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ANNUAL REPORT TO THE ALMOND BOARD OF CALIFORNIA

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Nitrogen on Drip Irrigated Almonds

by

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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 nitrogen application under drip emitters. (3) To evaluate the effects of two rates of potassium on growth, nutrient concentrations in leaves and nut yields. (4) To develop recommendations for nitrogen, irrigation and soil management for use in the establishment and early maturity stages of almond orchards. (5) Evaluate changes in nutrient movement in drip zone as a result of acidification, leaching and nutrient uptake.

Problem and its Significance: Drip irrigation is a unique method of providing water to trees which makes for a number of challenging management situations. 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 during 1992. 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 on 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 planned for 1993 are 0, 4, 8, 16 and 32 oz/tree. Urea is the nitrogen fertilizer source and it is applied on a monthly basis in five (6 in 1986-89) equal increments beginning April 1st. Plans for 1993 are to apply 1/3 of the total on about April, May and July 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.

Yields in 1992 were somewhat lower than in the past several years with only two plots having yields greater than 3000 and 8 plots (out of 60) greater than 2500 meat pounds per acre. The lowest plot yield was 1019 and the highest was 3233. Average yields for the three varieties Butte, Carmel and Nonpareil (20 plots each) were 2135, 1543 and 2022 meat pounds per acre respectively. There was an increase in yield from the lowest nitrogen rate (4 oz/tree) to the third rate (16 oz/tree) with a leveling off at the higher rates and a trend for a decrease at the highest rate (32 oz/tree) at the 0.6 ET irrigation level (Figure 1). The yield differences between the 0.6 and 1.0 ET irrigation levels were 200 to 500 meat pounds per acre across the five nitrogen rates (Figure 1). Meat yield responses for the three varieties to nitrogen rate at the two water levels are given in Figures 2-4. Nine year accumulative meat yields are illustrated in Figure 5. Yields increase from the lowest nitrogen rate to the third rate and then level off or possibly decline slightly at the lower (0.6 ET) water level.

The first observations taken at the beginning of each year, usually early January, have been tree trunk circumference or diameter measurements to monitor tree growth the previous season. Tree cross-sectional area was calculated for the 1991 growing season (299 trees) and the data analyzed to indicate that the high water level along with some of the higher and lower nitrogen rates had significantly greater increases in growth. The intermediate nitrogen rates at the low water level generally resulted in the smaller growth increases. These growth increases are similar to those observed in 1990 but somewhat different from earlier years when nitrogen rate was the more dominant factor in influencing trunk growth than water level. Significant differences were observed between varieties as the Butte variety had greater growth increases than the Nonpareil and both had larger increases than the Carmel. Previous year's growth increases have indicated that Butte has had equal or greater increases than Nonpareil and that Nonpareil has had equal or greater increases than the Carmel variety.

Twig samples taken in January (60 plots) indicated significant differences among nitrogen rate-water level treatments for concentrations of total nitrogen (N), sulfur (S), zinc (Zn) and manganese (Mn) but no differences for phosphorus (P), potassium (K) and calcium (Ca). Higher twig total N, S and Mn concentrations were associated with higher applied nitrogen rates and the lower water level while lower concentrations were observed for the higher water level at each of the nitrogen rates. Total nitrogen increased in the twigs from the lowest to the third nitrogen rate for both water levels (Figure 7). Twig total zinc was highest with the higher nitrogen rates irrespective of water level.

