A. Project Title:

Influence of Irrigation Management on Nitrogen Use Efficiency, Nitrate Movement and Ground Water Quality in a Peach Orchard.

CDFA Contract No.: 91-0646

Principal Investigators:

Dr. R. Scott Johnson, Extension Pomology Specialist, University of California, Kearney Agricultural Center, 9240 S. Riverbend Ave., Parlier, CA. (209) 891-2500 (Project leader).

Dr. Claude J. Phene, Soil Scientist and Research Leader, USDA Water Management Laboratory, 2021 S. Peach Ave. Fresno, CA., 93727 (209) 453-3100

Cooperators:

Dale Handley, Post-Graduate Researcher, University of California, Kearney Agricultural Center, 9240 S. Riverbend, Parlier, CA., (209) 891-2521 (Project manager).

Bob Cochran, Shanti Handley, Paul Wiley, Technical Support, Kearney Agricultural Center.

B. Statement of Objective:

Justification: In order to minimize pollution of groundwater resources by leaching of nitrates, stone fruit growers must be provided with information on strategies to maximize nitrogen uptake efficiency while maintaining optimal production.

Objectives:

1) To measure soil nitrate movement under different low-volume irrigation regimes.
2) To investigate the interaction of fertilizer use and irrigation on the yield and fruit quality of peaches.
3) To obtain information on water and fertilizer use patterns of stone fruit growers.
4) To summarize existing information from the literature on fertilizer use efficiency and nitrate leaching in stone fruit.
5) To disseminate the information obtained under the first four objectives to stone fruit growers.

C. Executive Summary

1. Literature Reviews: Two literature reviews were written and made available to Cooperative Extension stone fruit farm advisers and specialists and to the California Department of Food and Agriculture:

   a) The Effects of Various Cultural and Environmental Factors on Nitrogen Use Efficiency and Nitrate Leaching in Stone Fruit Orchards.

   b) Techniques for Sampling Soil Nitrates: Ceramic Cup Extractors

Dr. Johnson was also coauthor of a review of nitrogen fertilization of fruit crops published in Horticulture Technology, Jan-Mar, 1992.

2. Preparatory field work for plot study: The vertical extent of the rootzone of peaches under different existing irrigation regimes and the horizontal and vertical distribution of nitrates in the rootzone were measured in backhoe pits dug in January, 1992. The majority of roots were within 4 feet of the ground surface. The distribution of nitrates both horizontally and vertically was highly variable, and not attributable to historical irrigation treatments. In order to follow movement of nitrates through the rootzone, ceramic cup "suction lysimeters" were installed at four depths within and below the rootzone in all treatment replicates in March, 1992.

3. Plot Study of Fertilization and Irrigation Regimes: Multiple applications of N fertilizer through a low-volume system were compared to one-time applications within three different irrigation regimes. The three irrigation regimes were high-frequency supplying 100% of evapotranspiration (ET)(T1), low frequency supplying 100% of ET (T8), and high-frequency supplying 100% ET except for 150% of ET during the final fruit growth stage (T3). Plots receiving single fertilizer applications (A) received 30 units of N on May 29 and 75 units on August 29. Plots receiving multiple applications (B) received the same total amount of N, but in 10 units weekly beginning May 29 and 25 units every two weeks beginning August 29.

   There were no significant effects of fertilization treatments on any measured yield or growth parameters. Yield (total fresh weight) and number of fruit per tree were significantly reduced in T3, which received 150% of ET for 6 weeks prior to harvest. This treatment is similar to common grower practice.

   Detection of treatment differences in soil nitrate concentrations was hindered by spatial and temporal variability of NO_3-N levels. However, based on trends in NO3-N concentrations, soil water content, and applied water measurements, several conclusions regarding nitrate distribution and nitrate leaching are presented:

   1) Initial soil solution NO3 levels down to 72" were low (below 10 ppm). Following a slight increase in NO3-N in T1 and T8 at 12" in response to the spring fertilization, NO3-N levels dropped off and remained very low at all depths, reaching a mean level of 2 ppm by August 24. Following the fall fertilization there was a trend for a high spike in NO3-N levels at 12" (100-200 ppm) with the "slug" (A) fertilization. In T-8 (low-frequency irrigation) the slug of nitrogen resulted in high levels of N at 12" to 72" for 12-18 days after the fertilization, while the split treatment led to sustained increases at a lower concentration for 60 days. By October 15 almost all NO3-N concentrations were lower than the initial May 24 concentrations.

   2) T3, which received 150% ET for six weeks, had 6 to 8 inches of water leaching below the rootzone. However NO3-N levels at 72" remained below 2.5 ppm throughout the season, and estimated NO3-N leaching was less than 1 lb/ac for the season. Water contents above field capacity may have provided anaerobic conditions necessary for significant amounts of denitrification.

3) T1 (100%ET, high-frequency) had little water or nitrates leaching below the rootzone during the season.

4) T8 (100% ET, low-frequency) was irrigated for a much longer duration than T-1 and after the fall fertilization NO3-N concentrations reached relatively high levels at all depths down to 72". There seems to be increased potential for nitrate leaching with this treatment. However, water content measurements indicated that little water was percolating below the 3.5 foot depth during the entire season, so there is no concrete evidence of significant levels of nitrate leaching.

4. Grower Survey of Fertilization and Irrigation Practices: A questionnaire was prepared and tested on ten growers. The questionnaire was revised and mailed to 1700 stone fruit growers in five counties in January, 1993. Results of the survey will be published by December, 1993.

D. Work Description

TASK 1. Literature Review

Subtask 1.1: A literature review entitled The Effects of Various Cultural and Environmental Factors on Nitrogen Use Efficiency and Nitrate Leaching in Stone Fruit Orchards was completed in August, 1992 and submitted to the CDFA. Dr. Johnson was also coauthor of a review of nitrogen fertilization of fruit crops published in Horticulture Technology, Jan-Mar, 1992 (Weinbaum et al., 1992). Portions of this published review relating to nitrogen use efficiency and nitrate leaching are included in the project review. Additional literature related to nitrogen loss pathways, irrigation and nitrate leaching, and soil factors affecting nitrogen use efficiency was reviewed for the project literature review.

Based on the literature review preliminary guidelines for minimizing over-fertilization and for improving NUE in orchards were prepared. (See subtask 1.3).

Subtask 1.2: A literature review entitled Techniques for Sampling Soil Nitrates: Ceramic Cup Extractors was completed in October, 1992 and is submitted with this final report.

Subtask 1.3: A newsletter article entitled Efficient Use of Nitrogen Fertilizers in Orchards was prepared by Dr. Johnson for distribution to stone fruit growers via newsletters of the stone fruit farm advisers. A copy of the article is submitted with this final report.

