ANNUAL REPORT

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Project Title: **Nitrogen management in citrus under low volume irrigation**

Introductions and Objectives

Over the past several seasons, and particularly during 1993-1996, rind quality problems caused serious economic damage to the CA navel orange crop. Pioneering work by Embelton, Eaks, Coggins and others during the 1960's and 1970's largely solved rind stain problems by providing leaf analysis fertilization guidelines based in part on fruit quality considerations and also by improving the design of packinglines and postharvest handling of fruit.

Over the past 2 decades orchard practices have changed. Most irrigation systems installed or renovated in the 1980's and 1990's are micro-irrigation systems with drippers or minisprinklers, rather than furrow, flood or high volume dragline sprinklers that dominated the industry previously. Nitrogen (N) remains relatively inexpensive. Its ability to provide lush foliage growth and good looking groves has led in recent years to considerable over-use in the industry. Leaf analysis has provided the industry with a tool for monitoring fertilizer needs in citrus orchards, but too often growers are comfortable with nitrogen levels in the high end of the 'optimum' range, or even higher. The common thinking is that high nitrogen in the leaf analysis provides a good degree of safety and no tree in the orchard will suffer nitrogen deficiency. The effect of heavy nitrogen applications (in excess of 2 lb. N/tree), however, could be devastating to postharvest fruit quality.

Many growers have turned to foliar applications of low biuret urea to their trees in January and February to improve fruit set and ultimate yields. Additionally, the threat of nitrate groundwater contamination has changed the way some fertilizer recommendations are made, with several small applications of nitrogen over the season considered less likely to pollute than a single application. It is hoped that this project will assist in developing recommendations that can be made that minimizes nitrate movement into the groundwater while maintaining fruit quality and productivity.

The projects objectives are:

a) to determine the effect of nitrogen applications on navel orange fruit quality and leaching losses of nitrogen;

b) to compare the effects of foliar versus soil applied nitrogen on fruit quality and leaching losses of nitrogen;

c) to evaluate the impact of nitrogen application timing on fruit quality and leaching losses of nitrogen; and

d) to determine the effectiveness of various nitrogen application levels and methods on maintaining optimal nitrogen levels in navel orange trees.

Project Description

Main Project Site

A site for the study in the Exeter - Woodlake area of Tulare County was identified in March 1996. The 15.3 acre experimental site is a mature navel orange grove (Frost Nucellar) on Troyer Citrange rootstock. The tree spacing is 22 x 20 feet. Each experimental plot consists of 12 trees with the central 2 trees serving as the data trees. The experimental treatments for this site are listed in Table 1. The differential nitrogen treatments were imposed commencing January 1997. The final harvest was completed in Spring 2002.

Leaf samples were collected in September for leaf analysis. Trunk circumference, tree height, and canopy volume of the data trees were measured in October. Trees were also monitored for the average timing of color break and attainment of minimum maturity. In spring the data trees were harvested. All fruit was taken to UC Lindcove REC, where the fruit was run over the packingline at the Fruit Evaluation Center. We collected both size and grade information from the packingline. A subsample of fruit (from the average peak size) was taken from each data set, waxed and treated with fungicide and subsequently held under simulated storage and transit conditions.

Monitoring of the water and nitrogen status in selected experimental plots within the study site was carried out throughout the year. Soil water content was determined using a neutron probe in access tubes. Soil solution samples were collected from suction lysimeters.

Satellite Sites

The two remaining sites (Sat 1 & Sat 2) are located in commercial groves in Exeter/Woodlake and Orange Cove. The treatments at each site are listed in Table 2. The procedures for site monitoring were the same as outlined for the main site. All sites were harvested upon consultation with the owner and the cooperating packinghouse. All fruit from each site were commercially harvested and treated with standard packinghouse procedures. Yield, fruit size and packout were determined. Three cartons of each of two sizes (determined at the time of harvest) for each treatment were separated at the time of packing and held under simulated storage and transit conditions at the Mitchell Postharvest Lab at the UC-KAC. When sufficient export fruit were available, at least one pallet of fruit from each treatment was included in a Japan export shipment and inspected on arrival for incidence of rind disorders and decay.

Results

Leaf Nitrogen

The differential N applications were applied from 1997 through 2001. The average leaf N contents of each treatment in the first 3 years of the project are shown in Figure 1. Note that it took multiple years to establish the treatment differentials as reflected by leaf N. Figure 2 reports the same data but for the second 3 years of the project (1999 – 2001). In these three years there is a clear treatment (amount of N) effect on leaf N, however the effect of the method of application and timing of application is less clear with the possible exception of the foliar only applications.

The mean leaf N contents (1999-2001) for all treatments at the two satellite sites were quite similar to those found at the Main site (Figure 3). The data points representing the main site are the means of the data points shown in Figure 2. The data points for the satellite sites, which represent the same time period, are almost indistinguishable from those for the main site. These data demonstrate that the responses in leaf N at the three sites in response to the differential nitrogen application rates were quite similar.