Significant differences in leaf nutrient concentrations for the nitrogen rate-water level treatments were observed in the April sampling: N, P, K, Ca, magnesium (Mg), S, Mn and copper (Cu); the May sampling: N, P and K; the June sampling: N, P and K; the July sampling: N, K, Ca, Mg, S, Mn, Cu and Boron (B); and the August sampling: N and K. No significant differences were noted in the April sampling for leaf total Zn and B or in the July P and Zn. Responses were generally of two types: those where leaf nutrient concentrations increased as the applied nitrogen rate increased at both water levels and the second type where the leaf concentrations decreased as applied nitrogen increased, again at both water levels. The sample date-nutrients in the first response type were the April N, S, Mn, Cu; May N; June N; July N, Mg, S, Mn, Cu: and the August N. The sample date-nutrients in the second response type were the April P, K, Ca, Mg; May P, K; June P, K; July K, Ca, B; and the August K. The nutrient concentrations for the July sample date indicated that the three highest applied nitrogen rates (16, 24 and 32 oz/tree) were all above the minimum suggested of 2.2% (Figure 6). The minimum concentration of each of the other nutrients was 0.10% P, 1.30% K, 2.85% Ca, 0.89% Mg, 1280ppm S, 12ppm Zn, 60ppm Mn, 5ppm Cu and 29ppm B. These concentrations were in the adequate range for optimum almond production. The highest manganese concentration of 718ppm was reached in the highest nitrogen-lower water treatment in the October sampling while the highest nitrogen-higher water treatment concentration was 572ppm.

Figure 8 illustrates the leaf total potassium from early April to August for several intermediate low nitrogen-low water and high nitrogen-high water treatments to which two potassium rates (0 and 1.5 lbs K_2O/tree in 1989 plus 2 lbs K_2O/tree in 1990) were applied. Note particularly how the leaf potassium has been increased significantly for the intermediate high nitrogen-high water treatment where potassium applications have been made. Even though yields have shown a similar trend for improvement where potassium has been applied, significant differences have not yet been recorded (Figure 8).

Soil sampling has been completed and laboratory analysis is currently underway to investigate pH, nitrate, ammonium and other cation distribution under the emitter basins of several intermediate nitrogen rates at both water level treatments. Samples were taken immediately under and at various distances from the emitters to sufficient depth to assess nitrate and other nutrient movement within the "emitter ball" and below the root zone. Complimentary funding from the Fertilizer Research and Education Program of the California Department of Food and Agriculture has provided more extensive sampling of nitrogen rate-water level treatments.

The nitrogen source trial initiated in 1986 has ten treatments: (1) calcium nitrate annually, (2) calcium nitrate alternated yearly with urea, (3) urea-ammonium nitrate solution 32 annually, (4) N-phuric (urea-sulfuric acid) annually and (5) through (10) urea annually 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 has been applied for to take soil samples to assess the degree of nitrate movement in the soil profile as well as reassess the degree of change of acidification prior to the application of different lime, gypsum, potassium hydroxide and perhaps other treatments during 1993.

<u>Discussion</u>: Our research continues to show (for the 9th year) 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 2.2 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.

The approval of a complimentary proposal from the California Department of Food and Agriculture-Fertilizer Research and Education Program in 1992 has provided the necessary resources to assess the extent of nitrate leaching for several of the intermediate rates as well as resample the lowest and highest rates of applied nitrogen. Sampling in 1985 and 1989 of the lowest rate revealed very little, if any nitrate movement below the root zone. Nitrate concentrations in the soil under the emitter of the highest nitrogen rate were quite high (>50 ppm at 6.0-6.5 ft depth) in 1989, suggesting considerable nitrate movement below the root zone. Sampling the three intermediate rates of nitrogen after 9 years of known fertilizer application history will provide an understanding of which rate (or rates?) can maximize meat yields and yet not contribute significantly to nitrate movement below the root zone and potentially to the groundwater. It is important to learn at which rate(s) of applied nitrogen significant potential contributions of nitrates to the groundwater might occur.

Plans for 1993 are to maintain the rates of nitrogen application so as to achieve a range in yield response whereby the long term effect of soil acidification can be measured. At the present the only observed effect has been the increasingly higher leaf manganese levels (slightly over 700 ppm) in the leaf samples (Oct 1992). No effect on leaf, bark or tree growth has been observed. It seems prudent to continue the trial to take leaf samples to monitor manganese and other nutrient levels, twig samples and trunk circumference measurements, meat yields and observe tree growth to note the onset of the adverse effects of the very acidified soil in the "drip emitter ball." The observation of significantly increased leaf K and a trend for yield increases during 1992 from potassium applied in 1989 and 1990 deserves continued investigation. No additional potassium was applied in 1991 or 1992 nor is any planned for 1993. Funding has been requested from CDFA-FREP to assess nitrate and other nutrient movement below the root zone in a second experiment where different N sources have been applied for several years. The fertilizer source treatments are: urea, calcium nitrate, urea-calcium nitrate in alternating years, UN 32, N-phuric and 5 additional urea treatments to which different soil pH amendment materials will be added. Soil samples will be taken immediately under and at various distances from the emitters to sufficient depth to assess nitrate and other nutrient movement in the soil profile.

