Project Number: 85-Q4

ANNUAL REPORT TO THE ALMOND BOARD OF CALIFORNIA

December 30, 1985

# 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 develop recommendations for nitrogen, irrigation and soil management for use in the establishment of almond orchards.

Interpretive Summary: Drip irrigation has a dramatic influence upon the rooting pattern of trees. Because of the confined soil area from which the tree roots must take up both water and nutrients, this situation offers opportunities and potential problems. Numerous applications of fertilizer injected into the drip irrigation system throughout the growing season provide a way to maximize the utilization of plant nutrients and water. The high concentrations of some fertilizers, such as the ammonium form of nitrogen, may result in an undesirable plant root environment. The low pH created may bring into solution sufficient levels of manganese and aluminum to reach toxic proportions. In addition to following nutrient concentrations in leaves to monitor the nitrogen status of trees, early dormant season twig samples may provide an effective and more desirable time for growers to develop fertility management strategies.

The orchard was planted on the Nickels Estate Ranch in the spring of 1981 to three almond varieties-Butte, Carmel and Nonpareil. 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 ounces per tree in 1982; 0, 0.8, 1.7, 3.5 and 7.0 ounces per tree in 1983; 0, 2, 4, 8 and 16 ounces per tree in 1984; and 4, 8, 16, 24 and 32 ounces per tree in 1985. The lowest rate of nitrogen was increased to 4 oz N/tree because severe twig tip dieback was observed in the trees receiving no nitrogen. Urea is the nitrogen fertilizer source. The 1.0 ET irrigation level is based on climatic data 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 1982 and 1983 the lower two nitrogen rates were split into thirds and applied three times during the season (60 day intervals) while the two higher rates were split into fourths and applied four times during the season (40 day intervals). All rates of nitrogen were split and applied 4 times during the season in 1984 and 5 times in 1985. All nitrogen application regimes begin on April 1st and end on August 1st.

Almond meat yields during 1984 (fourth season) ranged from about 400 to slightly over 1800 pounds per acre (12' X 18' spacing, 202 trees/A). It should be noted that the weather in the spring of 1984 was very favorable for attaining high yields. The three varieties responded somewhat differently with the Nonpareil having the same yield level for the 1.0 and 0.6 ET irrigation treatments and an increase from about 700 to 1400 pounds meats per acre for the 0 to 16 ounce per tree nitrogen rates. The Carmel variety had nearly the same average response to nitrogen but showed a markedly greater response to nitrogen at the 1.0 ET irrigation level (approx. 1700 at the 16 oz N/tree rate). The Butte variety showed a constant yield difference between the two irrigation levels at all rates of nitrogen with the 1.0 ET treatment averaging about 200 pounds more meats. Also, the 8 and 16 ounces N/tree rates gave nearly the same yields, and the highest yields at the 1.0 ET level were approximately 1300 pounds meats per acre.

The 1985 or fifth season almond meat yields ranged from about 400 to just under 2900 pounds per acre (12' X 18' spacing, 202 trees/A). As in 1984, the weather in the spring of 1985 was quite favorable for a good set and early nut development. The three varieties had very similar responses to the water treatments in that yields were 200-400 pounds greater for the 1.0 ET level. The Carmel and Nonpareil varieties had similar patterns of response to added nitrogen, but at slightly different yield levels. Yields ranged from 500 to 1700 for Nonpareil and 1100 to 2300 for Carmel for the 4 oz and 32 oz nitrogen rates (Figure 1-2). The Butte variety indicated a trend for yields to increase up to the 24 oz N/tree rate but very little more at the 32 oz rate (Figure 3).

Bloom and set data taken in 1985 show an increase with increasing water and applied nitrogen. Figure 4 indicates the greater bloom count and yield as nitrogen rates are increased from 4, 16 and 32 oz/tree. Bloom count and yield increases associated with the 0.6 and 1.0 ET drip irrigation levels are given in Figure 5. It would appear that water is a limiting factor since the lower water level reaches a maximum yield of about 1900 pounds meats/A with 6000 blooms/tree and yields do not increase even when bloom counts go up to 10,000/tree.

Kernel weight as a percent of hull plus shell plus kernel in 1985 for the three varieties is given in Figure 6. It is interesting to note that the relative weight of the kernel is increased by approximately 10% as the nitrogen rate increases from 4 to 32 oz/tree. Nearly the same increase is recorded in the three varieties for the kernel weight as a percent of shell plus kernel across the nitrogen rates (Figure 7).

Total nitrogen concentrations in leaf samples showed a slightly different trend in 1985. Whereas in both 1983 and 1984 the April concentrations were the same for all nitrogen and water treatments, the April 1985 levels were slightly higher for the 24 and 32 oz/tree nitrogen rates and generally higher at all nitrogen rates for the 0.6 ET water level. Initial total nitrogen levels in 1985 were 2.7% as compared to 2.2% in April 1984 and 3.7% in 1983. As in previous years, increasing nitrogen concentrations were observed following the differential nitrogen rates applied.

To more thoroughly characterize soil pH and other parameters under the drip emitters, one quarter of the sphere below the point of water entry into the soil was sampled as 3" X 3" X 3" cubes. These samples were taken in the 3" increments from an area 21" by 21" from the injection point and to a depth of 18" from the control and 30" from the highest nitrogen rate treatments. Laboratory analysis of these samples has not been completed to present at this time. Data from preliminary samples taken last year indicated dramatic lowering of pH levels immediately under the point of emitter discharge.

Concurrent with the soil samples, manganese concentrations in leaves collected on October 8, 1984 show a trend of increasing levels, particularly at the highest nitrogen application rate (Figure 8).

Experimental Procedure: The orchard was planted on the Nickels Estate Ranch in the spring of 1981 to three almond varieties-Butte, Carmel and Nonpareil. 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 ounces per tree in 1982; 0, 0.8, 1.7, 3.5 and 7.0 ounces per tree in 1983; 0, 2, 4, 8 and 16 ounces per tree in 1984; and 4, 8, 16, 24 and 32 ounces per tree in 1985. The 1.0 ET irrigation level is based on climatic data 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. Urea was used as the nitrogen fertilizer source. In 1982 and 1983 the lower two nitrogen rates were split into thirds and applied three times during the season (60 day intervals) while the two higher rates were split into fourths and applied four times during the season (40 day intervals). All rates of nitrogen were split and applied four times during the season in 1984 and five times in 1985. All nitrogen application regimes begin on April 1st and end on August 1st. Bloom and set count data was recorded on index trees and estimated for all plots. Index tree measurements included taking final nut harvest weights. Leaf samples were taken from each of the 60 individual plots each month beginning April 1st and ending October 1, 1982 or November 1st in 1983, 1984 and 1985. Twig samples were taken once during the December 1981-January 1982 period, three times during the December 1982-January 1983 period and two times during the December 1983-January 1984 and December 1984-January 1985 periods. Only moderate pruning was carried out after the first growing season with much more severe pruning at the completion of the second season. Only minor pruning was carried out after the third (Dec 1983-Jan 1984) and fourth seasons (Dec 1984-Jan 1985). Leaf and twig samples were analyzed for total, nitrate, and ammonium nitrogen, total phosphorus, potassium, calcium, magnesium and selected sample dates were chosen for micronutrients-zinc, manganese, copper, iron and boron. Tree trunk diameters were recorded during January of 1982, 1983, 1984 and 1985 to calculate the change in cross-sectional area for the five tree plots.

Results: Visual observation of the orchard indicated that tree leaf color was good during most of 1985. The small amount (4 oz) of nitrogen on the previously unfertilized control was sufficient to greatly improve leaf color and new shoot growth. Even with the relatively good bloom and nut set the trees maintained fairly good leaf color at the intermediate nitrogen rates with the higher rates exhibiting very dark green leaf color. At the 24 and 32 oz nitrogen rates, leaf tip (approximately 3/8 inch) necrosis or death was observed from April 15 (2 weeks after first nitrogen application began) until leaf drop. In previous years the zero and two lower nitrogen rate treatments showed yellow-green leaf color while the two higher rates had very dark green color. The difference in color between nitrogen treatments was more dramatic in 1984 than 1983 or 1982. This would be expected with the higher rates of nitrogen applied for the second and third year as compared to treatments receiving little or no nitrogen. In addition, the very favorable weather in the spring of 1984 provided for an extremely large set and developing nut yield which served as a nitrogen sink. Treatments receiving the 0.6 ET water level showed some leaf wilt indicating plant moisture stress during the latter part of the growing seasons.

Although nut yields were recorded after the third season of growth (1983) the small and erratic nature of these yields was not related to applied treatments. During 1984 however, the very favorable weather in the spring provided for a large set and the development of high meat yields. The fourth season meat yields ranged from about 400 to slightly over 1800 pounds per acre (12' X 18' spacing, 202 trees/A). The three varieties responded somewhat differently with the Nonpareil having the same yield level for the 0.6 and 1.0 ET irrigation treatments and an increase from about 700 to 1400 pounds meats per acre for the 0 to 16 ounce per tree nitrogen rates. The Carmel variety had nearly the same average response to nitrogen (about 800 to 1500 pounds meats per acre), but showed a markedly greater response to nitrogen at the 1.0 ET irrigation level (approx. 1700 at the 16 oz N/tree rate). The Butte variety showed a yield difference between the two irrigation levels at all rates of nitrogen with the 1.0 ET treatment averaging about 200 pounds more meats. Also, the 8 and 16 ounces nitrogen per tree rates gave nearly the same yield.

The 1985 or fifth season almond meat yields ranged from about 400 to just under 2900 pounds per acre (12' X 18' spacing, 202 trees/A). As in 1984, the weather in the spring of 1985 was quite favorable for a good set and early nut development. The three varieties had very similar responses to the water treatments in that yields were 200-400 pounds greater for the 1.0 ET level. The Carmel and Nonpareil varieties had similar patterns of response to added nitrogen, but at slightly different yield levels. Yields ranged from 500 to 1700 for Nonpareil and 1100 to 2300 for Carmel for the 4 oz and 32 oz nitrogen rates (Figure 1-2). Yields of the Nonpareil variety were reported as being lower in the Arbuckle area relative to other varieties for 1985. The Butte variety indicated a trend for yields to increase up to the 24 oz N/tree rate but very little more at the 32 oz rate (Figure 3).

Bloom and set data taken in 1985 show an increase with increasing water and applied nitrogen. Figure 4 indicates the greater bloom count and yield as nitrogen rates are increased from 4, 16 and 32 oz/tree. Bloom count and yield increases associated with the 0.6 and 1.0 ET drip irrigation levels are given in Figure 5. It would appear that water is a limiting factor since the lower water level reachs a maximum yield of about 1900 pounds meats/A with 6000 blooms/tree and yields do not increase even when bloom counts go up to 10,000/tree.