To date this article has been published in the following newsletters:
Tulare County Orchard Notes. Jan-Feb, 1992 (591 subscriptions);
Fresno County Tree Topics. Jan, 1992 (614 subscriptions).

TASK 2. Preparatory field work before beginning plot study.

Subtask 2.1: Determine initial extent of rootzone and baseline nitrate levels within and below the rootzone.
Two different fertilization frequency treatments are being overlaid on top of three irrigation treatments which have been in effect for the previous two years. This subtask had two purposes:

1) to determine the vertical extent of the rootzone under the different irrigation treatments and different soil profiles existing in the field.

2) to obtain baseline levels of nitrates in the soil before the fertilizer treatments were imposed and to examine the spatial variability of soil nitrates both horizontally and vertically within the rootzone.

In January 1992 six backhoe pits were dug in the experimental field. Two replicates of each of the three irrigation treatments were selected so that each of the six blocks had one backhoe pit. In this way we could observe the different soil profiles existing in the field and the root distributions under different irrigation regimes in different profiles. Backhoe pits were dug parallel to and approximately 3 feet from the tree row (Fig. 1). Backhoe pits were five feet deep and six feet long.

The trench wall facing the trees was gridded into 1 foot squares, and the approximate number of roots were recorded on a map of the wall. The number of roots was not counted, but the relative distribution of roots was portrayed by this method. Where it existed, the approximate location of a grey silt layer in the profile was also recorded.

Two sets of soil samples were collected and analyzed prior to the imposition of irrigation and fertilizer treatments in 1992. Soil samples collected from the "root profile trenches" in January 1992 were collected at one foot depth intervals down to five feet from 4 sites within a 6 foot by 5 foot rectangle adjacent to a single tree (Fig. 1). The second set of soil samples was collected from the installation holes for the SSAT, at the depth of the ceramic cup. Samples for nitrate analysis were air-dried, crushed and analyzed for nitrate content at the DANR laboratory at U.C. Davis. Nitrate concentrations of KCl extracts were measured by the diffusion-conductivity method. Sub-samples for water content determination were weighed, dried at 70°C, and reweighed.

Subtask 2.2: Develop Quality Assurance program for nitrate testing.
Approximately 2700 soil-water samples were analyzed for NO3-N concentration at the USDA Water Management Laboratory in Fresno, California. Appendix 1 outlines the Quality Assurance Program for nitrate testing.

Subtask 2.3: Design and install a system of soil water solution vacuum extractors for the field plot study.
In order to follow movement of nitrates through the rootzone, the design called for "suction lysimeters" (Grossman and Udluft, 1991) at depths of 12", 30", 48" and 72" at each site. Due to the high variability reported for nitrates extracted in this manner (Alberts et al., 1977; Hansen and Harris, 1975) it was decided to install extractors at two sites in each replicate of each treatment for a total of 36 sites and 144 extractors.

SSAT (soil solution access tubes) from the Irrometer Company, Riverside, CA. were installed at the second and fifth trees in the treatment row in each replication between March 31 and April 16, 1992. Tubes were installed approximately 27" from the centerline of the tree row, beginning 12" north of the tree, with tubes spaced 6" apart. A 2" diameter hole was augered to the desired depth, a slurry of diatomaceous earth was poured to a 2" depth in the hole, the SSAT cup was placed in the slurry, and the hole was backfilled (Morrison, 1982). A bentonite plug was placed in each hole to prevent channeling of irrigation water along the edge of the tube (Morrison, 1982) (Fig. 2).

In order to semi-automate the collection of samples, manifolds were built for each site and connected to a 5-CFM vacuum pump (GasT Mfg. Corp., Benton Harbor, Mich.) via a closed conduit system. The four SSAT's at each site were connected to the site manifold via a test tube "trap" for each SSAT (Fig. 2). When the vacuum pump is in operation soil solution is extracted from each cup into its respective test tube. The vacuum pump cycles on and off between -18 and -22 kPa suction. When sufficient solution has collected in a test-tube the connection hose to the extractor is clamped, eliminating further suction in that extractor. This prevents extraction of large volumes of solution from particular depths in the profile, which could effect the hydraulic gradient in the soil.

TASK 3: Plot study of varying frequency and duration of low-volume irrigation.

The purpose of this task is to study the effect of different low-volume irrigation regimes in combination with different fertilization regimes on nitrogen use efficiency, soil nitrate movement, yield, fruit size and tree water status.

The experimental site is a 2.5 acre field of 4 year old O'Henry peach trees at Kearney Agricultural Center, Parlier California. Trees are planted at high density, (454 trees per acre) and trained to a perpendicular V. Each tree is irrigated by a fan jet emitter (6 gph). The soil is a Hanford fine sandy loam with a subsurface silt layer occurring between three and six feet below the ground surface in some areas of the field.

This field has received differential irrigation treatments for two years previous to 1992. The irrigation treatments are controlled by a large weighing lysimeter containing two trees located in the center of the field. There are eight irrigation treatments replicated six times. Six of the treatments apply different percentages of full evapotranspiration (ET) during three different fruit growth periods. Two treatments receive full evapotranspiration for the full season, but at 1/3 and 1/6 the frequency of the Control.

Subtask 3.1 Select irrigation and fertilizer treatments.
Three irrigation treatments were selected from the eight existing irrigation treatments (Fig. 3, Table 1). T1 receives 100% of full evapotranspiration, and is irrigated when the lysimeter has lost .21 inches of water, resulting in daily irrigations during mid-season. T8 receives 100% ET but is irrigated at 1/6 the frequency of T1. A comparison of T1 and T8 will test the effects of irrigation frequency on nitrate leaching, NUE and tree performance. T3 is irrigated at the same frequency as the Control, but receives 150% ET during the final fruit growth period (June 18 through August 4 in 1992), and 100% ET during the remainder of the season. A comparison of T1 and T3 will test the effects of over irrigation during mid-summer on nitrate leaching, NUE and tree performance.

In 1992 the irrigation experiment was modified to include two different fertilization frequencies using liquid fertilizer (acidified 8-4-8) applied through the irrigation system (Table 1). Each treatment receives a total of 105 units of N during the season, but treatment A has two applications and treatment B has six applications. Treatment A consists of a single application of 30 units of N/acre on 5/29/92 and a single application of 75 units of N/acre on 8/29/92. Treatment B consists of three applications of 10 units of N/acre at weekly intervals beginning on 5/29/92 and three applications of 25 units of N/acre at biweekly intervals beginning on 8/29/92. Each fertilizer treatment is applied to three of the six replicates of each irrigation treatment resulting in three replicates of each irrigation/fertilization combination. Each replicate consists of three rows of 8 trees, with the center 6 trees used as experimental trees (Fig. 3). The experimental design is a split-plot design, with three blocks, with nitrogen as the main plot and irrigation as the sub-plot.