Yields

Figure 4 reports the yield data collected in March 2002. The 2002 yield was greatly reduced as compared to previous years (Figure 5). This was in line with overall yield throughout the citrus industry in the San Joaquin Valley due to intense heat during the early stages of fruit set in May 2001 which caused extensive fruit drop. In spite of the reduced yield, we observed similar trends in yield data collected in 2000 and 2001 with yield increasing up to 1.0 to 1.5 lb N per tree regardless of application methodology. The cumulative yields for 2000 – 2002 related to applied N are reported in Figure 6. The data show the same trend of maximum production, under our experimental conditions, being achieved between 1.0 to 1.5 lb N/tree.

Nitrogen below the rootzones

Soil solutions were extracted from the plots almost monthly from 1997 through early 2002. These extracts were analyzed for nitrate-nitrogen (NO_3-N) to determine the levels of nitrogen in soil solutions leaching from the root zones and for chloride (Cl) which can be used to account for different fractions of applied water leaving the root zones under the different plots. The soil nitrate data for the main site over the course of the study show an increase in the NO_3-N concentrations in the soil leachate with increasing nitrogen application, i.e. higher nitrogen application, higher NO_3-N concentrations in leachates leaving the rootzones (Figure 7). While yields did not appear to be affected by method of application, it clearly impacted the NO_3-N concentrations in leachates. The highest NO_3-N concentrations were found in leachates collected from the plots receiving the soil-only treatments. The foliar-only applications resulted in the lowest concentrations, ones that were not different from the control treatment. The concentrations leaving the combination treatments were intermediate. Within the soil-only treatments the single application always resulted in higher concentrations of NO_3-N in the leachates than the split or continuous applications.

The Cl concentrations in extracts were not related to the amounts of nitrogen applied (Figure 8). This is to be expected as the source of the Cl was the irrigation water and the irrigation system was designed to apply water uniformly across the experimental field. The different Cl concentrations are an indication of different fractions of applied water leaching from the plots, i.e. the higher the concentrations, the lower the proportion of applied water leaching below the rootzone. The different leaching fractions are likely caused by different soil properties (permeability, layering, cementation) in the various plots.

In examining the NO_3-N:Cl ratios, the same general trends in nitrogen levels in soil solutions extracted from the plots hold (Figure 9). As applied nitrogen increases, the NO_3-N levels relative to Cl increase. These increases are greater for the soil-only treatment, least for the foliar-only treatments and intermediate for the combination treatments. The difference seen in Figure 9 compared to Figure 7 is that the continuous soil application resulted in higher NO_3-N to Cl ratios than either the single or split nitrogen application.

The nitrate-nitrogen concentrations in soil solutions leaching beneath the rootzones at the two satellite sites were quite similar to those at the main site (Figure 10). The concentrations at Sat 1 were slightly lower. The concentrations at Sat 2 were slightly higher. But overall they fell within the range of concentrations found at the main site.

Soil samples (6 – 20 ft) were collected during summer 2002 in order to evaluate nitrate leaching below the treated plots by a second method. Comparison of the results obtained by the two methods (soil solutions vs. soil extracts) are shown in Figure 11. Soil applied N is used as the x-axis. The left figure is the same as Figure 7 when adjusted for soil applied N rather than total. The same trends in nitrate-nitorgen concentrations were found by both methods. Overall the average concentrations found by the soil extract method were about 10 mg/l higher at equivalent N soil application rates. The soil solution method measured real time nitrate-nitrogen concnetrations leaving the rootzone; whereas, the soil extract method measured nitrate-nitrogen concentrations in soil below the rootzone that has moved there during past years. It likely represents nitrogen leaching during the time of our study and some history before we imposed the differential N treatments. But even in the five years of the study the soil zone from 6 to 20 feet reflects the treatments imposed on the surface. Both methods show that when soil applied N exceeded 1 pound per tree the nitrate-nitrogen concentrations increased more rapidly.

FIGURE LEGENDS

Figure 1. Average leaf nitrogen content for the Main experimental site for 1996 - 1998. Leaves collected in September of each year.

Figure 2. Average leaf nitrogen content for the Main experimental site for 1999 – 2001. Leaves collected in September of each year.

Figure 3. Average leaf nitrogen content for 1999 – 2001 for the various treatments at the three sites.

Figure 4. Average yields (lbs of fruit per tree) from the Main experimental site. Fruit harvested in March 2002.

Figure 5. Average yields (lbs of fruit per 2-tree plot) at the Main for each year of the study. 1997, 1998 are prior to establishment of differential results in leaf N per tree. 2000 – 2002 are yields from years where there were differential trends in leaf N related to treatment. No yield data was collected in 1999 due to the December 1998 freeze. Fruit harvested in March of each year.