Kernel weight as a percent of hull plus shell plus kernel in 1985 for the three varieties is given in Figure 6. It is interesting to note that the relative weight of the kernel is increased by approximately 10% as the nitrogen rate increases from 4 to 32 oz/tree. Nearly the same increase is recorded in the three varieties for the kernel weight as a percent of shell plus kernel across the nitrogen rates (Figure 7). Actual kernel weight increased for the first three nitrogen rates and then remained the same at higher applied nitrogen rates. The two irrigation levels had no influence on relative kernel weight. Although figures given are from 1985 data, similar trends were observed in 1984.

Total nitrogen concentrations in leaf samples showed a slightly different trend in 1985. Whereas in both 1983 and 1984 the April concentrations were the same for all nitrogen and water treatments, the April 1985 levels were slightly higher for the 24 and 32 oz/tree nitrogen rates and generally higher at all nitrogen rates for the 0.6 ET water level. Initial total nitrogen levels in 1985 were 2.7% as compared to 2.2% in April 1984 and 3.7% in 1983. As in previous years, increasing nitrogen concentrations were observed following the differential nitrogen rates applied.

During the dormant periods of January 1982, 1983, 1984 and 1985 tree trunk diameters have been recorded and cross-sectional areas for the five trees per plot calculated. Since the January 1982 samples were taken prior to the establishment of any treatments, cross-sectional areas for the five trees per plots were not expected to be nor were they different. Average increases in cross-sectional tree trunk area relationships during the 1983 and 1984 growing seasons have shown larger differences with increasing rates of applied nitrogen and water. Whereas the difference between the 0.6 and 1.0 ET water level was the same for all nitrogen rates during the 1982 growing season, the higher water level combined with higher nitrogen rates showed larger increases in cross-sectional trunk area during 1983 and 1984.

To more thoroughly characterize soil pH and other parameters under the drip emitters, one quarter of the sphere below the point of water entry into the soil was sampled as 3" X 3" X 3" cubes. These samples were taken in the 3" increments from an area 21" by 21" from the injection point and to a depth of 18" from the control and 30" from the highest nitrogen rate treatments. Laboratory analysis of these samples has not been completed to present at this time. Data from preliminary samples taken last year indicated dramatic lowering of pH levels immediately under the point of emitter discharge. Concurrent with the soil samples, manganese concentrations in leaves collected on October 8, 1984 show a trend of increasing levels, particularly at the highest nitrogen application rate (Figure 8).

Discussion: It appears that the first five years growth (second, third, fourth and fifth with treatments applied) of the experimental orchard has been normal to slightly better than expected. The trees receiving higher rates of nitrogen are making good to excellent growth and have responded with excellent meat yields for the fourth and fifth seasons. The concern of last year that trees having received no nitrogen the first four years and showing tip dieback plus other signs of unthrifty growth are looking much better after having received 4 ounces nitrogen per tree the past year. Nitrogen concentrations in plant tissues have been in the range desired with low applied nitrogen rates falling below and higher applied rates remaining above adequate levels. Based on only two years of data, twig samples taken before January 1st should have concentrations of total nitrogen of approximately 0.85% or above after the second growing season and 0.7% after the third. If any nitrogen rates were to be suggested from the study for the early years of growth they would be in the range of 1 to 3 ounces nitrogen per tree during the first season, 2 to 6 ounces the second, 4 to 8 ounces the third, 6 to 16 ounces the fourth and 16 to 32 ounces the fifth. If a larger set and potential nut yield is developing, the higher rates should be used. These rates are suggested for drip irrigated almonds when the emitters are placed approximately 30" on either side of the tree and nitrogen applications are split into 3 to 5 equal increments.

Publications:

Schulbach, H. and Meyer, R. D. 1985. Nitrogen Effects at Two Drip Irrigation Levels on Almonds. Proceedings of the Third International Drip/-Trickle Irrigation Congress, Fresno, California. November 17-21, 1985. ASAE Publication 10-85, Vol. 1. pp 365-370.

Schulbach, H., Edstrom, J. and Meyer, R. D. 1985. Nickel's Trust Almond Fertilizer-Irrigation Study. Handout for November 1985 Almond Short Course.

Schulbach, H. and Meyer, R. D. 1985. Effects of Nitrogen on Drip-Irrigated Almonds. Soil and Water Newsletter 63:11-15. Summer 1985.

Meyer, R. D., Schulbach, H. and Edstrom, J. 1985, Rates of Nitrogen at Two Drip Irrigation Levels on Almonds. Handout for May 28, 1985 Nickels Estate Field Day.

Edstrom, J. 1985. Nickels Estate Nitrogen/Irrigation Trial. Handout for January 16, 1985 Yolo-Solano-Colusa Almond Meeting.

Schulbach, H. and Meyer, R. D. 1984. Yields of Three Varieties of Fourth Year Almonds as Influenced by Nitrogen and Water Applied Through Drip Irrigation System. Handout for November 1984 Almond Short Course.

Meyer, R. D., Schulbach, H. and Aldrich, T. M. 1984. Rates of Nitrogen at Two Drip Irrigation Levels on Almonds. Handout for May 9, 1984 Nickels Estate Field Day.

Meyer, R. D., Schulbach, H. and Aldrich, T. M. 1983. Rates of Nitrogen at Two Drip Irrigation Levels on Almonds. Soil and Water Newsletter 55:1-3. Summer 1983.

Figure 1. Carmel almond meat yields in 1985 as influenced by nitrogen rate and water applied through drip system. Nickels Ranch

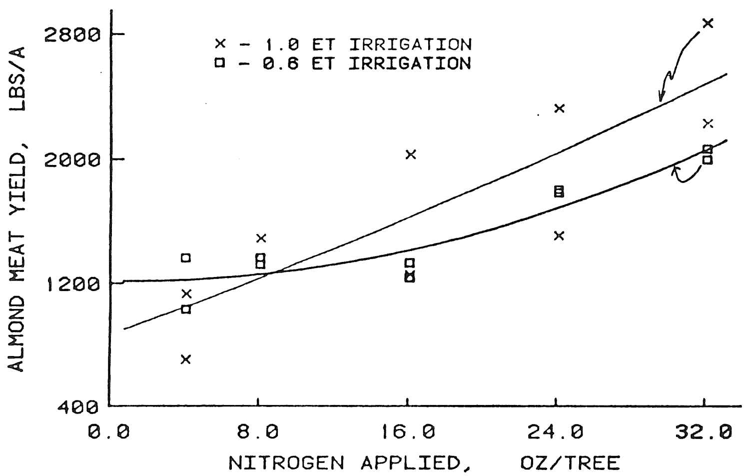



Figure 2. Nonpareil almond meat yields in 1985 as influenced by nitrogen rate and water applied through drip system. Nickels Ranch

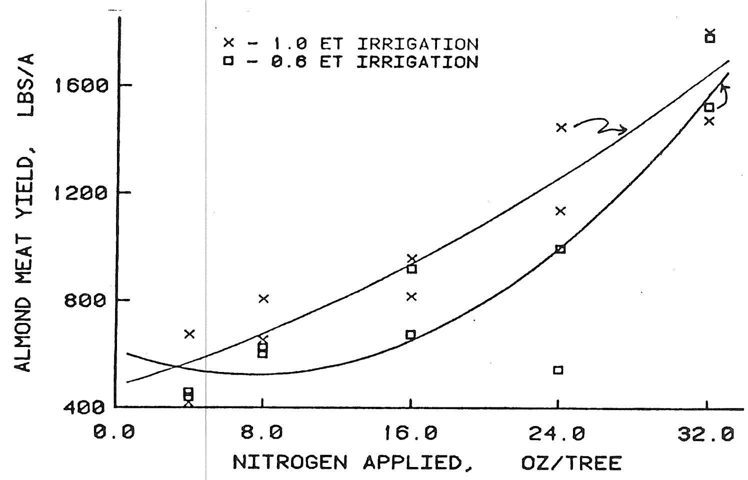



Figure 3. Butte almond meat yields in 1985 as influenced by nitrogen rate and water applied through drip system. Nickels Ranch

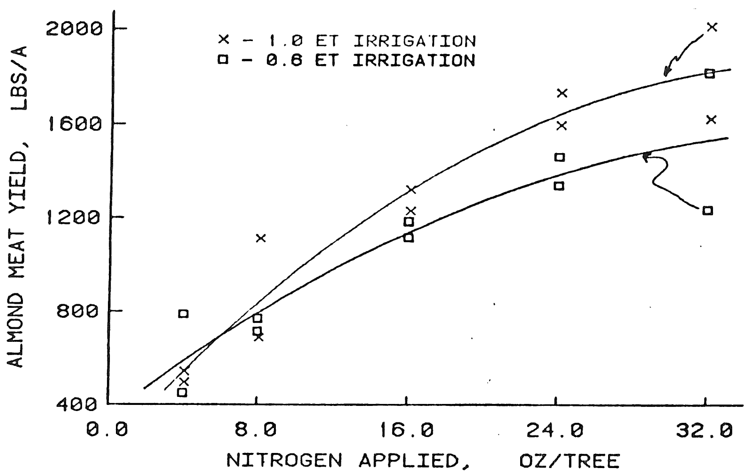



Figure 4. Almond meat yields in 1985 related to bloom count as influenced by nitrogen rate applied through drip system. Nickels Ranch

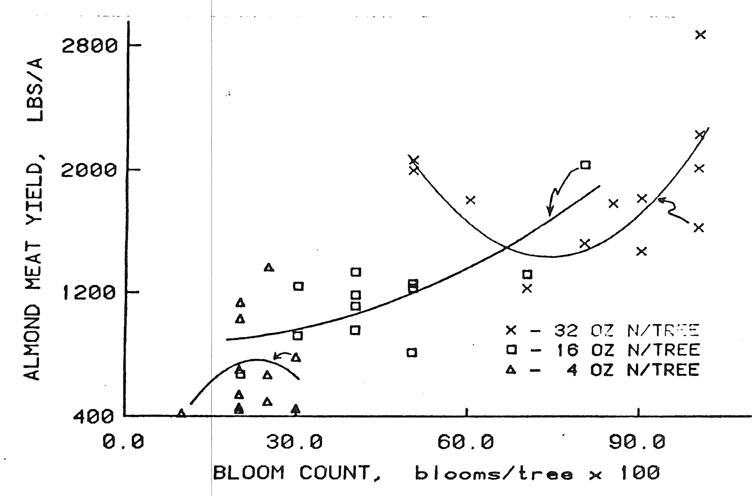


Figure 5. Almond meat yields in 1985 related to bloom count as influenced by water applied through drip system. Nickels Ranch

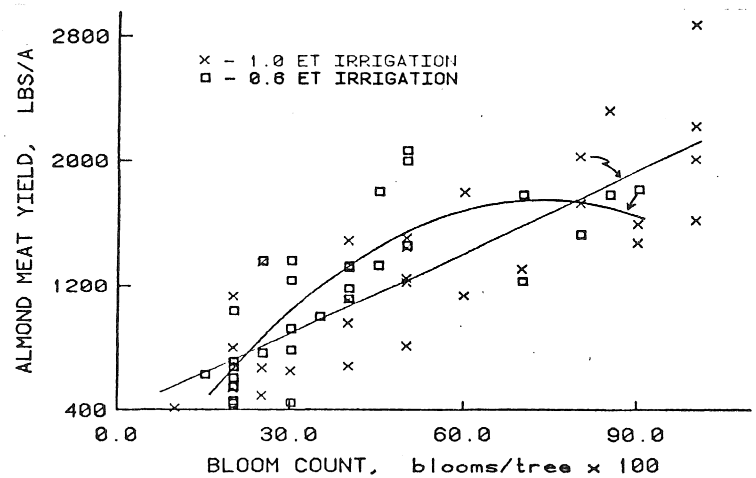



Figure 6. Kernel weight as a percent of hull+shell+kernel in 1985 as influenced by almond variety and nitrogen rate applied through drip system.