Subtask 3.2: Monitor soil water content and leaf water potential in the selected treatments.
Soil water content was measured every two weeks in each replicate at one foot intervals to a 5.5 foot depth, using a neutron probe in a single access tube in each replicate.

Midday stem water potential (SWP) was monitored every two weeks using a Scholander pressure bomb. SWP was measured on leaves which were bagged in plastic bags with a reflective surface one hour prior to measurement. Two leaves from two trees per replicate were measured each time.

Subtask 3.3 Monitor soil nitrate levels.
Soil water solutions samples were extracted periodically from 12", 30", 48" and 72" at from two sites in each replicate (144 samples) via the SSAT suction lysimeter system described in Subtask 2 (Fig. 2). Soil moisture samples were collected every 3 to 6 days following the initial fertilization on 5/29/92 through 6/22/92 and every two weeks from 6/22/92 through 8/24/92. Following the initial N injection of the second fertilization cycle on 8/29/92 soil moisture samples were collected on a weekly basis for six weeks (until the split N applications were completed), and then on a bi-weekly basis through 11/17/92 (approximate leaf fall) 11/15/92). Soil moisture samples were collected on 19 separate dates, and a total of 2736 separate samples were analyzed for nitrate concentration using the Alp-Chem Rapid Flow Analyzer RFA300 at the USDA Water Management Laboratory in Fresno, CA.

Time needed to collect 10 ml of solution varies from 15 minutes to 36 hours depending on soil water content, individual tube location, and vacuum settings. If vacuum level can be maintained at 75 kPa 90% of the extractors have sufficient volume within 8 hours.

Subtask 3.4 Monitor leaf nitrogen levels.
Leaf samples were collected from each treatment replicate on July 9, 1992. Forty leaves from each of the six treatment trees of each replicate were collected, dried at 70°C, ground, and analyzed for total nitrogen levels at the DANR laboratory (U.C., Davis) using conventional methods.

Subtask 3.5 Harvest fruit and measure harvest parameter.
Fruit was harvested according to commercial maturity standards in 3 picks on July 24, July 29 and August 4. All fruit from each treatment tree were weighed and counted. One-half of the fruit from each replicate were run through an optical sizing machine, to determine the percentage of fruit in each commercial size. Total fresh weight, mean fruit weight, number of fruit per tree, and the percentage of fruit in each size category were determined for each treatment.

Subtask 3.6 Prepare interim report.
The interim annual report was submitted in September, 1992.

Subtask 3.7 Prepare a final report on the findings and results of this plot study. This document is the final report.

TASK 4: Do preliminary work on a survey of stone fruit growers regarding fertilization and irrigation practices with low-volume irrigation systems.

The purpose of this task is to provide statistical information on grower fertilization and irrigation practices.

Subtask 4.1 Prepare survey questions.
Preliminary survey questions were compiled after a meeting of Dr. Johnson and Dale Handley with stone fruit farm advisers Kevin Day (Tulare County) and Harry Andris (Fresno County). The draft questionnaire was submitted to cooperating stone fruit farm advisers and the CDFA for review in September, 1992.

Subtask 4.2 Administer preliminary survey.
The revised questionnaire was distributed to approximately 15 stone fruit growers for completion and evaluation in November, 1992. Ten of the questionnaires were completed and returned along with an evaluation of the questionnaire.

Subtask 4.3 Tabulate results of preliminary survey.
Results from the preliminary survey have been summarized and are included in this final report. The questionnaire was modified based on a review of the preliminary survey responses and comments from growers. A copy of the final questionnaire is included with this report(Appendix III). 1700 copies of this questionnaire were mailed in January 1993. Names were obtained from the County Commissioners' lists of persons registered to apply pesticides on stone fruit for Fresno and Kern counties, and from the lists of fruit growers newsletter subscribers in Kings and Tulare counties.

TASK 5: Report results and findings of the first year's work.
This annual report satisfies task 5.

E. Results, Discussions and Conclusions

TASK 1. Literature Review

The Effects of Various Cultural and Environmental Factors on Nitrogen Use Efficiency and Nitrate Leaching in Stone Fruit Orchards (Handley, et. al., 1992) was submitted to the CDFA in fulfillment of Subtask 1.1. A brief summary of the literature review is included here.

Low fertilizer nitrogen use efficiencies for orchard crops have been related to higher than average levels of nitrate in ground water. Several studies indicate that orchard crops are more likely to receive excess N than most other crops and recent findings of the DWR indicate a substantial increase in ground water nitrates in an area predominated by citrus and stone fruit orchards.

High nitrogen use efficiencies result when the plants recover a high proportion of the fertilizer N applied. Loss of N from the soil occurs via three main pathways: ammonia volatilization, nitrate leaching or denitrification. There are environmental and cultural factors which contribute to each of these pathways, and some of them are controllable by the grower.

Ammonia volatilization can be limited by using non-urea fertilizers, or by proper application of urea fertilizers. Denitrification is an anaerobic process and is highly dependent on soil drainage characteristics. Proper irrigation management can limit denitrification in many situations. Nitrate leaching is the most prevalent loss pathway for California orchards. Nitrate leaching occurs when nitrates in excess of plant needs exist within the rootzone and are subject to irrigation or rainfall in excess of soil water holding capacity.

Nitrate leaching can be limited by good fertilization and irrigation practices. These practices are summarized in the Newsletter Efficient Use of Nitrogen Fertilizers in Orchards, which was a product of this project. They include:

1) Determining the amount of fertilizer to apply by,
   a) Testing well water to determine nitrate content. This indicates how much nitrogen from the water is available for plant use.
   b) Estimating the availability of N from the soil.
   c) Estimating removal of N by the crop.

2) Avoiding winter fertilization.

3) Using split applications of N fertilizer.

4) Using fertigation procedures where feasible.

5) Using an N formulation appropriate to soil chemistry.

6) Using proper application procedures for different formulations.

7) Avoiding over-irrigation following application of fertilizer.

8) Scheduling irrigations to avoid deep percolation or run-off.

TASK 2, 3 PLOT STUDY: Effects of fertilization timing and frequency and duration of low-volume irrigation on nitrogen use efficiency, soil nitrate concentrations, and harvest parameters in a peach field.

Extent of rootzone

Representative diagrams of soil profiles and root distributions are illustrated in Figures 4-6. The majority of roots observed in all three irrigation treatments was in the top four feet of the soil profile. The highest density of roots was in the first foot of the profile in all treatments and there was an extremely low density of roots in the 5th foot of the profile. Observations were generally limited to five feet in depth by the depth of the trench. Several excavations to the six foot depth in each trench revealed no roots in the sixth foot.