Figure 6. Average cumulative yield (lbs of fruit per tree) from the Main experimental site for 2000 - 2002. Fruit harvested in March of each year.

Figure 7. Mean nitrate N in soil solution extracts collected from 1997 – 2002 from the Main experimental site.

Figure 8. Mean chloride levels in soil solution extracts collected from 1997 – 2002 from the Main experimental site.

Figure 9. Mean nitrate-N:Chloride levels in soil solution extracts collected from 1997 – 2002 for the Main experimental site.

Figure 10. Mean nitrate-N soil solution extracts for all treatments at the three sites for 1997 – 2002. The data points for 1, 1.5, and 2 pounds per tree have been offset slightly to show the data more clearly.

Table 1. Schedule of experimental treatments for nitrogen management project at the Main site.

Treatment	Soil Applied (lb/tree/yr)	Timing (times/yr)	Foliar (# applications)	Total N (lb/tree/yr)
1	0	-	-	0.00
2	0	-	1	0.25
3	0	-	2	0.50
4	0	-	4	1.00
5	0.5	1	-	0.50
6	0.5	2	-	0.50
7	0.5	C	-	0.50
8	1.0	1	-	1.00
9	1.0	2	-	1.00
10	1.0	C	-	1.00
11	1.5	1	-	1.50
12	1.5	2	-	1.50
13	1.5	C	-	1.50
14	2.0	1	-	2.00
15	2.0	2	-	2.00
16	2.0	C	-	2.00
17	0.5	C	1	0.75
18	0.5	C	2	1.00
19	0.5	C	4	1.50
20	1.0	C	1	1.25
21	1.0	C	2	1.50
22	1.0	C	4	2.00
23	1.5	C	1	1.75
24	1.5	C	2	2.00
25	2.0	C	1	2.25

Foliar Only

# Applications[z]	Lb N/tree/yr
0	0
1	0.25
2	0.50
4	1.00

Soil Only

Lb N/tree/year	Timing[y]
0.5	1, 2, C
1.0	1, 2, C
1.5	1, 2, C
2.0	1, 2, C

Combination Treatments

Soil Application (lb N/tree/yr)[x]	Foliar Applications (# applications)[z]	Total Lb N/tree/yr
0.5	1, 2, 4	0.75 - 1.50
1.0	1, 2, 4	1.25 - 2.00
1.5	1, 2	1.75 - 2.00
2.0	1	2.25

[z] **Foliar Application:** Low Biuret Urea will be applied to foliage at a rate of 0.25 lb/tree per application. Trees receiving one application will have urea applied in late May. Trees receiving 2 applications will have an additional application in late winter. Trees receiving 4 applications will have additional applications at the pre-bloom stage and 30 days following the late May application.

[y] **Soil Application:** All applications will be made through the irrigation system: 1 = single application per year in late winter; 2 = split application, late winter and early summer; C = Applied with every irrigation from late winter through summer.

[x] Soil Nitrogen will be applied as in the "C" treatment described above for the soil applications.

Table 2. Schedule of experimental treatments for nitrogen management project for satellite experimental sites in Tulare County (Orange Cove, Woodlake/Exeter).

Treatment	Soil Applied (lb/tree/yr)[z]	Timing (times/yr)	Foliar (# applications)[y]	Total N (lb/tree/yr)
1	1.00	1	-	1.00
2	1.50	1	-	1.50
3	2.00	1	-	2.00
4	1.50	C	-	1.50
5	1.25	1	1	1.50
6	1.00	1	2	1.50

[z] **Soil Application:** All applications will be made through the irrigation system: 1 = single application per year in late winter; 2 = split application, late winter and early summer; C = Applied with every irrigation from late winter through summer.

[y] **Foliar Application:** Low Biuret Urea will be applied to foliage at a rate of 0.25 lb/tree per application. Trees receiving one application will have urea applied in late May. Trees receiving 2 applications will have an additional application in late winter.

Figure 1. Average leaf nitrogen content for Main experimental site for 1996 - 1998. Leaves collected in September of each year.