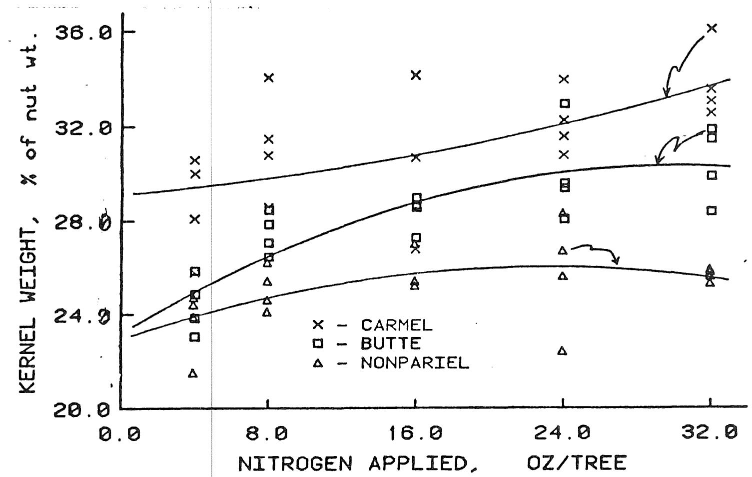



Figure 7. Kernel weight as a percent of shell+kernel in 1985 as influenced by almond variety and nitrogen rate applied through drip system. Nickels Ranch

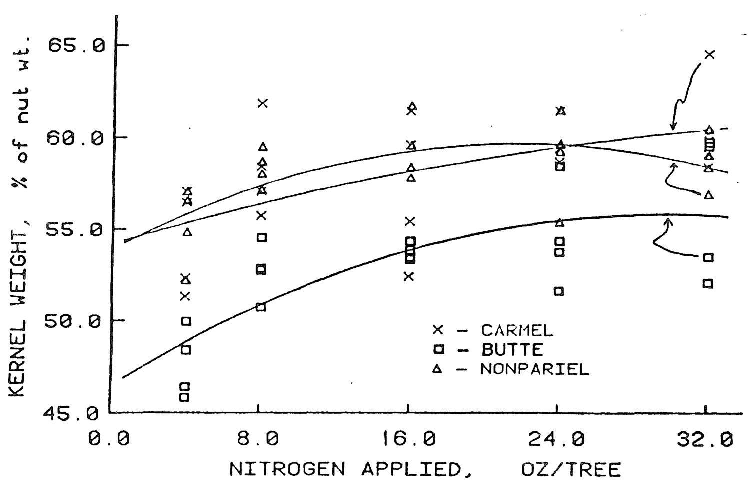
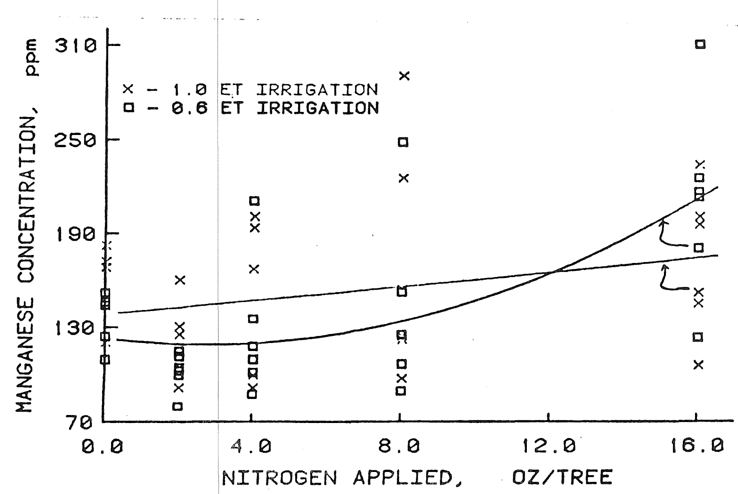



Figure 8. Manganese concentration in almond leaves on October 8, 1984 as influenced by nitrogen rate and water applied through drip system. Nickels Ranch



*Almond School Handout*
*Nov 6, 1[illegible] 5*

| TREE NO. | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NONPAREIL | 56 0/4 L | | | | | 57 8/24 H | | | | | 58 4/16 L | | | | | 59 0/4 H | | | | | (tree) | 60 16/32 H | | | | | (trees) | | 12 |
| BUTTE | (tree) | 55 8/24 H | | | | | 54 2/8 H | | | | | 53 8/24 L | | | | | 52 0/4 | | | (tree) | L | 51 4/16 H | | | | | | (tree) | 11 |
| CARMEL | 46 0/4 H | | | | | 47 8/24 L | | | | | 48 2/8 L | | | | | 49 2/8 | | | | (tree) | H | 50 | (tree) | 16/32 L | | | | (tree) | 10 |
| NONPAREIL | (trees) | | 45 4/16 H | | | | | 44 8/24 L | | | | | 43 2/8 L | | | | | 42 2/8 H | | | | | 41 16/32 L | | | | | (tree) | 9 |
| BUTTE | 36 0/4 H | | | | | 37 16/32 H | | | | | 38 2/8 L | | | | | 39 16/32 L | | | | | 40 4/16 L | | | | | (trees) | | | 8 |
| CARMEL | (tree) | 35 4/16 L | | | | | 34 0/4 L | | | | | 33 16/32 H | | | | | 32 4/16 H | | | | | (tree) | 31 8/24 | | | (tree) | H | | 7 |
| NONPAREIL | (tree) | 26 16/32 H | | | | | 27 2/8 H | | | | | 28 4/16 H | | | | | (tree) | 29 0/4 L | | | | | 30 16/32 L | | | | | (tree) | 6 |
| BUTTE | (trees) | | 25 8/24 H | | | | | 24 4/16 H | | | | | 23 8/24 L | | | | | 22 4/16 L | | | | | 21 16/32 H | | | | | (tree) | 5 |
| CARMEL | (tree) | 16 8/24 H | | | | | 17 16/32 H | | | | | 18 0/4 H | | | | | (tree) | 19 2/8 H | | | | | 20 0/4 L | | | | | (tree) | 4 |
| NONPAREIL | (tree) | 15 8/24 L | | | | | 14 0/4 H | | | | | 13 8/24 H | | | | | 12 2/8 L | | | | | (tree) | 11 4/16 L | | | | | (tree) | 3 |
| BUTTE | (tree) | 6 0/4 H | | | | | 7 16/32 L | | | | | 8 2/8 L | | | | | 9 0/4 L | | | | | 10 2/8 | | | (tree) | H | | (tree) | 2 |
| CARMEL | (trees) | | | 5 16/32 L | | | | | 4 4/16 L | | | | | 3 2/8 L | | | | | 2 8/24 L | | | | | 1 16/32 H | | | | | 1 |

PLOT NO. — 1 84/85 L — IRRIGATION LEVEL:

NITROGEN LEVEL 1984/1985 OZ./TREE

L = 0.6 ET H = 1.0 ET

NON PLOT TREES (tree)

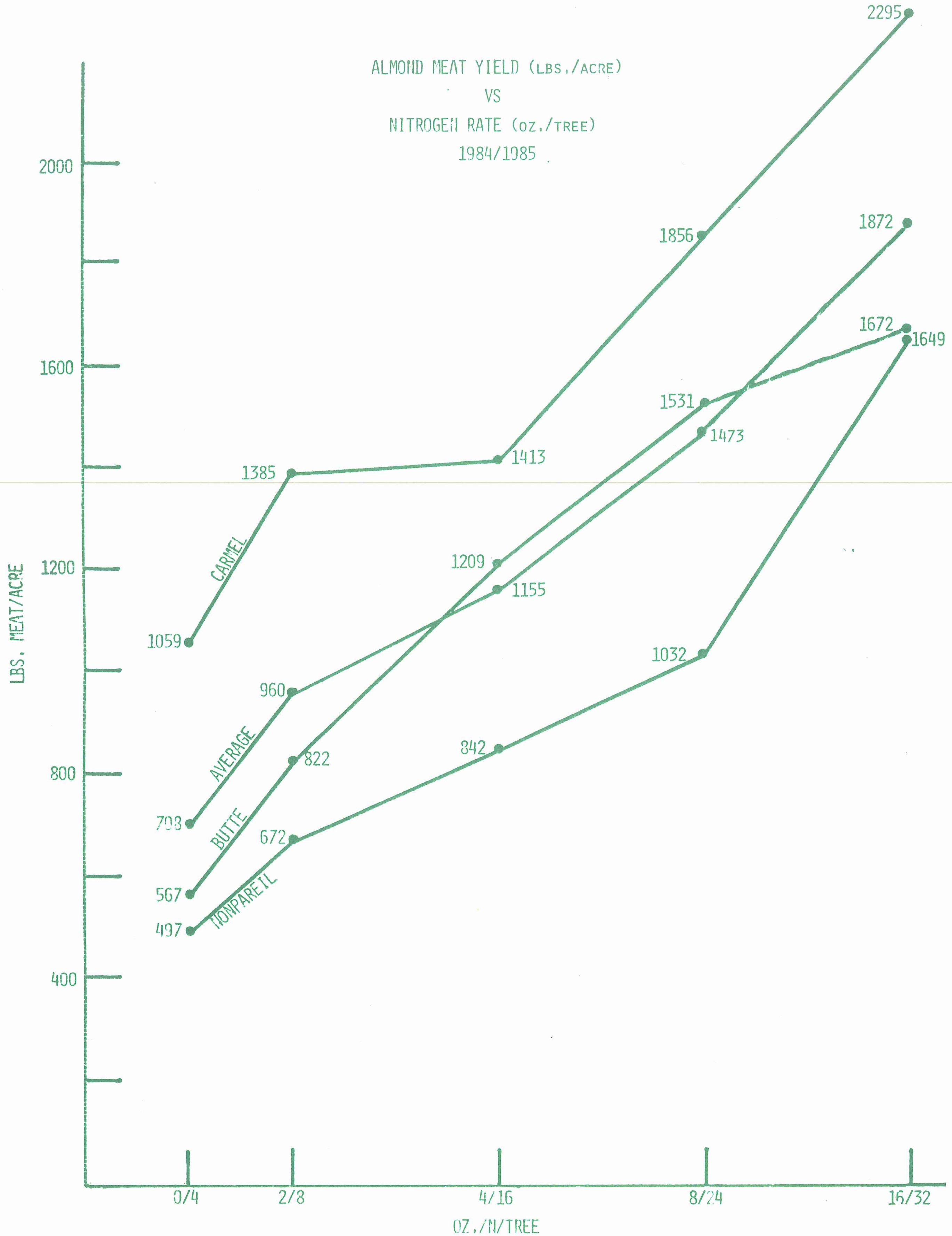
| TREE NO. | 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 | | | | | |
|---|---|---|---|---|---|---|
| NONPAREIL | 458 | 1451 | 921 | 674 | 1806 | 12 |
| BUTTE | 1735 | 1110 | 1335 | 786 | 1227 | 11 |
| CARMEL | 706 | 1804 | 1366 | 1494 | 2000 | 10 |
| NONPAREIL | 816 | 997 | 605 | 806 | 1785 | 9 |
| BUTTE | 1364 | 1299 | 731 | 1818 | 1112 | 8 |
| CARMEL | 1238 | 1031 | 2879 | 2035 | 2330 | 7 |
| NONPAREIL | 1477 | 655 | 959 | 440 | 1528 | 6 |
| BUTTE | 1597 | 1318 | 1459 | 1170 | 2017 | 5 |
| CARMEL | 1510 | 2070 | 1134 | 1360 | 1364 | 4 |
| NONPAREIL | 546 | 418 | 1138 | 626 | 675 | 3 |
| BUTTE | 542 | 1231 | 766 | 446 | 685 | 2 |
| CARMEL | 1256 | 1334 | 1322 | 1782 | 2234 | 1 |