In the Control (100% ET, high frequency) root densities were very low in the second foot, compared to the other two treatments (Fig. 4-6). Root densities from 2 to 5 feet were not consistently different between treatments, but were visibly more dense in Block 5 (T3) (Fig. 5) and Block 4 (T8) (not illustrated).

Based on these limited observations, the rootzone is limited to the five foot depth and there appear to be no consistent effects on root distribution of three prior years of differential irrigation treatments.

The soil texture of the majority of the profile was a fine sandy loam. One or two layers of silty substratum were found in five of six back-hoe pits between 3.5 and 5 feet. The layers were 4 inches to 1.5 feet thick. The root density in the silty substratum was generally very low, but pockets of very fine roots were dispersed throughout the substratum.

Baseline soil nitrate levels

Soil samples from the installation holes for the SSAT, taken at the depth of the ceramic cup in January 1992 were analyzed for nitrates. The mean irrigation treatment NO_3-N values (ppm on dry soil weight basis) by depth ranged from 2.34 ppm to 5.74 ppm (Table 2). There were no significant differences between irrigation treatments at any depth. This indicates that 3 years of prior irrigation treatments had no consistent effect on vertical distribution of nitrates in the soil profile.

Tree and soil water status. All three treatments received the same amount of water through June 15, 1992, but T8 was irrigated at 1/6 the frequency of T1 and T3. From June 15 through August 15, T3 received 1.5 times as much water as T1 and T8. After August 15 all three treatments received the same amount of water. The seasonal pattern of SWC in response to the irrigation treatments varied by depth (Figs. 7,8). Differences between treatments in initial SWC on March 1, 1992 at all depths of were very small. The initial SWC for each treatment increased with depth, a reflection of greater water holding capacity in the lower profile.

Below the .75 foot depth there is a seasonal downward trend in SWC for T1 and T8. Below 2.5 feet this trend is more pronounced for T8. These trends indicate that these treatments are actually receiving less than full evapotranspiration, and that there is essentially no water percolating out of the rootzone. T1 and T8 received the same amounts of water, so the greater reduction in SWC for T8 suggests a lower irrigation efficiency for this low frequency treatment. This may be due to greater soil surface evaporation, since water does tend to pond on the soil surface with this treatment.

The SWC values from March 1 through July 1 for T3 are similar to those of T1 down to 3.5 feet, but higher for T3 at 4.5 and 5.5 feet. There is a similar downward trend for both treatments at all depths. From July 1 through August 15 the SWC of T3 has an upward trend in response to the increased water application at all depths. This indicates that there is downward percolation of water to at least a depth of 5.5 feet.

The immediate decrease of SWC in T3 at the 9" depth after resumption of 100% evapotranspiration would indicate that SWC had reached a level above "field capacity", and upon resumption of 100% ET, free drainage allowed the return to "field capacity" conditions. Below 9", the SWC of T3 gradually decreased from August 15 through the end of the season, but remained higher than the SWC of T1 until the end of the season. This may indicate that T3 has soils with a higher SWC, and, in fact, the SWC at 4.5 and 5.5' was higher in T3 even at the beginning of the season. However, the slow decrease in SWC in T3 may also indicate impeded drainage due to the compacted silt layer in this field.

Midday stem water potential values indicate that there were no significant differences in tree water status between treatments during the May 1 through August 1 period (Fig. 9). The downward trend in stem water potential for all treatments suggests that transpirational demand exceeded soil water availability. This is in agreement with the downward trends of SWC for T1 and T8, but the increase in SWC in T3 between July 1 and August 15 is not reflected by an increase in stem water potential. Is this due to saturated conditions in the rootzone limiting root water uptake or is transpirational demand just greater than the ability of the trees to extract soil moisture at any SWC?

Tree nitrogen status

Analysis of leaf samples collected on July 9, indicated that total leaf N was 2.94% in T1, 2.72 % in T3 and 3.05% in T8 (Table 3). Means for T3 and T8 were significantly different at the $P = .05$ level. The reduction in N in T3 may be related to reduced availability of soil N due to increased nitrate leaching or to saturated conditions resulting from application of 150% of crop ET beginning June 18th.

Seasonal patterns of soil moisture nitrate concentrations

Figure 10 illustrates the seasonal patterns of nitrate concentrations at four depths for the three irrigation treatments. The mean value plotted for each irrigation treatment is the mean of 12 measurements (6 replications with two extractor sites per replication). Due to the high temporal and spatial variability the apparent differences in nitrate concentrations attributable to irrigation treatment are significant in only a few cases (Fig. 10).

Following the spring fertilization event the peak in nitrate concentrations which occurred in T1 and T8 was significantly different than the value for T3. At 48" and 72" nitrate values for T1 were significantly different from those of T8 on several dates prior to harvest, but the difference in nitrate levels was small.

Following the August fertilization event there was a peak in nitrate levels in all three treatments at 12", and levels in T1 were significantly different from T3 and T8 on one date. At 30", 48" and 72" nitrate levels in T8 were significantly higher than those in T1 on several dates following the August fertilization.

At 48 inches and 72 inches there are large differences between treatment means that are not significant due to high variability. The relatively high means (17-24 mg/l) for T8 for the first four sampling dates are attributable to nitrate concentrations above 150 mg/l at one site in T8-Block 4. These high nitrate concentrations were consistent with relatively high nitrate levels measured in the soil samples collected from the trench near this site in February and from the extractor hole in April. This area has a cemented hardpan layer beginning at the 5 foot depth. The 72" extractor at this site recovered relatively large volumes of soil moisture. Nitrates may have been trapped in a pocket in the hardpan and removed by the early soil moisture extractions.

In spite of the variability, several generalizations are suggested by the seasonal patterns of mean nitrate concentrations which are supported by examination of seasonal patterns at individual sites:

1) Initial soil solution NO3 levels down to 72" were low (below 10 ppm). Following a slight increase in NO3-N in T1 and T8 at 12" in response to the spring fertilization, NO3-N levels dropped off and remained very low at all depths, reaching a mean level of 2 ppm by August 24. Following the fall fertilization there was a trend for a high spike in NO3-N levels at 12" (100-200 ppm) with the "slug" (A) fertilization (Fig. 11). In T-8 (low-frequency irrigation) the slug of nitrogen resulted in high levels of N at 12" to 72" for 12-18 days after the fertilization, while the split treatment led to sustained increases at a lower concentration for 60 days. By October 15 almost all NO3-N concentrations were lower than the initial May 24 concentrations.