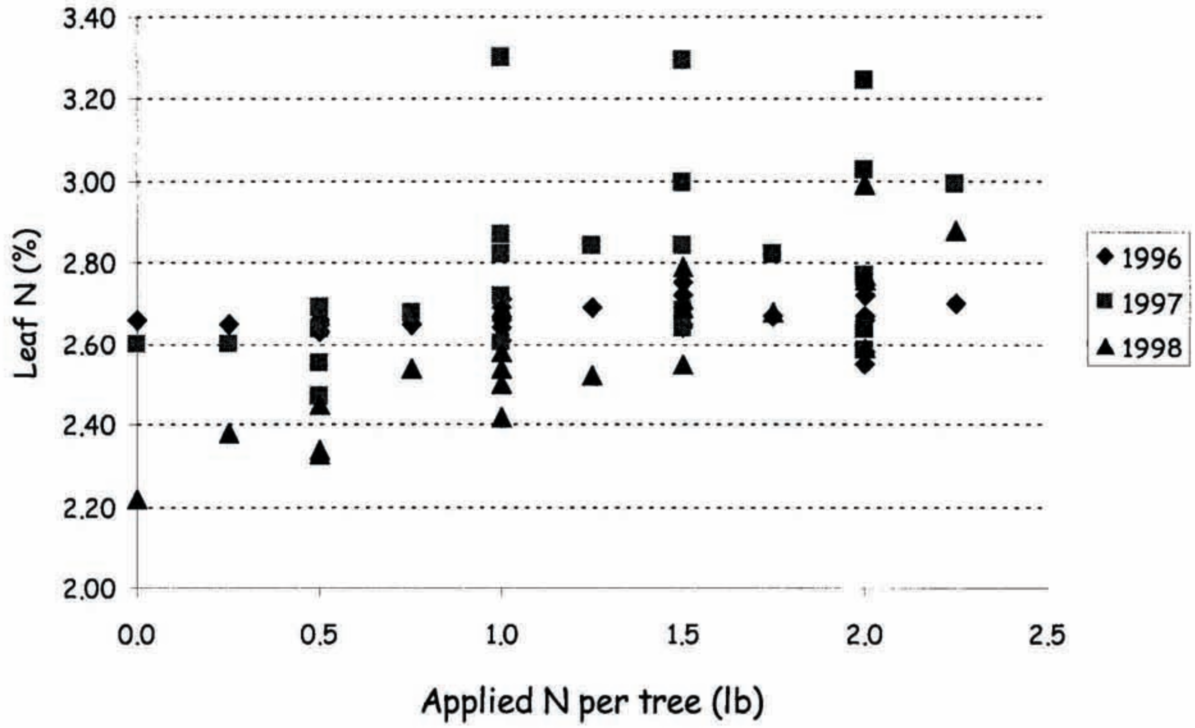

Figure 2. Average leaf nitrogen content for Main experimental site for 1999 – 2001. Leaves collected in September of each year.

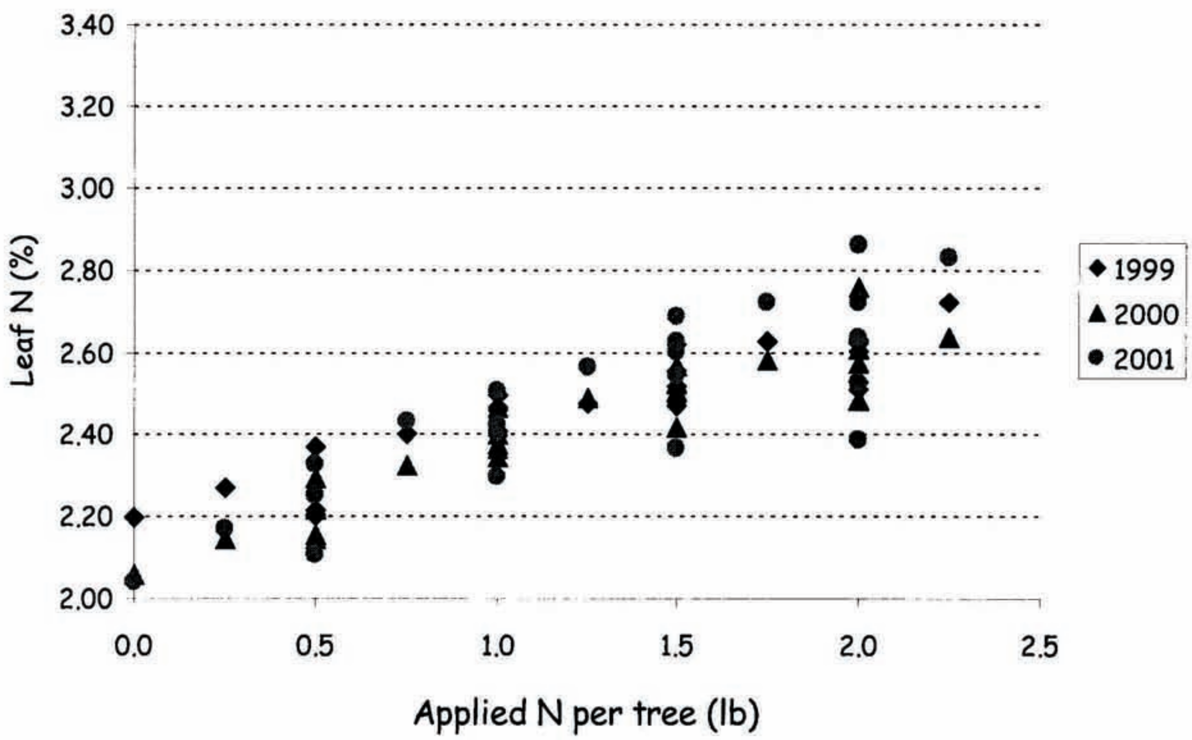

Figure 3. Average leaf nitrogen content for 1999 – 2001 for the various treatments at the three sites.