**1985 NICKELS FERTILIZER & IRRIGATION STUDY**
**YIELD lbs./acre**

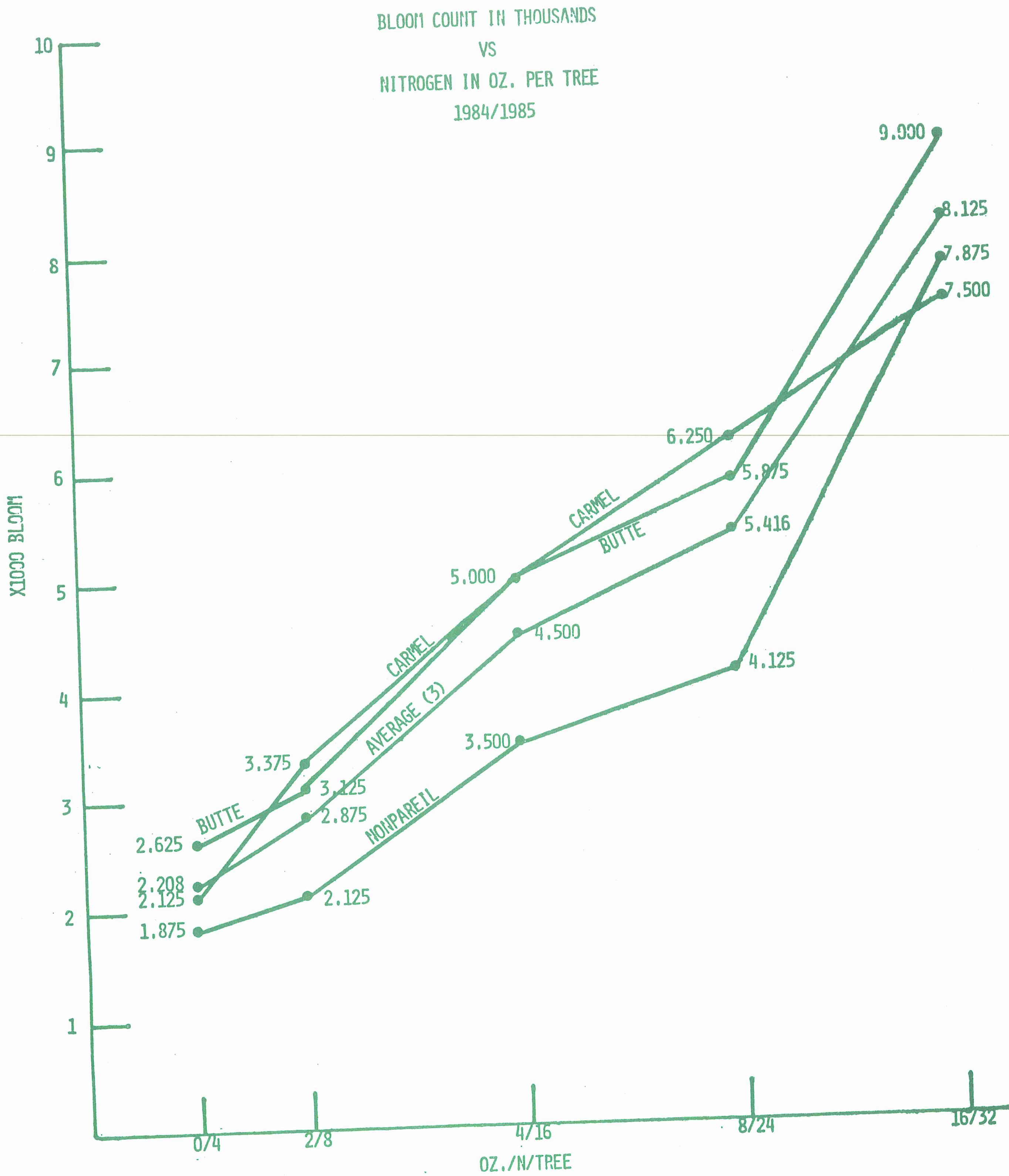
NON PLOT TREES

# NICKEL'S TRUST FERTILIZER-IRRIGATION STUDY:YIELD SUMMARY 1984 + 1985

| 1985 Irr. Level | .6 ET | | | | | | 1.0 ET | | | | | | .6 + 1.0 ET's | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treat. No. | 1 | 2 | 3 | 4 | 5 | Ave. | 6 | 7 | 8 | 9 | 10 | Ave. | 1+6 | 2+7 | 3+8 | 4+9 | 5+10 | Ave |
| N Applied Oz | 4 | 8 | 16 | 24 | 32 | | 4 | 8 | 16 | 24 | 32 | | 4 | 8 | 16 | 24 | 32 | |
| Yield | | | | | | | | | | | | | | | | | | |
| Carmel | 1364 | 1322 | 1334 | 1782 | 2070 | | 1134 | 1360 | 1256 | 1510 | 2234 | | | | | | | |
| | 1031 | 1366 | 1031 | 1804 | 2000 | | 706 | 1494 | 2035 | 2330 | 2879 | | | | | | | |
| Ave. | 1198 | 1344 | 1182 | 1793 | 2035 | 1510 | 920 | 1427 | 1646 | 1920 | 2556 | 1694 | 1059 | 1385 | 1413 | 1856 | 2295 | 1600 |
| Butte | 446 | 766 | 1182 | 1459 | 1231 | | 542 | 685 | 1318 | 1597 | 2017 | | | | | | | |
| | 786 | 710 | 1112 | 1335 | 1818 | | 496 | 1110 | 1227 | 1735 | 1624 | | | | | | | |
| Ave. | 616 | 738 | 1147 | 1397 | 1524 | 1084 | 519 | 897 | 1272 | 1663 | 1820 | 1234 | 567 | 822 | 1209 | 1531 | 1672 | 1160 |
| Nonpareil | 440 | 626 | 675 | 546 | 1528 | | 418 | 655 | 959 | 1138 | 1477 | | | | | | | |
| | 458 | 605 | 921 | 997 | 1785 | | 674 | 806 | 816 | 1451 | 1806 | | | | | | | |
| Ave | 449 | 615 | 798 | 771 | 1657 | 858 | 546 | 730 | 887 | 1294 | 1641 | 1020 | 497 | 672 | 842 | 1032 | 1649 | 930 |
| All Ave | 754 | 899 | 1042 | 1320 | 1739 | 1151 | 661 | 1018 | 1268 | 1625 | 2005 | 1316 | 708 | 960 | 1155 | 1473 | 1872 | 1230 |
| N-84 + 85 | 4 | 10 | 20 | 32 | 48 | | 4 | 10 | 20 | 32 | 48 | | 4 | 10 | 20 | 32 | 48 | |
| Carmel 84 | 768 | 924 | 1067 | 1037 | 1289 | 1017 | 874 | 935 | 1281 | 1262 | 1685 | 1207 | 821 | 930 | 1174 | 1150 | 1487 | 1110 |
| Carmel 85 | 1198 | 1344 | 1182 | 1793 | 2035 | 1510 | 920 | 1427 | 1646 | 1920 | 2556 | 1694 | 1059 | 1385 | 1413 | 1856 | 2295 | 1600 |
| Total 84 + 85 | 1966 | 2268 | 2249 | 2830 | 3324 | 2527 | 1794 | 2362 | 2927 | 3182 | 4241 | 2901 | 1880 | 2315 | 2587 | 3006 | 3782 | 2710 |
| Butte 84 | 610 | 675 | 892 | 1070 | 1142 | 878 | 740 | 790 | 959 | 1270 | 1238 | 999 | 675 | 732 | 926 | 1170 | 1190 | 930 |
| Butte 85 | 616 | 738 | 1147 | 1397 | 1524 | 1084 | 519 | 897 | 1272 | 1663 | 1820 | 1234 | 567 | 822 | 1209 | 1531 | 1672 | 1160 |
| Total 84 + 85 | 1226 | 1413 | 2039 | 2467 | 2666 | 1962 | 1259 | 1687 | 2231 | 2933 | 3058 | 2233 | 1242 | 1554 | 2135 | 2701 | 2862 | 2090 |
| Nonpareil 84 | 620 | 804 | 788 | 1152 | 1497 | 972 | 623 | 835 | 972 | 904 | 1416 | 950 | 622 | 820 | 880 | 1082 | 1456 | 960 |
| Nonpareil 85 | 449 | 615 | 798 | 771 | 1657 | 858 | 546 | 730 | 887 | 1294 | 1641 | 1020 | 497 | 672 | 842 | 1032 | 1694 | 930 |
| Total 84 + 85 | 1069 | 1419 | 1586 | 1923 | 3154 | 1830 | 1169 | 1565 | 1859 | 2198 | 3057 | 1970 | 1119 | 1492 | 1722 | 2114 | 3150 | 1890 |
| Ave T+ 84 + 85 | 1420 | 1700 | 1958 | 2407 | 3048 | 2106 | 1407 | 1871 | 2339 | 2771 | 3452 | 2368 | 1413 | 1787 | 2148 | 2607 | 3264 | 2230 |



ALMOND MEAT YIELD (LBS./ACRE)
VS
NITROGEN RATE (OZ./TREE)
1984/1985
LBS. MEAT/ACRE
2000
1600
1200
800
400
CARMEL
AVERAGE
BUTTE
NONPAREIL
1059
1385
1413
1856
2295
708
960
1209
1531
1672
567
822
1155
1473
1872
497
672
842
1032
1649
0/4
2/8
4/16
8/24
16/32
OZ./N/TREE


BLOOM COUNT IN THOUSANDS
VS
NITROGEN IN OZ. PER TREE
1984/1985
X1000 BLOOM
10
9
8
7
6
5
4
3
2
1
9.000
8.125
7.875
7.500
6.250
5.875
5.416
5.000
4.500
4.125
3.500
3.375
3.125
2.875
2.625
2.208
2.125
1.875
2.125
CARMEL
BUTTE
CARMEL
AVERAGE (3)
BUTTE
NONPAREIL
0/4
2/8
4/16
8/24
16/32
OZ./N/TREE

# Rates of Nitrogen at Two Drip Irrigation Levels on Almonds

Roland D. Meyer, Extension Soils Specialist
John Edstrom, Farm Advisor

Herbert Schulbach, Area Soil and Water Specialist
Nickels Estate Trust

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 develop recommendations for nitrogen, irrigation and soil management for use in the establishment of almond orchards.