<u>Suggestions/Recommendations</u>: The easiest, most effective and economical way for growers to assess the nitrogen and other nutrient status of almonds is by the use of leaf analysis with a July (1st week) leaf sampling. Total nitrogen levels in the 2.2 to 2.5% range for leaf samples taken the first week in July have consistently resulted in optimum and near maximum meat yields. After observing the large differences in leaf potassium concentrations during the early growing season samples 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.

Figure 1. Almond meat yields in 1992 as influenced by nitrogenrate and water applied through drip system. Nickels Ranch.

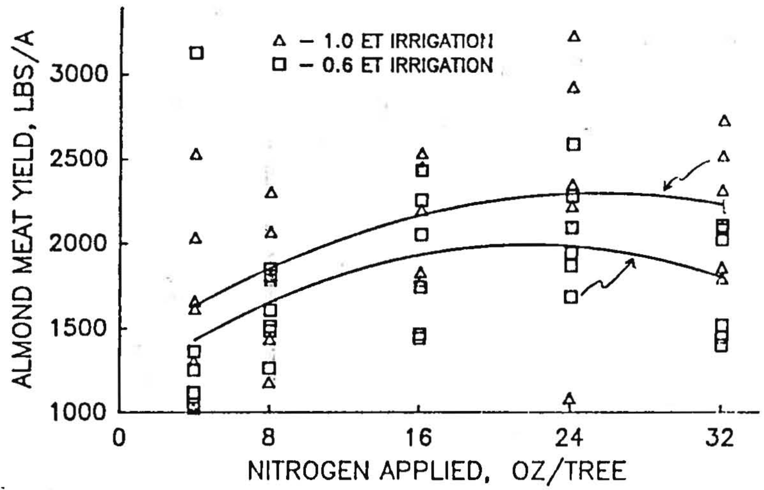


Figure 2. Butte almond meat yields in 1992 as influenced by nitrogen rate and water applied through drip system. Nickels Ranch.

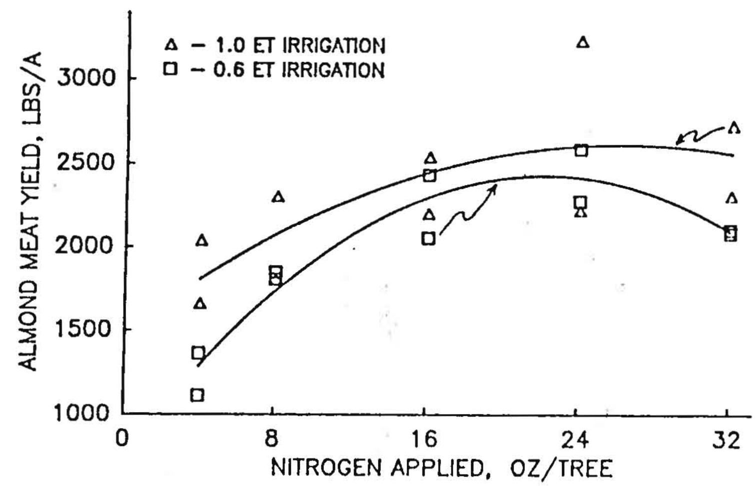


Figure 3. Carmel almond meat yields in 1992 as influenced by nitrogen rate and water applied through drip system. Nickels Ranch.