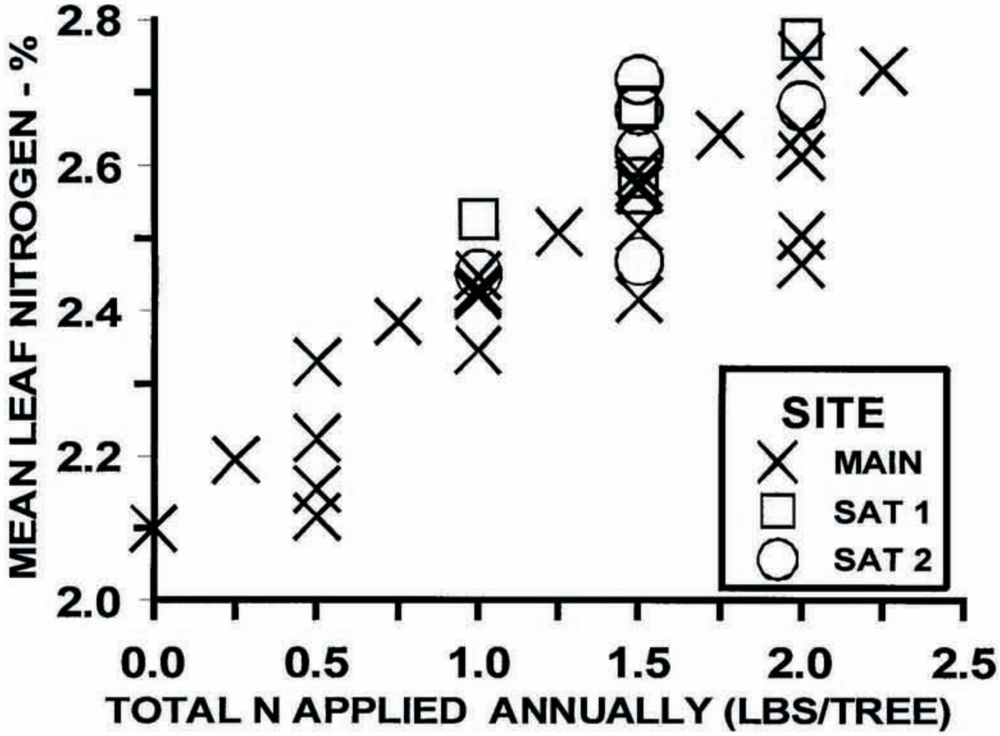

Figure 4. Average yields (lbs of fruit per tree) from the Main experimental site. Fruit harvested in March 2002.

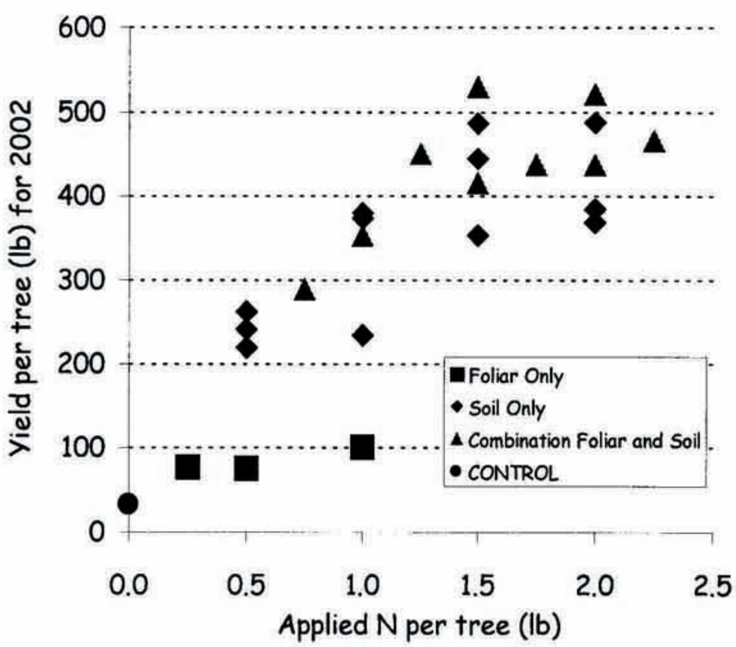

Figure 5. Average yields (lbs of fruit per 2-tree plot) at the Main site for each year of the study. 1997, 1998 are prior to establishment of differential results in leaf N per tree. 2000 – 2002 are yields from years where there were differential trends in leaf N related to treatment. No yield data was collected in 1999 due to the December 1998 freeze. Fruit harvested in March of each year.