Drip irrigation has a dramatic influence upon the rooting pattern of trees. Because of the confined soil area from which the tree roots must take up both water and nutrients, this situation offers opportunities and potential problems. Numerous applications of fertilizer injected into the drip irrigation system throughout the growing season provide a way to maximize the utilization of plant nutrients and water. The high concentrations of some fertilizers, such as the ammonium form of nitrogen, may result in an undesirable plant root environment. The low pH created may bring into solution sufficient levels of manganese and aluminum to reach toxic proportions. In addition to following nutrient concentrations in leaves to monitor the nitrogen status of trees, early dormant season twig samples may provide an effective and more desirable time for growers to develop fertility management strategies.

The orchard was planted on the Nickels Estate Ranch in the spring of 1981 to three almond varieties-Butte, Carmel and Nonpareil. 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 ounces per tree in 1982; 0, 0.8, 1.7, 3.5 and 7.0 ounces per tree in 1983; 0, 2, 4, 8 and 16 ounces per tree in 1984; and 4, 8, 16, 24 and 32 ounces per tree in 1985. Urea is the nitrogen fertilizer source. The 1.0 ET irrigation level is based on climatic data 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 1982 and 1983 the lower two nitrogen rates were split into thirds and applied three times during the season (60 day intervals) while the two higher rates were split into fourths and applied four times during the season (40 day intervals). All rates of nitrogen were split and applied 4 times during the season in 1984 and 5 times in 1985. All nitrogen application regimes begin on April 1st and end on August 1st. Almond meat yields during 1984 (fourth season) ranged from about 400 to slightly over 1800 pounds per acre (12' X 18' spacing, 202 trees/A). It should be noted that the weather in the spring of 1984 was very favorable for attaining high yields. The three varieties responded somewhat differently with the Nonpariel having the same yield level for the 1.0 and 0.6 ET irrigation treatments and an increase from about 700 to 1400 pounds meats per acre for the 0 to 16 ounce per tree nitrogen rates. The Carmel variety had nearly the same average response to nitrogen but showed a markedly greater response to nitrogen at the 1.0 ET irrigation level (approx. 1700 at the 16 oz N/tree rate). The Butte variety showed a constant yield difference between the two irrigation levels at all rates of nitrogen with the 1.0 ET treatment averaging about 200 pounds more meats. Also, the 8 and 16 ounces N/tree rates gave nearly the same yields. Highest yields at the 1.0 ET level were approximately 1300 pounds meats per acre.

Prepared for Nickels Estate Field Day - May 28, 1985

IRRIGATION RESPONSE - MEAT LBS/AC*

| Irrigation Level | Nitrogen Rate, oz/tree 0 | 2 | 4 | 8 | 16 |
|---|---|---|---|---|---|
| 0.6 ET | 666 | 801 | 916 | 1086 | 1310 |
| 1.0 ET | 745 | 854 | 1071 | 1145 | 1443 |

NITROGEN RESPONSE - MEAT LBS/AC AND ECONOMIC RETURN*

| | Nitrogen Rate 0 | 25 lbs/A 2 oz/tree | 50 lbs/A 4 oz/tree | 100 lbs/A 8 oz/tree | 200 lbs/A 16 oz/tree |
|---|---|---|---|---|---|
| Ave. Yield, Meat lbs. | 706 | 827 | 993 | 1116 | 1377 |
| Yield Increase, lbs | --- | 121 | 287 | 410 | 671 |
| N Cost/A at $.30 | 0 | $7.50 | $15.00 | $30.00 | $60.00 |
| Net Return at $1.00/lb | --- | $113.50 | $272.00 | $380.00 | $611.00 |

TREE GROWTH RESPONSE - Increase Over No Nitrogen Trees 1983 vs 1984*

| | Nitrogen Rate, oz/tree 0 | 2 | 4 | 8 | 16 |
|---|---|---|---|---|---|
| Increase in Trunk Cross Sectional Area | -- | 17% | 65% | 91% | 118% |

* Averages of Nonpareil, Butte and Carmel varieties combined, 4th leaf trees (12' X 18' spacing - 202 trees/acre).

SOIL REACTION (pH) BENEATH DRIP EMITTERS

| Nitrogen fertilizer | Soil Depth | Soil pH |
|---|---|---|
| Urea - High Rates | 0-3" | 7.0 |
| | 3-6" | 5.6 |
| | 6-10" | 5.1 |
| None Applied | 0-3" | 6.9 |
| | 3-6" | 6.9 |
| | 6-10" | 6.7 |

1984

# NICKELS ESTATE NITROGEN/IRRIGATION TRIAL

## IRRIGATION RESPONSE - MEAT LBS/AC.

| | NITROGEN RATE | | | | |
|---|---|---|---|---|---|
| | 0 | 2oz. | 4oz. | 8oz. | 16oz. |
| 60% IRRIGATION 0.6 ET | 666 | 801 | 916 | 1086 | 1310 |
| 100% IRRIGATION 1.0 ET | 745 | 854 | 1071 | 1145 | 1443 |

AVERAGES OF NONPAREIL, BUTTE AND CARMEL DATA COMBINED, 4TH LEAF TREES, 12' x 18' - 201 TREES/ACRE. NICKELS ESTATE SOILS LABORATORY, ARBUCKLE.

## NITROGEN RESPONSE

| | NITROGEN RATE | | | | |
|---|---|---|---|---|---|
| | 0 | 25LBS/AC 2OZ/TREE | 50LBS/AC 4OZ/TREE | 100LBS/AC 8OZ/TREE | 200LBS/AC 16OZ/TREE |
| AVE YIELD MEAT LBS. | 706 | 827 | 993 | 1116 | 1377 |
| YIELD INC. LBS | -- | 121 | 287 | 410 | 671 |
| N COST/AC @ 30¢ | 0 | $ 7.50 | $ 15.00 | $ 30.00 | $ 60.00 |
| NET YIELD RETURN @1.00/LB | -- | $113.50 | $272.00 | $380.00 | $611.00 |

## TREE GROWTH RESPONSE

| | | INCREASE OVER O-N TREES 83-84 | | | |
|---|---|---|---|---|---|
| N RATE | 0 | 2OZ/TREE | 4OZ/TREE | 8OZ/TREE | 16OZ/TREE |
| INCREASE IN TRUNK CROSS SECTIONAL AREA | -- | 17% | 65% | 91% | 118% |

AVERAGES OF NONPAREIL, BUTTE AND CARMEL DATA COMBINED, 4TH LEAF TREES, 12' x 18' - 201 TREES/ACRE. NICKELS ESTATE SOILS LABORATORY, ARBUCKLE.

# YOLO - SOLANO - COLUSA ALMOND MEETING

## JANUARY 16, 1985

## NICKELS ESTATE UPDATE

### SOIL pH BENEATH DRIP EMITTERS

#### MATURE TREES 10th LEAF

| N FERTILIZER | SOIL DEPTH | SOIL pH |
|---|---|---|
| Urea - Moderate Rates | 0-3" | 6.2 |
| | 3-6" | 5.5 |

#### YOUNG TREES 4th LEAF

| N FERTILIZER | SOIL DEPTH | SOIL pH |
|---|---|---|
| Urea - High Rates | 0-3" | 7.0 |
| | 3-6" | 5.6 |
| | 6-10" | 5.1 |
| None Applied | 0-3" | 6.9 |
| | 3-6" | 6.9 |
| | 6-10" | 6.7 |

Severely acid soil conditions are known to be detrimental to tree crops. All orchards under drip irrigation should be sampled every year for leaf nutrient status. Severely acid soil conditions can generally be diagnosed by interpreting the lab report results for leaf manganese and aluminum concentrations. Values above 200 ppm can alert managers to a possible developing problem. Consult your Farm Advisor on the advisability of applying any corrective measures.

Roland D. Meyer

ASAE Publication 10-85

**Volume I**

# DRIP/TRICKLE IRRIGATION IN ACTION

## Proceedings of the Third International Drip/Trickle Irrigation Congress

November 18-21, 1985
Centre Plaza Holiday Inn
Fresno, California USA

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**FERTIGATION WITH DRIP/TRICKLE IRRIGATION**



**DRIP/TRICKLE IRRIGATION DESIGN**

# NITROGEN EFFECTS AT TWO DRIP IRRIGATION LEVELS ON ALMONDS

Herbert Schulbach    Roland D. Meyer

A major deficiency in the cultural practices of young drip irrigated almond trees is the lack of precise data concerning nitrogen rates and timing with varying irrigation levels. Proposed rates are often suggested on the basis of personal experience with other crops, recognition of soils having different fertility levels, different cultural practices or growth performance expectations.

Fertilizer practices frequently result in inadequate nitrogen applications which retard growth and delay by one or more years the achievement of a productive bearing orchard. In other cases fertilizer rates have been excessive or applied in such a manner to cause severe damage to the root system or to the above ground portion of the plant which in some cases causes death of the tree.

The irrigation level for young trees must be properly managed so as to minimize the loss of growth potential from a lack of water. Excessive water should be avoided because the saturated root zone deprives the roots of oxygen, results in denitrification and subsequent loss of nitrogen or causes other adverse plant growth conditions.

A study to determine suitable levels of nitrogen was established on the Nickels Trust Estate near Arbuckle, California in early 1981. Tree rows were 18 feet (5.49 meters) apart with a tree spacing of 12 feet (3.66 meters) in the rows. This results in 202 trees per acre (498 trees per hectare). Varietal rows of Carmel, Butte, and Nonpareil were alternated on a 1-1-1 basis to ensure necessary cross-pollination.

The experiment was established with 10 treatments, five rates of nitrogen, each at two levels of water (Table 1). Nitrogen rates are modified annually as growth progresses. Applications for all treatments of nitrogen as urea begin on April 1 and end on August 1. Irrigation levels are at 0.6 and 1.0 of evapotranspiration (ET). Irrigations are scheduled using climatic data and the procedure described by Pruitt and Doorenbos (1977) and Fereres et. al. (1981). Water is applied on a daily basis and is controlled through time clocks and meters.