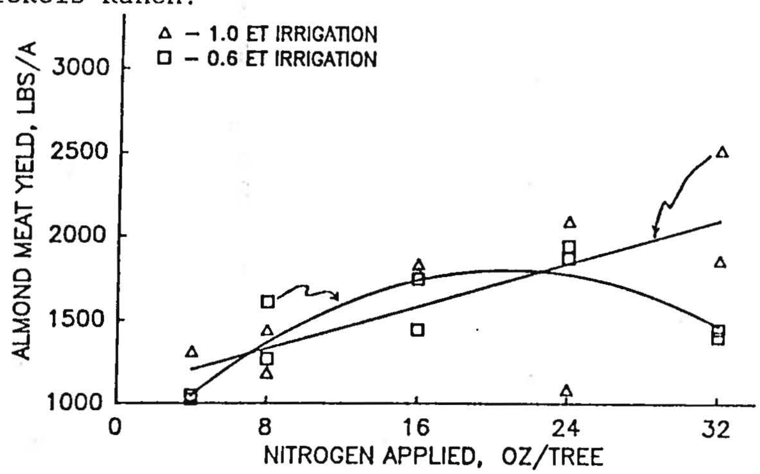
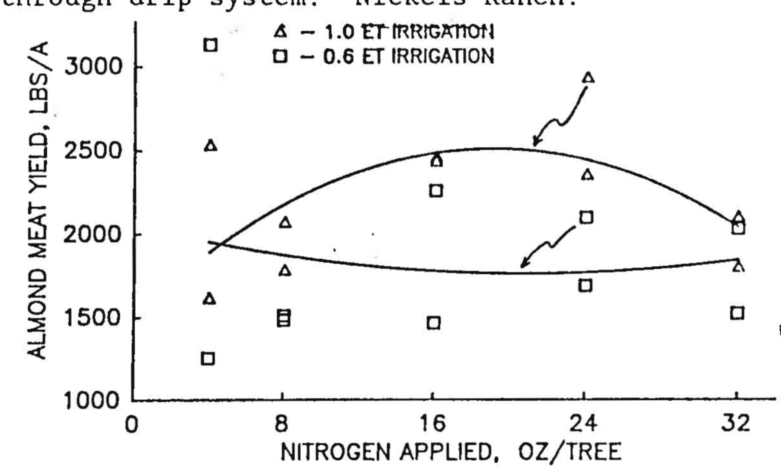


Figure 4. Nonpareil almond meat yields in 1992 as influenced by nitrogen rate and water applied through drip system. Nickels Ranch.



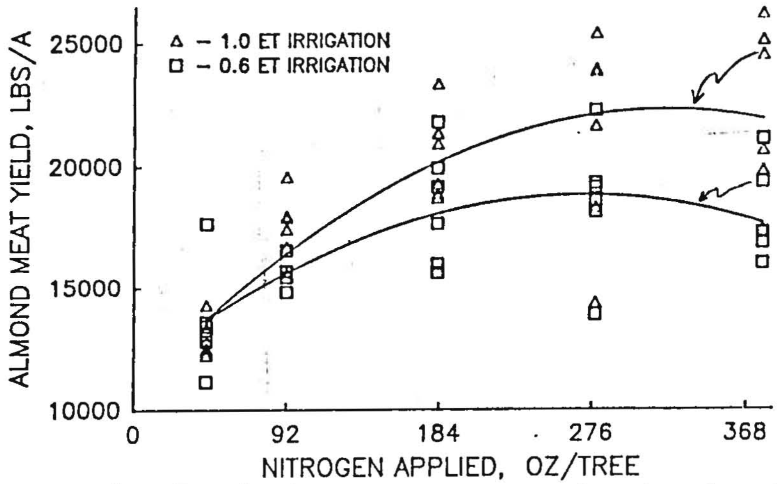


Figure 5. Nine year accumulated almond meat yields (1984-92) as influenced by nitrogen rate and water applied through drip system. Nickels Ranch.