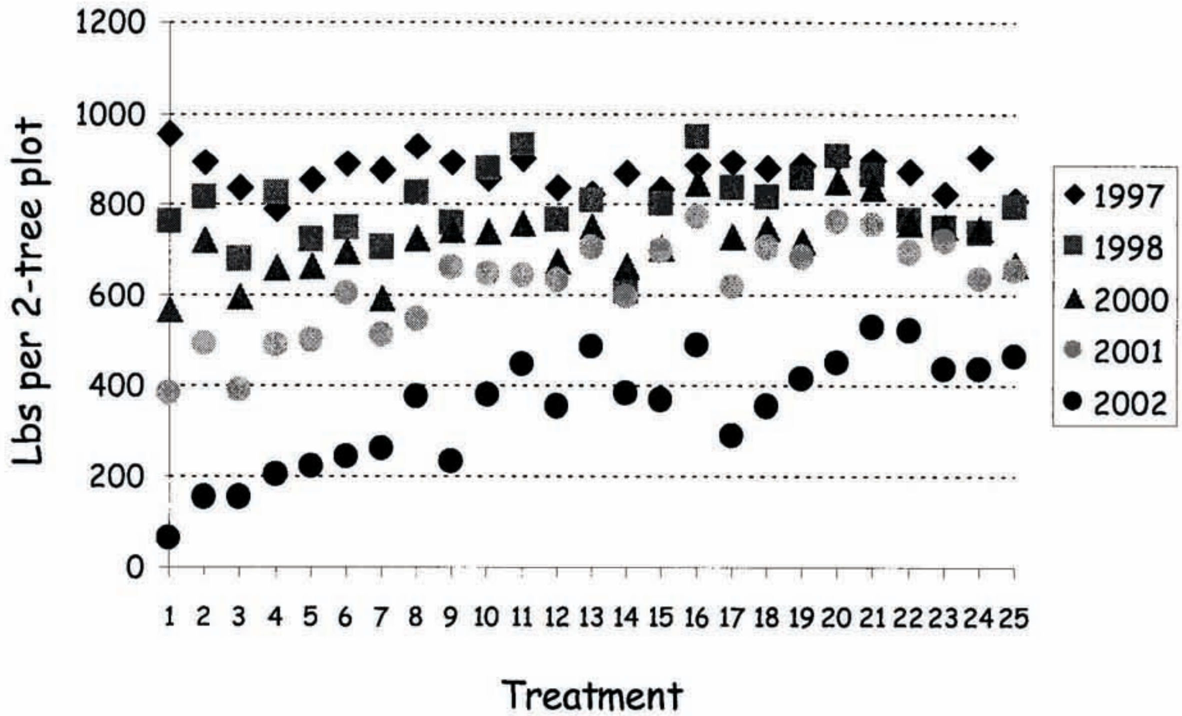

Figure 6. Cumulative yield (lbs of fruit per tree) from the Main experimental site for 2000 - 2002. Fruit harvested in March of each year.

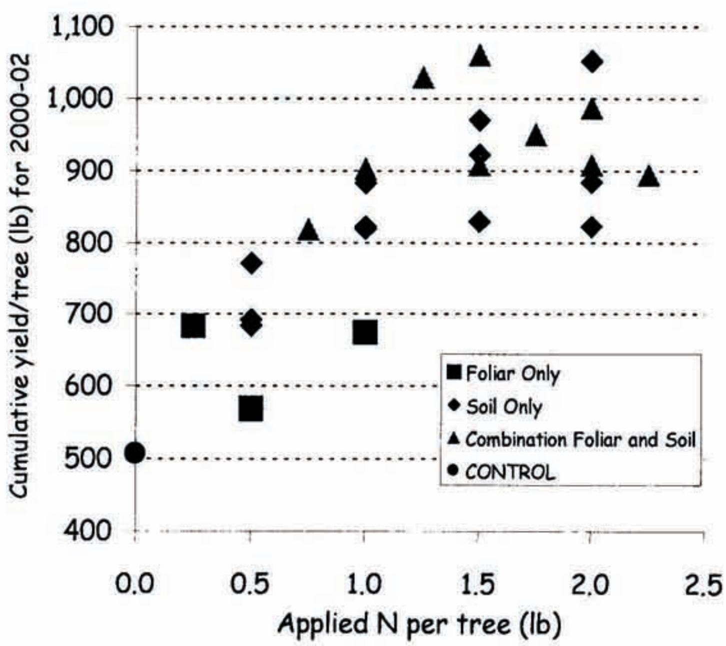

Figure 7. Mean nitrate N in soil solution extracts collected from 1997 – 2002 from the Main experimental site. In case of soil only, 1 = single application, 2 = split application, C = continuous application. For foliar treatments numbers indicate number of foliar applications.