2) T3, which received 150% ET for two months, theoretically had 6 to 8 inches of water leaching below the rootzone. However, NO3-N levels at 72" remained below 2.5 ppm throughout the season, and we estimate that NO3-N leaching was less than 1 lb/ac for the season. Water contents above field capacity may have provided anaerobic conditions necessary for significant amounts of denitrification.

3) T1 (100%ET, high-frequency) had little water or nitrates leaching below the rootzone during the season.

4) T8 (100% ET, low-frequency) was irrigated for a much longer duration than T-1 and after the fall fertilization NO3-N concentrations reached relatively high levels at all depths down to 72". There seems to be increased potential for nitrate leaching with this treatment. However, water content measurements indicated that little water was percolating below the 3.5 foot depth during the entire season, so there is no concrete evidence of significant levels of nitrate leaching.

Harvest Parameters

There were no significant differences in total yield (fresh fruit weight), number of fruit per tree or mean fruit weight attributable to the fertilizer treatments. The irrigation treatments had significant effects on number of fruit per tree and total yield (Table 4). T3 had a total yield of 51.13 kg/tree (25.53 tons/acre), compared to 57.06 kg /tree (28.94 tons/acre) for T1, and 56.06 kg/tree (28.00 tons/acre) for T8.

T3 had significantly less fruit per tree than T1 (260 vs 293 fruit per tree). T8 had 280 fruit per tree which was not significantly different from T1 or T3. Mean fruit weight was not significantly effected by irrigation treatment.

The reduction in yield of 3.4 tons per acre for T3 is an economic reduction. Since mean fruit weight was not different, this reduction is attributable to the reduction in number of fruit per tree. All trees in this experiment were commercially thinned in March, 1992 to a target level of 250 fruit per tree. The fruit set in T3 was lighter than in T1 and T8, and resulted in less fruit being left on the tree by the thinners.

This lighter set is probably due to lower flower densities, which are due to decreased floral initiation the previous summer. The reduction in floral initiation may be due to increased shading of floral buds, or to the high soil water contents at floral initiation time.

Conclusions

Detection of treatment differences in soil nitrate concentrations was hindered by spatial and temporal variability of NO_3-N levels. However, based on trends in NO3-N concentrations, soil water content, applied water measurements, harvest data and leaf nitrogen analysis, several conclusions regarding nitrate distribution, nitrate leaching and effects on crop production are presented:

The May nitrogen treatments (single application vs. split applications) did not significantly impact any measured tree growth or harvest parameters. Soil solution levels of NO3 were low (below 10 ppm) before the application. Following a slight increase at 12" in response to the fertilization, NO3 levels dropped off and remained very low at all depths, reaching a mean level of 2 ppm by August 24. The low concentration of nitrogen applied (30 pounds per acre) and the short period between the split applications probably account for the lack of measurable differences.

Due to the low levels of soil nitrate prior to harvest, very little nitrate was lost from the rootzone under any of the irrigation treatments, including T3, which received 150% of crop ET from June 18 through August 4, and theoretically had 6 to 8 inches of water move below the rootzone. However, leaf nitrogen levels and total yield were significantly reduced in this treatment. Water contents above field capacity may have provided anaerobic conditions necessary for significant amounts of denitrification. Reduced yield was attributed to poor return bloom in this treatment, which may be related to the water status in July, but probably not directly to the nitrogen status, which was not reduced below acceptable levels.

This treatment is similar to the common grower practice of applying excess water during the final fruit growth period. The measured reduction in yield is therefore important, since it is evidence for growers that over-irrigation during the final fruit sizing period is detrimental to their bottom line. This could be an impetus for reducing irrigation volumes during this period, which would contribute greatly to reduced nitrate leaching in the stone fruit industry.

Following the fall fertilization there was a trend for a high spike in NO3-N levels at 12" (100-200 ppm) with the "slug" (A) fertilization. In T-8 (low-frequency irrigation) the slug of nitrogen resulted in high levels of N at 12" to 72" for 12-18 days after the fertilization, while the split treatment led to sustained increases at a lower concentration for 60 days. T8 was irrigated for a much longer duration than T-1 and after the fall fertilization NO3-N concentrations reached relatively high levels at all depths down to 72". There seems to be increased potential for nitrate leaching with this treatment. However, water content measurements indicated that little water was percolating below the 3.5 foot depth during the entire season, so there is no concrete evidence of significant levels of nitrate leaching.

By October 15 almost all NO3-N concentrations were lower than the initial May 24 concentrations. This indicates that there is not increased potential for leaching of nitrates with winter rainfall under any of the irrigation or fertilization treatments in this study.

TASK 4. Survey of San Joaquin Valley stone fruit growers use of water and nitrogen fertilizer

The survey of grower fertilization and irrigation practices (Appendix II) was designed to provide a statistical profile of grower practices that influences nitrogen fertilizer use efficiency. The questionnaire is divided into three parts:

1) A general survey which asks questions regarding their over-all stone-fruit operation and questions about their sources of information for decisions regarding N fertilizer and water application. The responses to these questions will provide information which will help extension personnel plan specific education programs designed to improve fertilizer use efficiencies.

2) Survey of an early season orchard, and 3) Survey of a late-season orchard. These surveys ask questions pertaining to a single block of early or late-season fruit. Questions are designed to determine how much nitrogen fertilizer and water are applied to the block, and the timing of applications. Data obtained on water and fertilizer use will be used to estimate overall nitrogen fertilizer use efficiency by stone fruit growers in the central San Joaquin valley and to correlate nitrogen use efficiency with various variables.

Results of Preliminary Survey

The results of the preliminary survey are summarized below:

<u>Size of Operation</u>
Seven of the ten respondents had at least 500 acres of stone fruit and 4 of these had stone fruit acreage in excess of 1000 acres. These are some of the largest growers in the San Joaquin Valley, representing approximately 8000 acres of stone fruit production. Seven of the ten growers grow more than 20 different varieties of stone fruit.

<u>Irrigation Practices</u>
Some of the most progressive growers in Fresno and Tulare counties were represented in this group, but 73% of the acreage is still irrigated by furrow/flood irrigation. The condition of the trees and the calendar were used by all ten growers for scheduling irrigations. Seven of the ten used some type of soil moisture monitoring. The soil probe was the most popular method of moisture monitoring with six users, followed by the tensiometer with three. Only two indicated that they used ET data. Based on the response to this question the question was changed on the final survey to ask growers to indicate their first and second preferences.

<u>Fertilization Practices</u>

All ten growers indicated that they keep records of fertilizer applications and that they have had their water tested for nitrogen content. The final survey will ask how often they do these practices and what their value is.