The trees were planted in early 1981 and received a water level of 1.0 ET but no nitrogen. Residual soil nitrogen was considered adequate to provide for normal first year tree growth. Newly planted trees were reduced to 32 inches in height without branches. After making good growth the first year, trees were pruned to three primary branches. The treatments were randomly assigned to each of two rows in five tree plots. Each tree row contained 28 trees providing extra trees as guard trees at the end of rows unless a substitution in the row was required. Applications of the nitrogen source urea were placed under each of the two (3 in 1985) emitters per tree in a shallow depression into which the emitter discharged. The procedure used for applying nutrients by hand simulated the field scale applications often made by growers. To accomplish both 0.6 ET and 1.0 ET irrigation levels on the same drip line, elevation at each tree and head losses in the

Herbert Schulbach, Extension Area Soils and Water Specialist, Colusa, and Roland D. Meyer, Extension Soils Specialist, University of California, Davis.



TABLE 1. Nitrogen and water treatments applied to field experiment.

| TREATMENT | IRRIGATION LEVEL | | NITROGEN RATE, OZ/TREE | | | | |
|---|---|---|---|---|---|---|---|
| NUMBER | 0.6 ET | 1.0 ET | 1981 | 1982a | 1983a | 1984b | 1985c |
| 1 | x | | 0 | 0 | 0 | 0 | 4 |
| 2 | x | | 0 | .5 | .8 | 2 | 8 |
| 3 | x | | 0 | 1.0 | 1.7 | 4 | 16 |
| 4 | x | | 0 | 1.5 | 3.5 | 8 | 24 |
| 5 | x | | 0 | 2.0 | 7 | 16 | 32 |
| 6 | | x | 0 | 0 | 0 | 0 | 4 |
| 7 | | x | 0 | .5 | .8 | 2 | 8 |
| 8 | | x | 0 | 1.0 | 1.7 | 4 | 16 |
| 9 | | x | 0 | 1.5 | 3.5 | 8 | 24 |
| 10 | | x | 0 | 2.0 | 7 | 16 | 32 |

a The two lower rates of nitrogen were split into 3 applications at 60 day intervals and the two higher rates into 4 applications at 40 day intervals.
b Nitrogen was split into 4 applications at 40 day intervals.
c Nitrogen will be split into 5 applications at 30 day intervals.

line were determined to allow selection of proper micro tube lengths to achieve desired flow rates. Two emitters were placed 30 inches (.76 meters) on either side of the trunk and a third emitter per tree was added in 1985.

Parameters used to monitor plant response to nitrogen-irrigation treatments are yields of kernels, hulls, and shells; and chemical analyses to determine nutrient concentrations in leaves, twigs, kernels, hulls, and shells. Leaves are sampled on a monthly basis beginning April 1 and continuing into fall, a 7- to 8-month period. Twigs are sampled in December after leaf fall and in January before new growth begins. Nitrogen is determined as total nitrogen, nitrate-nitrogen, and ammonical-nitrogen on each of the samples taken. Total phosphorus, potassium, calcium, magnesium, zinc, copper, iron, and manganese are determined in early, mid, and end of the season leaf samples. Yields of kernels, hulls, and shells are determined using the five trees in each plot and expressed on a per acre basis. An average weight of the individual kernel, hull, and shell is determined from a 100 nut sample from the five trees per plot. In addition, tree growth is evaluated using trunk diameter measurements for each tree at 12 inches above ground during the dormant season of each year to determine annual increase in cross-sectional area. Beginning in 1985, bloom counts were made to estimate return bloom for all plots.

The first measurable yield was produced during the fourth growing season (1984). The season began with an exceptional spring for pollinating conditions and early set. Typical yields of well-managed 4-year-old trees are about 100 to 500 pounds per acre depending upon the plant density which ranges from 80 to 120 trees per acre (198 to 297 trees per hectare). Yields on a tree basis would be about 1-3 pounds of kernels.

TABLE 2. TREE RESPONSES TO NITROGEN-IRRIGATION TREATMENTS FOR 1984 GROWING SEASON.

| IRRIGATION LEVEL | 0.6 ET | | | | | | 1.0 ET | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TREATMENT NUMBER | 1 | 2 | 3 | 4 | 5 | AVE. | 6 | 7 | 8 | 9 | 10 | AVE. |
| NITROGEN APPLIED[a] | 0 | 2 | 4 | 8 | 16 | - | 0 | 2 | 4 | 8 | 16 | - |
| KERNEL YIELD (LB/A)[b] | | | | | | | | | | | | |
| CARMEL | 768 | 924 | 1067 | 1037 | 1289 | 1017 | 874 | 935 | 1281 | 1262 | 1685 | 1207 |
| BUTTE | 610 | 675 | 892 | 1070 | 1142 | 878 | 740 | 790 | 959 | 1270 | 1238 | 999 |
| NONPAREIL | 620 | 804 | 788 | 1152 | 1497 | 972 | 623 | 835 | 972 | 904 | 1416 | 950 |
| AVERAGE | 666 | 801 | 916 | 1086 | 1309 | 955 | 746 | 853 | 1071 | 1145 | 1446 | 1052 |
| GROSS YIELD (LB/A)[c] | | | | | | | | | | | | |
| CARMEL | 2840 | 3540 | 3634 | 3636 | 4303 | 3591 | 3238 | 3481 | 4490 | 4296 | 5546 | 4210 |
| BUTTE | 2449 | 2509 | 3291 | 3978 | 4309 | 3307 | 2792 | 2948 | 3425 | 4276 | 4168 | 3522 |
| NONPAREIL | 2672 | 3295 | 3030 | 4173 | 5346 | 3703 | 2651 | 3261 | 3654 | 4354 | 4951 | 3774 |
| TRUNK GROWTH ($CM^2$)[d] | | | | | | | | | | | | |
| CARMEL | 18.14 | 12.82 | 22.60 | 23.63 | 26.17 | 20.67 | 10.97 | 16.16 | 29.28 | 35.57 | 36.90 | 25.78 |
| BUTTE | 11.75 | 18.42 | 24.96 | 35.46 | 39.40 | 26.00 | 18.34 | 20.01 | 30.34 | 33.01 | 48.87 | 30.11 |
| NONPAREIL | 8.86 | 14.43 | 20.13 | 23.28 | 40.38 | 21.42 | 14.12 | 15.40 | 21.81 | 31.33 | 34.69 | 23.47 |
| AVERAGE | 12.92 | 15.22 | 22.56 | 27.46 | 35.32 | 22.69 | 14.48 | 17.19 | 27.14 | 33.30 | 40.15 | 26.45 |
| TRUNK GROWTH INCREASE OVER 1983 - % | | | | | | | | | | | | |
| CARMEL | 29.50 | 23.10 | 38.60 | 41.40 | 41.10 | 34.70 | 19.40 | 26.40 | 47.60 | 45.80 | 50.00 | 37.80 |
| BUTTE | 20.30 | 33.60 | 33.90 | 51.70 | 54.40 | 38.70 | 27.70 | 29.00 | 36.80 | 37.50 | 52.70 | 36.70 |
| NONPAREIL | 16.50 | 24.20 | 33.50 | 37.50 | 56.00 | 33.60 | 23.40 | 23.20 | 35.60 | 48.00 | 43.70 | 34.70 |
| AVERAGE | 22.10 | 27.00 | 35.30 | 43.50 | 50.50 | 35.70 | 23.50 | 26.20 | 40.00 | 43.80 | 48.70 | 36.40 |
| BLOOM COUNT 1985[e] | | | | | | | | | | | | |
| CARMEL | 2225 | 3500 | 3500 | 5750 | 5000 | 3995 | 2000 | 3250 | 6500 | 6750 | 10000 | 5700 |
| BUTTE | 3000 | 2250 | 4000 | 4750 | 8000 | 4400 | 2250 | 4000 | 6000 | 8500 | 10000 | 6150 |
| NONPAREIL | 2000 | 1750 | 2500 | 2750 | 8250 | 3450 | 1750 | 2500 | 4500 | 5500 | 7500 | 4350 |
| AVERAGE | 2408 | 2500 | 3333 | 4417 | 7083 | 3948 | 2000 | 3250 | 5667 | 6917 | 9167 | 5400 |

a Ounces of nitrogen applied during 1984 (1 oz = 28.35 gm)
b Conversion to SI units is lb/A x 1.12 = kg/ha
c Includes weight of kernel (nut), hull, and shell
d Average increase in trunk cross-sectional area of the five trees/plot
e Estimated blooms per tree



Figure 1. Total nitrogen concentration in almond leaves on April 7, 1983 as influenced by nitrogen rate and water applied through drip system. Nickels Ranch.

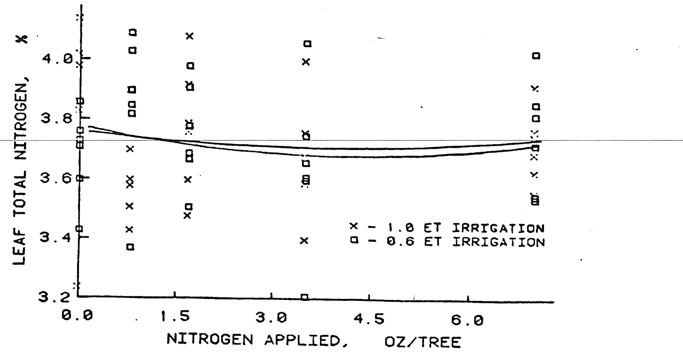



Figure 2. Total nitrogen concentration in almond leaves on September 2, 1983 as influenced by nitrogen rate and water applied through drip system. Nickels Ranch.

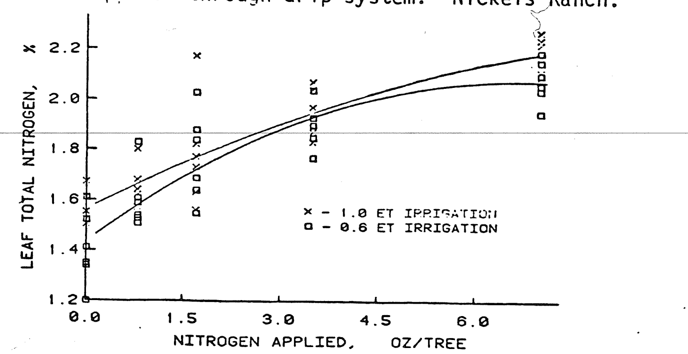



Figure 3. Total nitrogen concentration in almond twigs on December 28, 1983 as influenced by nitrogen rates and water applied through drip system. Nickels Ranch.