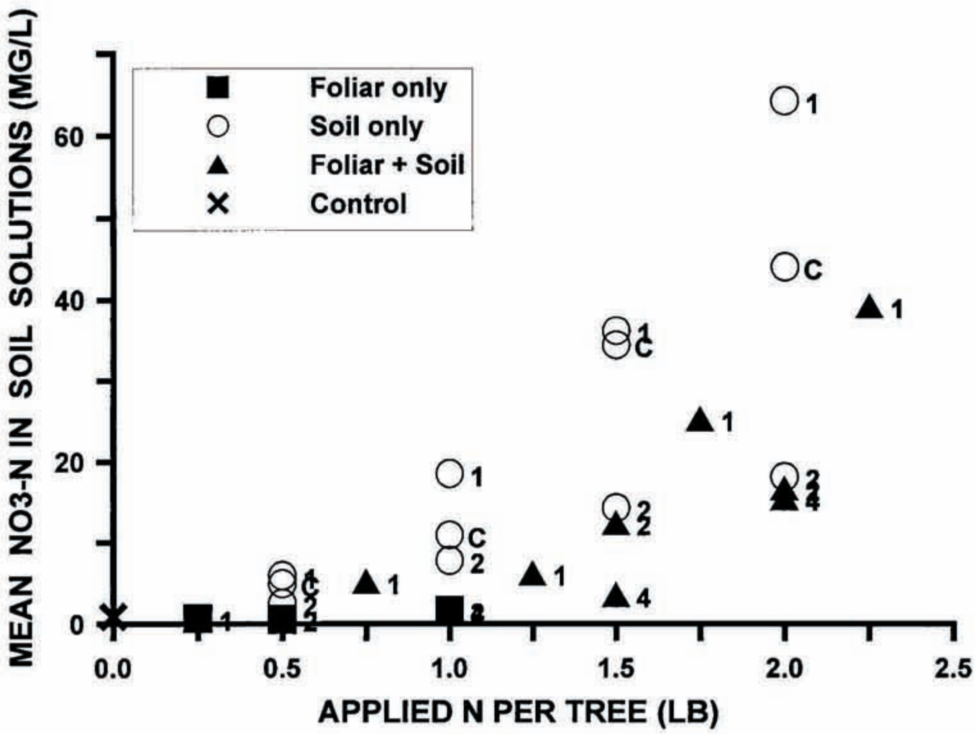

Figure 8. Mean chloride levels in soil solution extracts collected from 1997 – 2002 from the Main experimental site. In case of soil only, 1 = single application, 2 = split application, C = continuous application. For foliar treatments numbers indicate number of foliar applications.

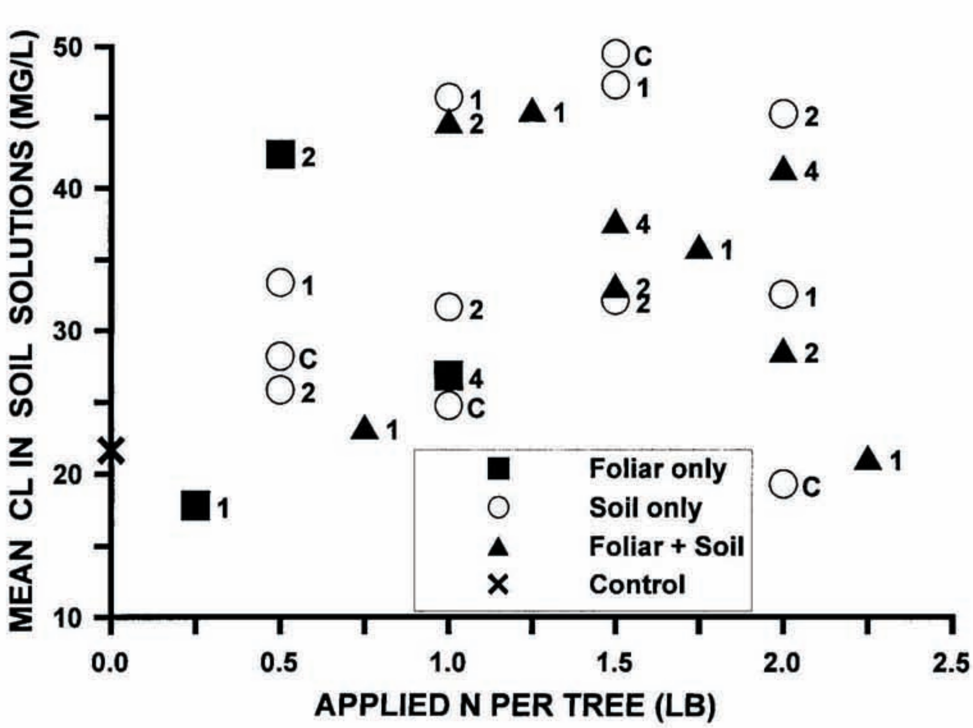

Figure 9. Mean nitrate-N:Chloride levels in soil solution extracts collected from 1997 – 2002 for the Main experimental site. In case of soil only, 1 = single application, 2 = split application, C = continuous application. For foliar treatments numbers indicate number of foliar applications.