Eight growers said they used leaf analysis to determine the amount of nitrogen to apply, six used soil analysis and five used tree appearance and variety. Nine said they used leaf analysis to determine the timing and number of applications, with tree appearance, university extension and convenience each receiving five votes. For these two questions most of them checked 3 to 5 of the choices. These questions are changed to ask the top two preferences in the final survey .

The responses to application method and form of nitrogen were also generally multiple responses. These questions have been added to the single orchard questionnaires for the final survey. It is clear from the responses that few growers broadcast fertilizer and that urea and mixed blends of fertilizer were the least popular forms, while ammonium nitrate and calcium nitrate were the most popular. Cost and lab recommendations were the most popular reasons for selecting a particular form of nitrogen. We assume that lab recommendations applies to soil pH. This question becomes a preference question for the final survey.

One-half of the growers said that they use cover crops to supply nitrogen. The final survey will ask them what benefits they foresee from cover crops.

Individual Field Background Information

Nine of the ten growers filled out the single orchard surveys. Six of the early orchards were standard plantings, versus 5 of the late orchards. The rest were higher densities. One early-season orchard was coarse textured, one late-season orchard was fine and medium textured, and all the rest were medium textured.
Use of herbicide on the berms and cultivation of the middles was used on 6 of the early-season and 5 of the late-season orchards. Use of herbicide on the berms and mowed middles was used by 3 growers on the early orchard and 4 on the late orchard.

Applied Water

Quantification of water applied was very rough because irrigation duration and number of trees per acre were specified as ranges rather than finite numbers. This was changed for the later survey. In calculating applied water from these responses it was discovered that a question regarding the number of irrigation sets needed to be added to the final survey.

Only six of nine fields in each category had answers in sufficient detail to calculate the amounts of applied water. Only five growers had sufficient data for both fields. The mean applied water of 30.4 inches for the early-season orchards was 71% of the 42.5 inches for the late-season orchards. For the five growers who had data for both fields, they applied an average of 56% as much water to the early-season orchard as to the late-season. Measured crop-water use for mid-season O'Henry peaches at Kearney Agricultural Center in 1992 was 46.1 inches.

The trend for substantially lower water application to early season fruit indicated in the preliminary survey is substantiated by the first 40 responses to the final survey that have been processed and verified for applied water. The estimates of applied water are not very precise, because the estimates of flow rates and number and duration of irrigations are not very precise. However, these estimate will give us some idea of the amounts of water being applied.

Fertilization

The mean annual application of nitrogen fertilizer was 114 lbs/ac of N to early-season orchards and 108 lbs/ac of N to late-season orchards. Current fertilizer N applications were 152% and 105% of applications 10 years ago for early and late-season orchards, respectively.

Eight growers answered questions related to frequency of fertilization. For early-season fruit, 6 growers applied fertilizer only in the fall, and two had spring/fall split application with a heavier application in the fall. For late-season fruit, 2 growers applied fertilizer only in the fall while six had spring/fall split applications, with a heavier application in the fall.

Five of nine growers responding used manure as a nitrogen source.

Literature Cited

Alberts, A.E., R.E. Burwell and G.E. Schuman. 1977. Soil nitrate-nitrogen determined by coring and solution extraction techniques. Soil Sci. Soc. Am. J. 41:90-92.

Grossman J. and P. Udluft. 1991. The extraction of soil water by the suction-cup method: a review. Journal of Soil Science 42:83-92.

Hansen, E.A. and A.R. Harris. 1975. Validity of soil-water samples collected with porous ceramic cups. Soil Sci. Soc. Am. Proc. 39:528-536.

Morrison, R.D. 1982. A modified vacuum-pressure lysimeter for water sampling. Soil Science:134:206-210.

Weinbaum, S., R.S. Johnson and T. DeJong. 1992. Causes and consequences of overfertilization in orchards. HortTechnology 2:112-120.