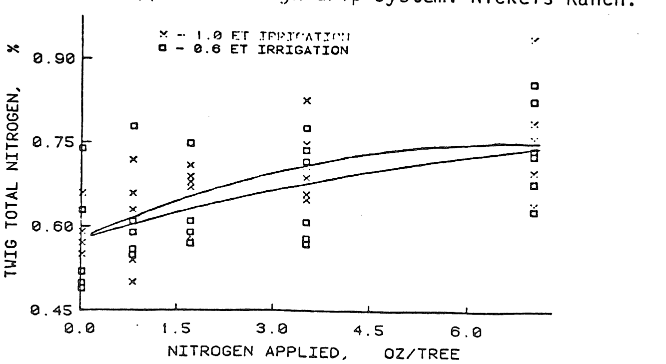
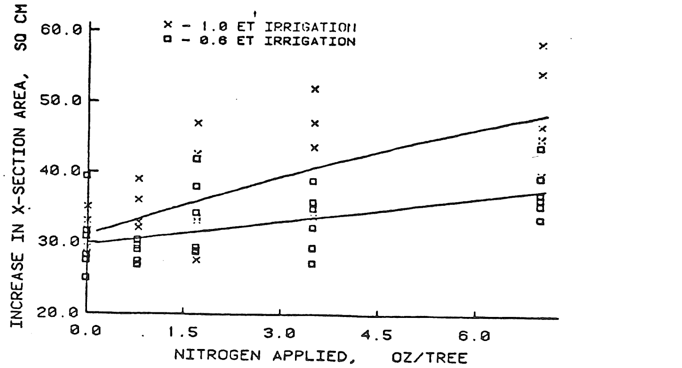



Figure 4. Average increase in trunk cross-sectional area from 1982 to 1983. Nickels Ranch.



## RESULTS:

Visual observation of the orchard during 1983 and 1984 indicated that the zero and two lower nitrogen rate treatments showed yellow-green leaf color while the two higher rates had very dark green color. The difference in color between nitrogen treatments was more dramatic in 1984 than in 1983 or 1982. This would be expected with the higher rates of nitrogen applied for the third and fourth year as compared to treatments receiving little or no nitrogen. In addition, the very favorable weather in the spring of 1984 provided for an extremely large set and developing nut yield which served as a nitrogen sink. Treatments receiving the 0.6 ET water level showed some leaf wilt indicating plant moisture stress during the latter part of the growing seasons.

Although nut yields were recorded after the third season of growth (1983), the small and erratic nature of these yields was not related to applied treatments. During 1984, very favorable weather during bloom provided for a large set and the development of high yields. Table 2 shows the fourth season kernel yields which ranged from 610 to 1,685 pounds per acre (12'x18' spacing, 202 trees/A or 498 trees/ha). The three varieties responded somewhat differently with the Nonpariel having the same yield level for the 0.6 and 1.0 ET irrigation treatments, and an average increase from about 622 to 1,456 pounds kernels per acre for the 0 to 16 ounce per tree nitrogen rates. The Carmel variety had nearly the same average response to nitrogen (821 to 1,487 pounds kernels per acre), but showed a markedly greater response to nitrogen at the 1.0 ET irrigation level (1,685 at the 16 oz N/tree rate). The Butte variety showed a yield difference between the two irrigation levels at all rates of nitrogen with the 1.0 ET treatment averaging about 200 pounds more kernels. Also, the 8 and 16 ounces nitrogen per tree rates gave nearly the same yield. Evaluation of 100 nut samples for relative weights of kernels, shells, and hulls, as well as chemical analyses of each fraction, has not been completed.

Estimated bloom counts per tree show a 2 to 3 fold increase across nitrogen rates with a smaller difference between water levels (Table 2). Percent set and kernel size measurements will be taken during 1985 to characterize aspects of the current season's kernel yield.

Results of leaf analyses across years show a progressively lower initial concentration for the trial beginning in April of 1982 with 4.5%, 3.7% in 1983, and 2.2% in 1984. Guidelines suggest 2.2% or greater for adequate nitrogen content in leaf samples taken in July, Reisenauer et. al. (1983). The rather low concentration in April 1984 could be due in part to the extremely large set and developing nut yield. Total nitrogen concentrations indicated no difference between water or nitrogen treatments until the August 4, 1982 sampling when the total nitrogen increased with increasing water and nitrogen applications. These relationships were not as apparent in later samplings in 1982. Figure 1 illustrates the near constant nitrogen concentration in the leaves across all treatments beginning with the April 7, 1983 sampling. Throughout the 1983 season, the nitrogen concentration for the two water levels remained the same but progressively increased with an increase in applied nitrogen (Figure 2). Leaf analyses for the first several months of 1984 indicated the same pattern of increasingly greater total nitrogen associated with higher rates of applied nitrogen.

Twig samples taken during the dormant period (December 1982-January 1983) following the first season of treatment application showed a trend for higher nitrogen concentrations with increasing rates of applied nitrogen.



The lower level of applied water (0.6 ET) however, indicated a trend of having greater total nitrogen concentrations. Samples taken during the December 1983-January 1984 dormant period showed the trend of higher nitrogen concentrations with increasing rates of applied nitrogen, but no difference between irrigation levels (Figure 3). It is very interesting to note that twig total nitrogen concentrations in samples taken December 28, 1983 followed closely the trends indicated in the later leaf sample dates of 1983, but by April 1984 leaf concentrations of total nitrogen were the same for all treatments. This seems to indicate that irregardless of tree levels of nitrogen or past nitrogen and water applications, initial leaves for each season will usually have the same nitrogen concentration.

During the dormant periods of January 1982, 1983, and 1984, tree trunk diameters have been recorded and average cross-sectional areas were calculated. The January 1982 measurements were taken prior to the establishment of any treatments and the average cross-sectional areas for the five tree plots were no different. Average increases in cross-sectional tree trunk area during the 1983 growing season show larger differences with increasing rates of applied nitrogen and water (Figure 4). Whereas the difference between the 0.6 and 1.0 ET water level was the same for all nitrogen rates during the 1982 growing season, the higher water level combined with higher nitrogen rates showed larger increases in cross-sectional trunk area during 1983. Average tree growth during 1984 as measured by increase in trunk cross-sectional area over 1983 is given in Table 2. Expressed as a percent increase, the two water levels are very similar (35.7% for 0.6 ET versus 36.4% for 1.0 ET), but nitrogen rates show a marked increase from 22.1 to 50.5% at the 0.6 ET water level and 23.5 to 48.7% at the 1.0 ET water level.

During 1983 from mid to late season, the difference in tree size was not as noticeable as it was at the end of the 1984 season. At the conclusion of the 1984 season, the high nitrogen treatments had markedly increased tree size as indicated by the extent of fruiting wood and new shoot growth which was more than twice that of trees receiving low nitrogen treatments. Much of the increase in tree size during 1984 is comprised of fruiting wood.

Trees receiving little or no nitrogen displayed severe symptoms of twig and shoot dieback. Not only were the growing tips shriveled and black, very few buds occurred on their shoots and twigs. Since most of the fruiting buds occur on the previous year's growth, total bud production observed in early 1985 was severely reduced. The lack of nitrogen restricted photosynthate production and essentially resulted in severe starvation.

## REFERENCES:

Pruitt, W. O. and J. Doorenbos. 1977. Empirical calibration, a requisite for evapotranspiration formulae based on daily or longer mean climatic data? International Commission on Irrigation and Drainage.

Fereres, E. et. al. 1981. Drip irrigation management. University of California Leaflet No. 21259.

Reisenauer, H. M. et. al. 1983. Soil and plant tissue testing in California. University of California Leaflet No. 1879.

References

HP-45 Applications Book, Hewlett Packard, Inc.

Spiegel, Murray R. 1975. Theory and Problems of Probability and Statistics. Schaum's Outline Series. McGraw-Hill Book Company.

## EFFECTS OF NITROGEN ON DRIP-IRRIGATED ALMONDS

H. Schulbach and R.D. Meyer

### Introduction:

A major deficiency in the cultural practices of young drip irrigated almond trees is the lack of precise data concerning tree response to nitrogen rates with varying quantities of irrigation water. Rates have often been suggested on the basis of personal experience with other crops, recognition of soils having different fertility levels, different cultural practices, or growth performance expectations.

Fertilizer practices frequently result in inadequate nitrogen which retard growth and delay by one or more years the achievement of a productive bearing orchard. In other cases, fertilizer practices have been excessive or applied in such a manner to cause severe damage to the root system or to the aerial portion of the tree which in some cases causes death of the tree.

Irrigation practices of young trees must be properly managed to maximize growth potential. Prolonged periods of water deficit can lead to suppressed vegetative growth and subsequent lower yield. Excessive water, on the other hand, deprives the roots of oxygen, results in denitrification and therefore loss of available nitrogen and may cause other adverse plant growth conditions.

A study to determine suitable quantities of nitrogen applications was established on the Nickels Trust Estate near Arbuckle, California, in 1981.

### Methods:

Tree rows were established 18 feet (5.5 meters) apart with a tree spacing of 12 feet (3.7 meters) in the rows. Thus, tree density was 202 trees per acre (498 trees per hectare). Varietal rows of Carmel, Butte, and Nonpareil were alternated on a 1-1-1 basis to ensure necessary cross-pollination.

The experiment consisted of 10 treatments: five rates of nitrogen each at two levels of water (Table 1). Nitrogen rates were increased annually as tree growth progressed. Applications for all treatments of nitrogen as urea began on April 1 and ended on August 1. Trees were irrigated at 0.6 and 1.0 of evapotranspiration (ET).

The trees were planted in early 1981 and were irrigated at full ET without applied nitrogen the first season. Residual soil nitrogen was considered adequate to provide sufficient first year tree growth. Newly planted trees were pruned to 32 inches in height without branches. After adequate first year growth, trees were pruned to three primary branches. Treatments were then randomized in each of two rows into five tree plots. Each tree row contained 28 trees which provided extra trees as guards at the end of rows unless a substitution in the row was required. Urea was placed by hand under each of the two emitters per tree in a shallow depression into which the emitter discharged. This technique was adopted to ensure accuracy and uniformity as well as to avoid complex insertions of nitrogen through a single drip line. This procedure used for applying nutrients simulated the field scale applications commonly used by growers.

Water application rates were varied along the same drip line by changing the length of the micro tube emitters to compensate for head losses. Proper adjustments were made until selected treatments received only 60% of the original flow rates. Thus, 0.6 and 1.0 ET treatments were attained. Two emitters, placed 30 inches (76 cm) on either side of the trunk supplied water to each tree.

Yields of kernels, hulls and shells were used to evaluate plant response to the various nitrogen and irrigation treatments. Nutrient concentrations were determined in leaves, twigs, kernels, hulls, and shells. In addition, tree growth was evaluated by measuring trunk diameters 12 inches above ground during the dormant season of each year. Beginning in 1985, bloom counts were made to estimate return bloom for all plots.

## Results:

### Visual Observation:

Visual observation of the orchard during 1983 and 1984 indicated that the plants grown at the three lowest nitrogen rates were chlorotic (yellow-green color) while those at the two higher rates were dark green in color. The difference in color between nitrogen treatments was more dramatic in 1984 than either 1983 or 1982. This was expected since higher rates of nitrogen were applied for the third and fourth year as compared to treatments receiving little or no nitrogen. In addition, favorable weather in the spring of 1984 provided for an extremely high set and developing nut yield that served as a nitrogen sink. Trees grown at 0.6 ET showed some leaf wilt indicating plant moisture stress during the latter part of the growing seasons. Trees that received little or no nitrogen displayed severe symptoms of twig and shoot dieback. Not only were the growing tips shriveled and black, very few buds occurred on their shoots and twigs. Since most of the fruiting buds occurred on the previous year's growth, total bud production observed in early 1985 was severely reduced on the low nitrogen treatments. We suspect that the lack of nitrogen restricted photosynthate production and essentially resulted in severe starvation.