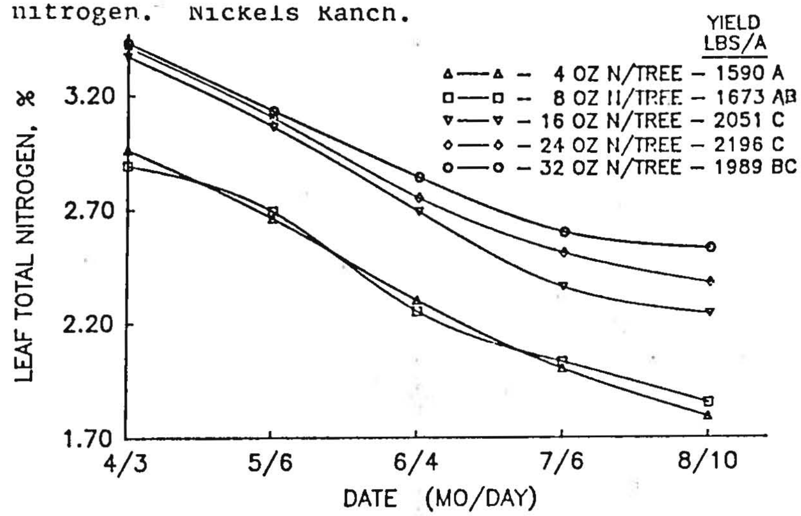


Figure 6. Almond leaf total nitrogen throughout 1992 for five rates of drip irrigation applied nitrogen. Nickels Ranch.

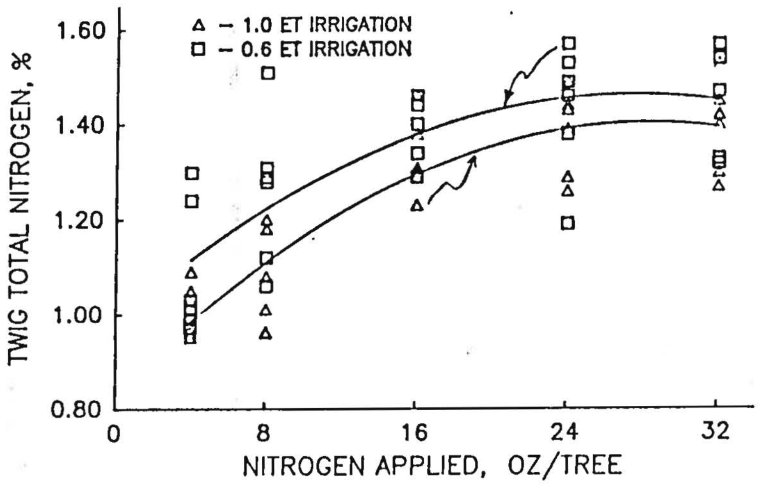


Figure 7. Total nitrogen concentration in almond twigs on January 24, 1992 as influenced by nitrogen rate and water applied through drip system. Nickels Ranch.

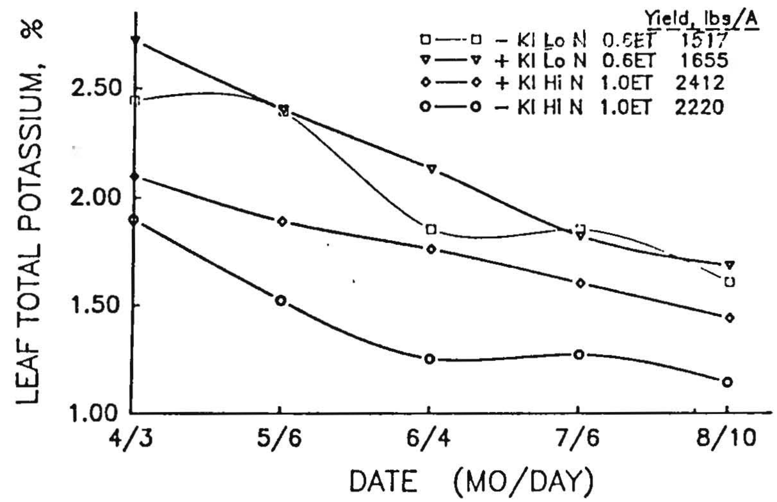


Figure 8. Almond leaf total potassium throughout 1992 for four drip irrigation applied nitrogen treatments. Nickels Ranch.