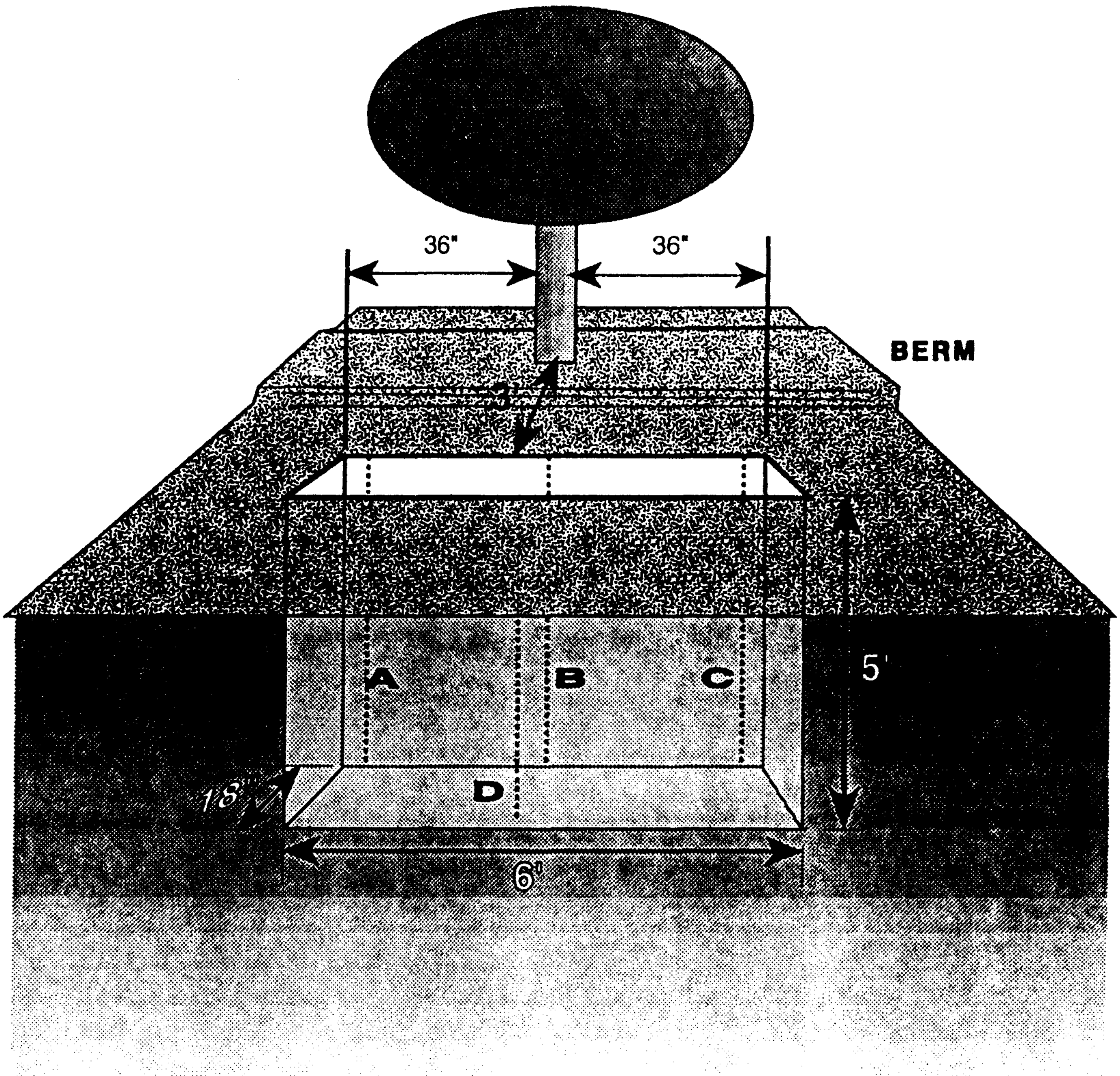

Figure 1. Schemata of typical trench for observing root distribution and soil profile characteristics beneath peach trees. A, B, C, D mark soil sampling sites.

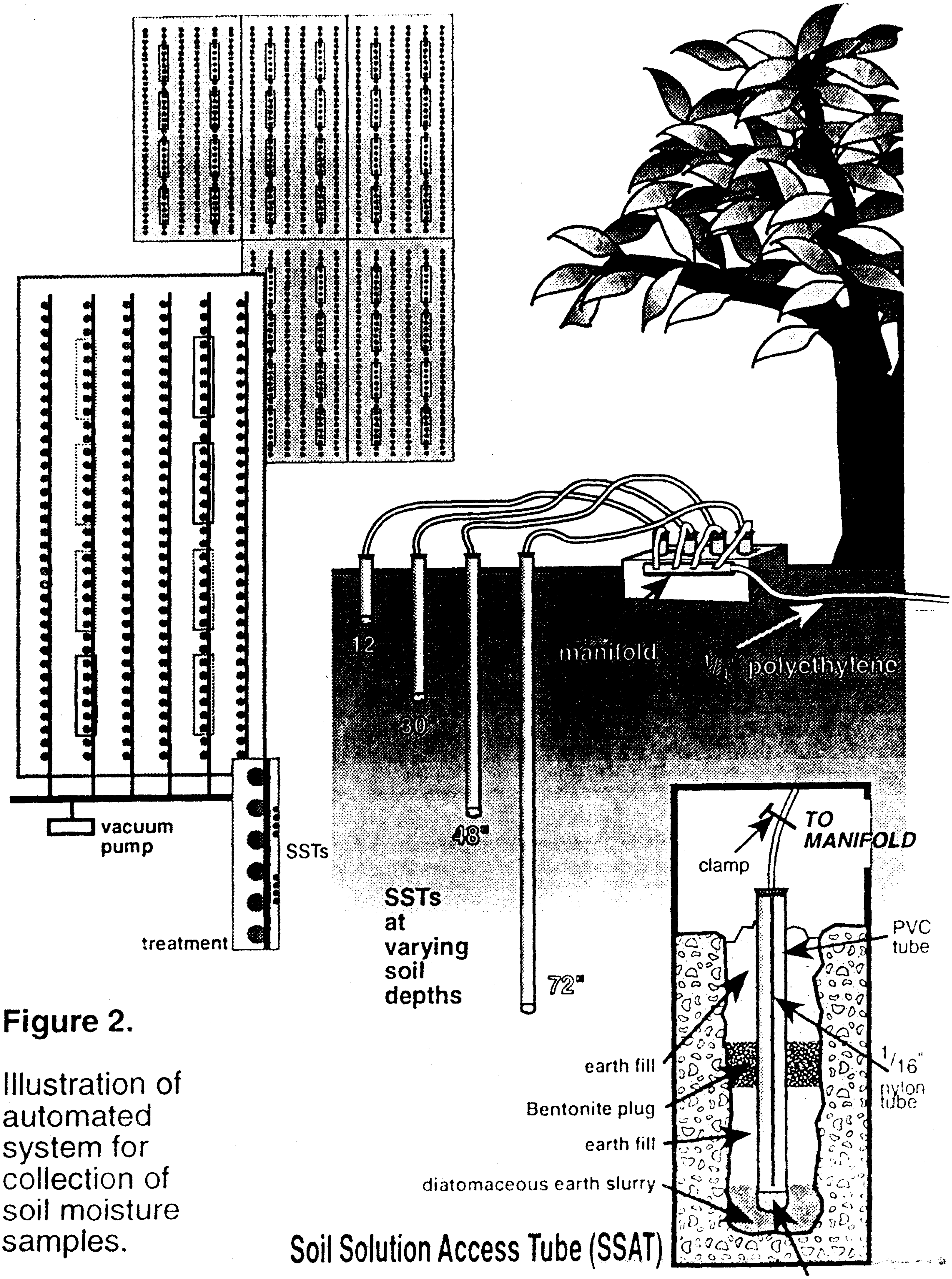

Figure 2.

Illustration of automated system for collection of soil moisture samples.

