 percent whereas the 12 and 6 ounces N per tree rate were just slightly below 2.2 percent.

Leaf N levels greater than 2.5 percent were required to achieve high yields in 1990, whereas levels higher than 2.3 percent were necessary in 1991. In 1992 and 1993, the nutrient concentrations for the July sample date indicated that the three highest applied



BSP Lime-Sulfur Solution Approved For Nuts

The U.S. Environmental Protection Agency and Cal/EPA have approved additional uses for BSP Lime-Sulfur Solution on almonds and pecans to control certain insects, mites and diseases.

BSP Lime-Sulfur Solution (calcium polysulfide) contains 22 percent colloidal sulfur and 6.6 percent soluble calcium. Its high alkaline allows it to act as a contact pesticide regardless of temperature conditions. The fine particle size of its colloidal sulfur allows for even distribution on targeted surfaces, and because it sticks tenaciously, it provides a residual effect and extended protection.

Under the new label guidelines, almond growers may use BSP Lime-Sulfur Solution to control brown rot blossom blight during the pre-bloom, early-bloom and full-bloom stages. The product can also now be used to treat pecans. ❑

nitrogen rates (16, 24 and 32 ounces per tree in 1992 and 8, 16 and 32 ounces per tree in 1993) were all above the minimum suggested of 2.2 percent. Also, total nitrogen increased in the twig samples taken on Jan. 24, 1992 from the lowest to the third nitrogen rate for both water levels.

These data indicate that it is doubtful yields will increase when leaf nitrogen levels are above 2.5 percent during the first week in July sampling. A summary of the leaf nitrogen level for the first week in July, the nitrogen rate to achieve that N level, and the meat yield (pounds per acre) for each year is given in the following table.

Year	Nitrogen Level (percent)	Nitrogen Rate (oz/tree)	Optimum Yield (lbs/acre)
1984	2.2	16	1375
1985	2.2	32	1850
1986	2.2	24 - 36	1800
1987	2.5	32 - 48	3100
1988	2.3	32 - 48	2300
1989	2.4	24 - 36	3000
1990	2.5	16 - 24	2750
1991	2.4	16 - 24	2800
1992	2.4	16 - 24	2300
1993	2.2	8 - 16	2500

The large yields harvested from the treatments with high rates of applied nitrogen have resulted in significantly lower leaf potassium concentrations in these trees. Leaf total potassium has significantly increased in the high nitrogen and high water treatments where potassium was applied (1.5 pounds K_2O per tree in 1989, plus 2 pounds K_20 per tree in 1990 and 1993). Even though yields have shown a similar trend for improvement where potassium has been applied, significant differences have not yet been recorded.

The effect of water level (0.6 versus 1.0 ET) applied through the drip irrigation system may also have a significant effect on almond yields. For the years 1984 through 1988, yields ranged from approximately 100 to as much as 400 meat pounds per acre more for the 1.0 ET water level than the 0.6 ET level.

From 1989 through 1993, yields were nearly the same for the three highest nitrogen rates at the 1.0 ET water level, and were 500-1,000 meat pounds per acre more than for the 0.6 ET water level. The 0.6 ET water level showed only a slight increase in meat yields from the lowest to next-highest nitrogen rate and remained the same at higher rates of applied nitrogen.

It should be noted that rates used from 1990-1993 were about half those used during 1987 and 1988, when substantial nitrogen was being utilized to grow the trees as well as produce the large meat yields. Yields in the 3,000 to 3,500 meat pounds per acre range would remove approximately 180 to 210 pounds nitrogen per acre, meaning that the recovery of the two highest nitrogen fertilizer rates, 24 and 32 ounces per tree, or 300 and 400 pounds N per acre, would be about 50 to 60 percent (180/300 x 100 = 60 percent; 200/400 x 100 = 50 percent).

For the 16-ounces-per-tree or 200-pounds-per-acre fertilizer rate, the recovery would be 75 to 90 percent. Thus, the yield for this middle rate can be expected to decrease further during this coming year because of the difficulty maintaining a 70- to 80-percent nitrogen recovery.

Another very interesting tree growth parameter observed during the winters of 1990 and 1991 was the lack of adequate new shoot growth. In past years, the amount—both the number and length of new shoot growth—has had a strong relationship to the rate of nitrogen applied. That is, more shoot growth is associated with higher nitrogen application rates. The lack of much shoot growth would suggest that excessive rates are not being applied or that slight periods of water stress during the active shoot growth period resulted in this phenomenon.

Therefore, this suggests that high nitrogen rates can be utilized by almonds during the early growth and development of the tree, which also has a varying need for nitrogen to produce large kernel yields. After the tree structure has been developed, the need for nitrogen is not as great, with the major portion going into the kernels and a lesser portion going into the development of new fruiting wood.

Another very important point to remember is that higher rates of nitrogen fertilizer will not be effectively utilized unless adequate amounts of irrigation water are applied. Thus if for any reason water supplies might be limiting such as during a drought year, applying a rate slightly below the "full" rate would be advisable. On the other hand, excessive irrigation water applications should be avoided so that nitrogen in the form of nitrate will not be leached below the tree root zone and potentially reach the groundwater. ❑

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BLOOM PROTECTION

ALMOND ADS CANCELED!

GATT TARIFFS

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