### Nut Yields:

Although nut yields were recorded from a few plots after the third season of growth (1983), no differences were found among treatments. During 1984, favorable weather during bloom provided for a large set and the development of high yields. Fourth season kernel yields ranged from 610 to 1,685 pounds per acre (Table 1). The three varieties responded somewhat differently. No differences in the yield of Nonpareil were found between ET irrigation treatments. Yields increase on the average from about 622 to 1,456 pounds kernels per acre as applied nitrogen increased from 0 to 16 oz/tree. The Carmel variety had nearly the same average response to nitrogen as Nonpareil (821 to 1,487 pounds kernels per acre), but showed a markedly greater response to nitrogen at the 1.0 ET irrigation level (1,685 at the 16 oz N/tree rate). Both increasing water and nitrogen levels increased the kernel yield of Butte, but yields were generally less than Carmel.

Table 1. Tree Responses to Nitrogen-Irrigation Treatments for 1984 Growing Season.

| Irrigation Treatment | 0.6 ET | | | | | 1.0 ET | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Nitrogen applied[a] | 0 | 2 | 4 | 8 | 16 | 0 | 2 | 4 | 8 | 16 |
| Kernel yield (LB/A)[b] | | | | | | | | | | |
| Carmel | 768 | 924 | 1067 | 1037 | 1289 | 874 | 935 | 1281 | 1262 | 1685 |
| Butte | 610 | 675 | 892 | 1070 | 1142 | 740 | 790 | 959 | 1270 | 1238 |
| Nonpareil | 620 | 804 | 788 | 1152 | 1497 | 623 | 835 | 972 | 904 | 1416 |
| Gross yield (LB/A)[c] | | | | | | | | | | |
| Carmel | 2840 | 3540 | 3634 | 3636 | 4303 | 3238 | 3481 | 4490 | 4296 | 5546 |
| Butte | 2449 | 2509 | 3291 | 3978 | 4309 | 2792 | 2948 | 3425 | 4276 | 4168 |
| Nonpareil | 2672 | 3295 | 3030 | 4173 | 5346 | 2651 | 3261 | 3654 | 4354 | 4951 |
| Trunk growth ($CM^2$)[d] | | | | | | | | | | |
| Carmel | 18.14 | 12.82 | 22.60 | 23.63 | 26.17 | 10.97 | 16.16 | 29.28 | 35.57 | 36.90 |
| Butte | 11.75 | 18.42 | 24.96 | 35.46 | 39.40 | 18.34 | 20.01 | 30.34 | 33.01 | 48.87 |
| Nonpareil | 8.86 | 14.43 | 20.13 | 23.28 | 40.38 | 14.12 | 15.40 | 21.81 | 31.33 | 34.69 |
| Trunk growth increase over 1985- % | | | | | | | | | | |
| Carmel | 29.50 | 23.10 | 38.60 | 41.40 | 41.10 | 19.40 | 26.40 | 47.60 | 45.80 | 50.00 |
| Butte | 20.30 | 33.60 | 33.90 | 51.70 | 54.40 | 27.70 | 29.00 | 36.80 | 37.50 | 52.70 |
| Nonpareil | 16.50 | 24.20 | 33.50 | 37.50 | 56.00 | 23.40 | 23.20 | 35.60 | 48.00 | 43.70 |
| Bloom count 1985[e] | | | | | | | | | | |
| Carmel | 2225 | 3500 | 3500 | 5750 | 5000 | 2000 | 3250 | 6500 | 6750 | 10000 |
| Butte | 3000 | 2250 | 4000 | 4750 | 8000 | 2250 | 4000 | 6000 | 8500 | 10000 |
| Nonpareil | 2000 | 1750 | 2500 | 2750 | 8250 | 1750 | 2500 | 4500 | 5500 | 7500 |

[a] Ounces of nitrogen applied during1985

[b] Conversion to SI units is lb/A x 1.12 = kg/ha

[c] Includes weight of kernel (nut), hull, and shell

[d] Average increase in trunk cross-sectional area of the five trees/plot

[e] Estimated number of blooms per tree

Figure 1. Average increase in trunk cross-sectional area from 1982 to 1983.

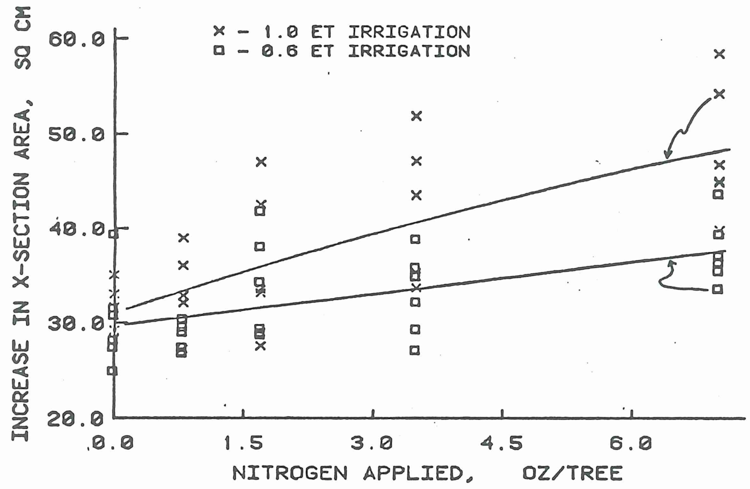



Figure 2. Total nitrogen concentration in almond leaves on April 7, 1983 as influenced by nitrogen rate and water applied through drip system.

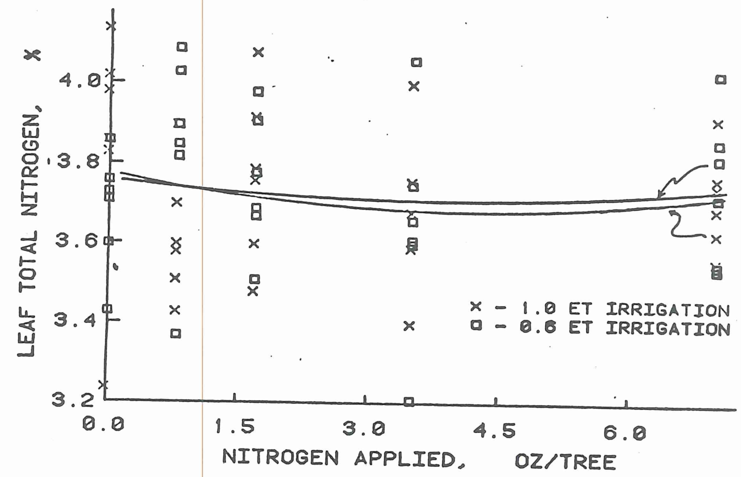



Figure 3. Total nitrogen concentration in almond leaves on September 2, 1983 as influenced by nitrogen rate and water applied through drip system.

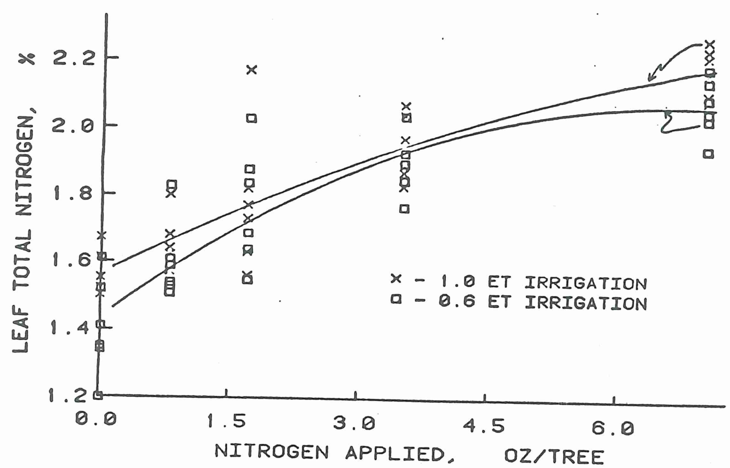
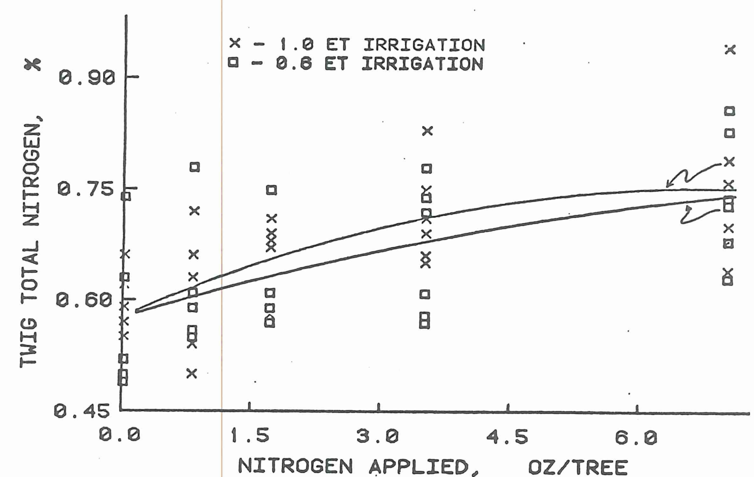



Figure 4. Total nitrogen concentration in almond twigs on December 28, 1983 as influenced by nitroge rates and water applied through drip system.



Bloom Count:

Applied nitrogen increased the number of blooms per tree 2 to 3 fold as compared to the non fertilized controls.

Tree Growth:

During the dormant periods of January 1982, 1983, and 1984, tree trunk diameters were recorded and average cross-sectional areas were calculated. The January 1982 measurements were taken prior to the establishment of any treatments. Thus, the average cross-sectional areas for the five tree plots were no different. Cross-sectional tree trunk area increased with increasing rate of applied nitrogen and water (Figure 1). During 1983 from mid to late season, the difference in tree size was not as noticeable as it was at the end of the 1984 seson. At the conclusion of the 1984 season, the high nitrogen treatments had markedly increased tree size as indicated by the extent of fruiting wood and new shoot growth which was more than twice that of trees receiving low nitrogen treatments. Much of the increase in tree size during 1984 was comprised of fruiting wood.

Leaf and twig nitrogen data are presented in Figures 2-4. Leaf N concentrations from trees treated at the highest N level progressively decreased from 4.5% in April, 1982, to 2.2% in April, 1984. In April, 1983, no differences in leaf N were found among treatments (Figure 2). In September and December, 1983, both leaf and twig N, respectively, increased as applied N increased. No differences, however, were found among trees receiving different irrigation levels. The low concentration of N in the leaf samples in early 1984 could be due in part to the large set and developing nut yield. Differences in twig N concentration among N-application treatments were not as pronounced as differences in leaf concentrations. Twig nitrogen concentrations were approximately one-third the level in leaves.