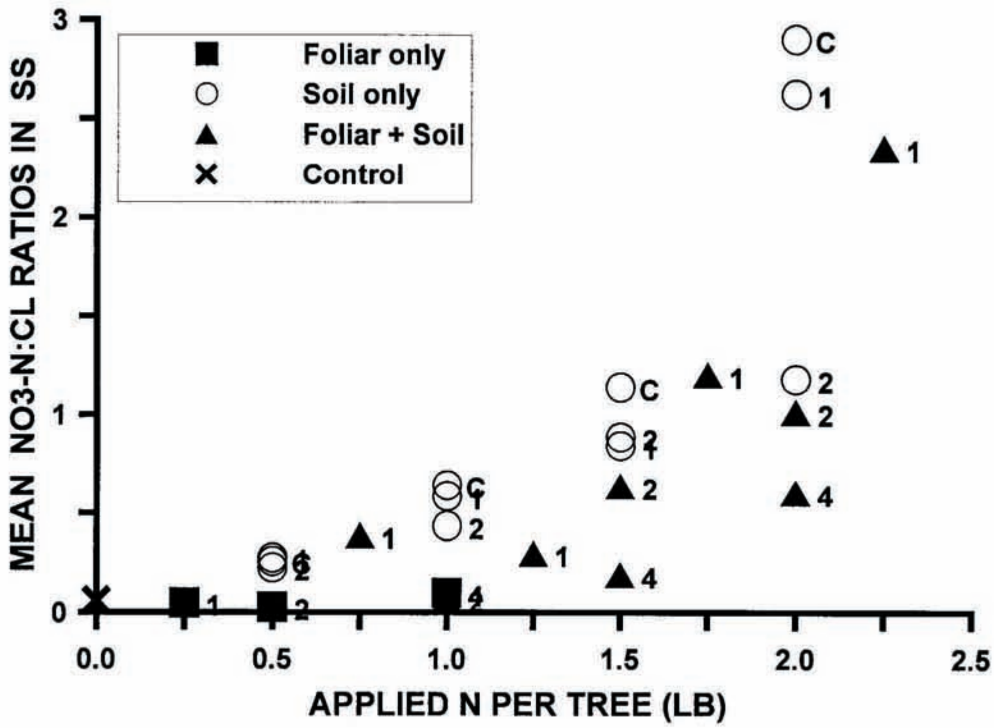

Figure 10. Mean nitrate-N soil solution extracts for all treatments at the three sites for 1997 – 2002. The data points for 1, 1.5, and 2 pounds per tree have been offset slightly to show the data more clearly.

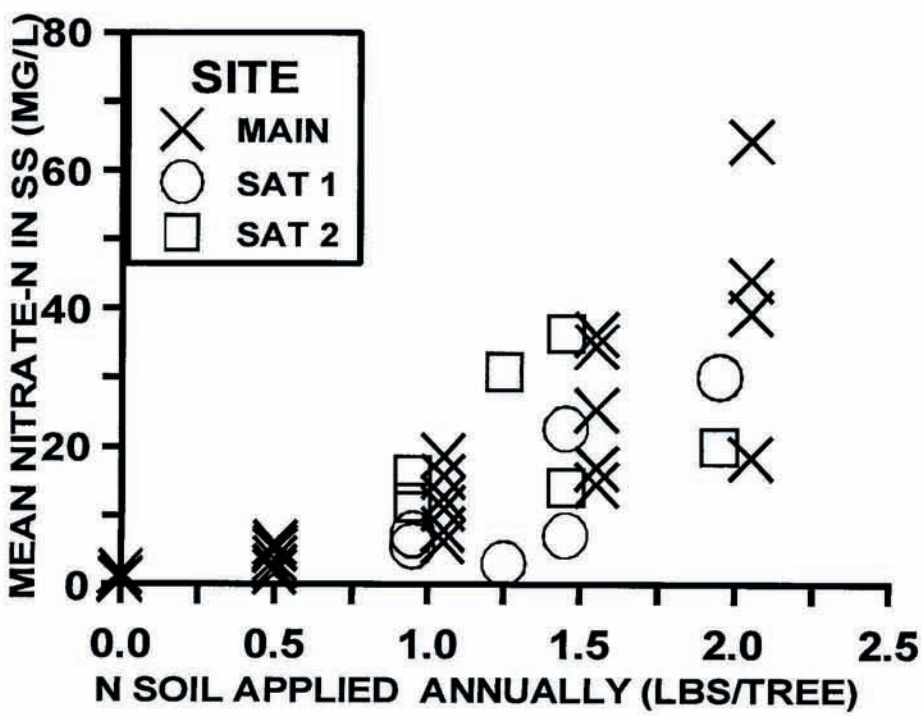

Figure 11. Comparison of mean nitrate-N leaching from soils at main site as assessed by two measurement methods, soil solutions and soil extracts.