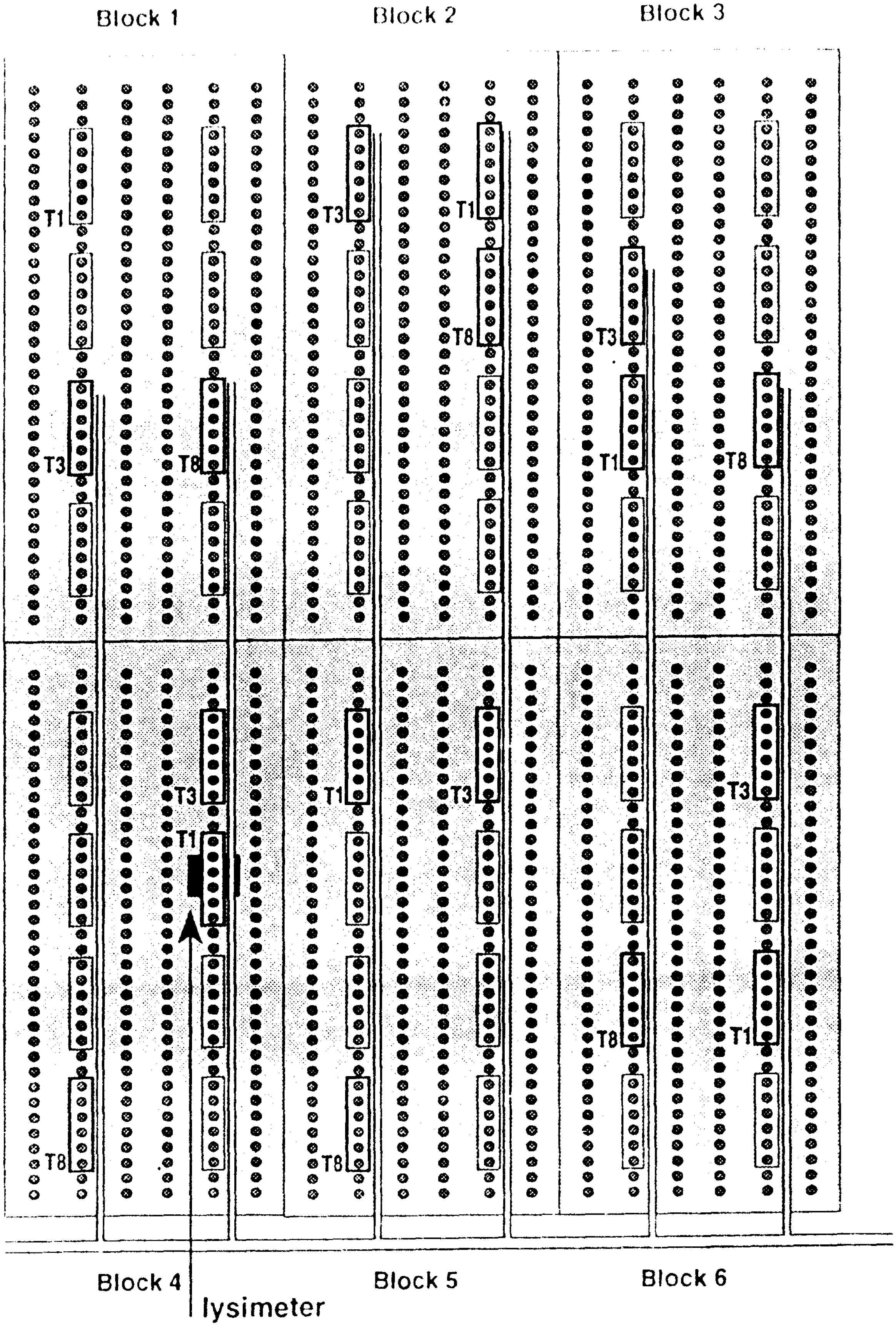

Figure 3.

Map of peach lysimeter block indicating treatment replications fo the 3 irrigation treatments used in the Fertilization and Irrigation Management plot study.

Figure 4. Root distribution of peach tree in trench parallel to row. February 1992. Treatment: T1 (100% ET - High frequency irrigation). Block 3.

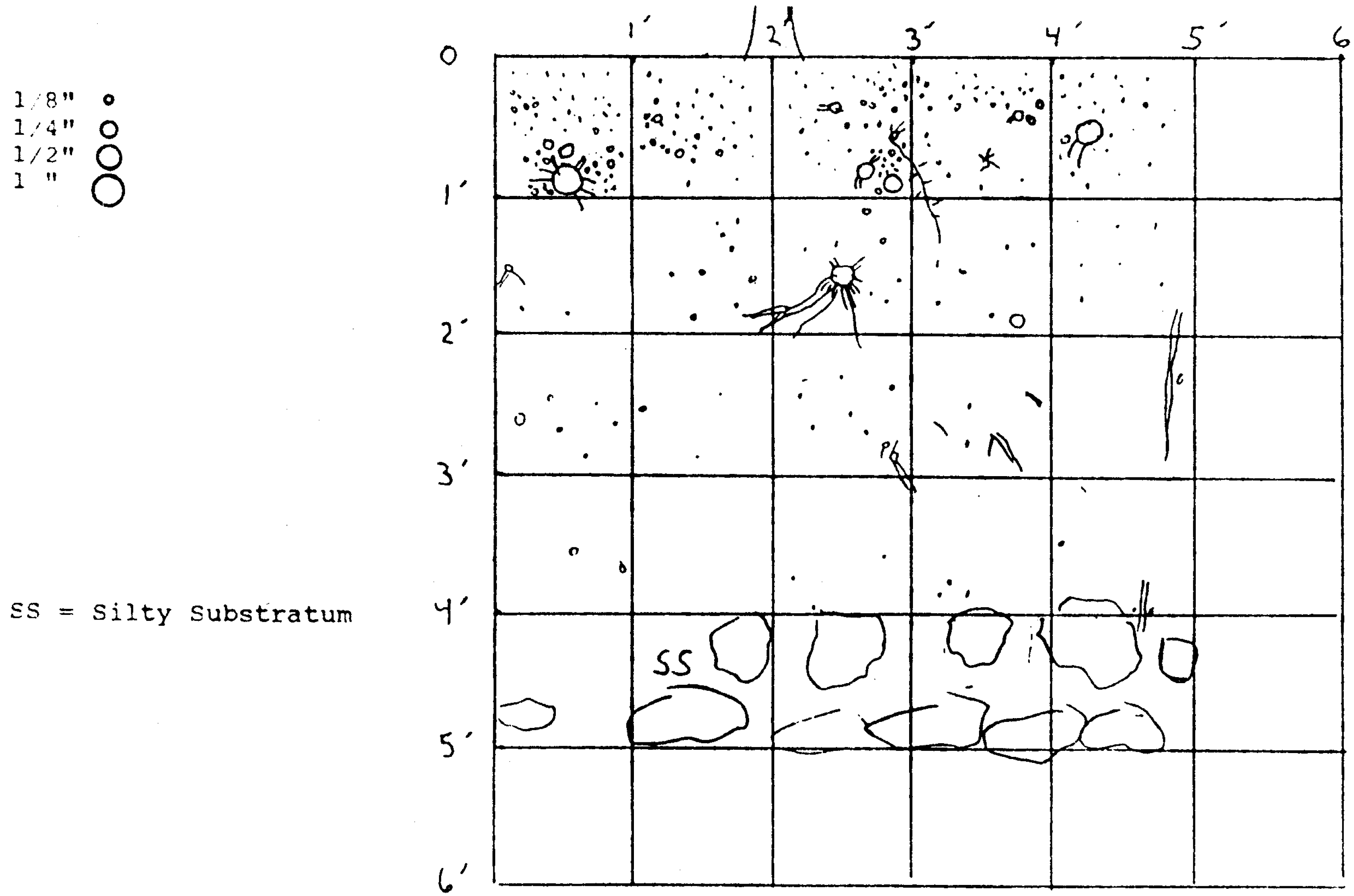

Figure 5. Root distribution of peach tree in trench parallel to row. February 1992. Treatment: T3 (100 to 150% ET - High frequency irrigation). Block 5.

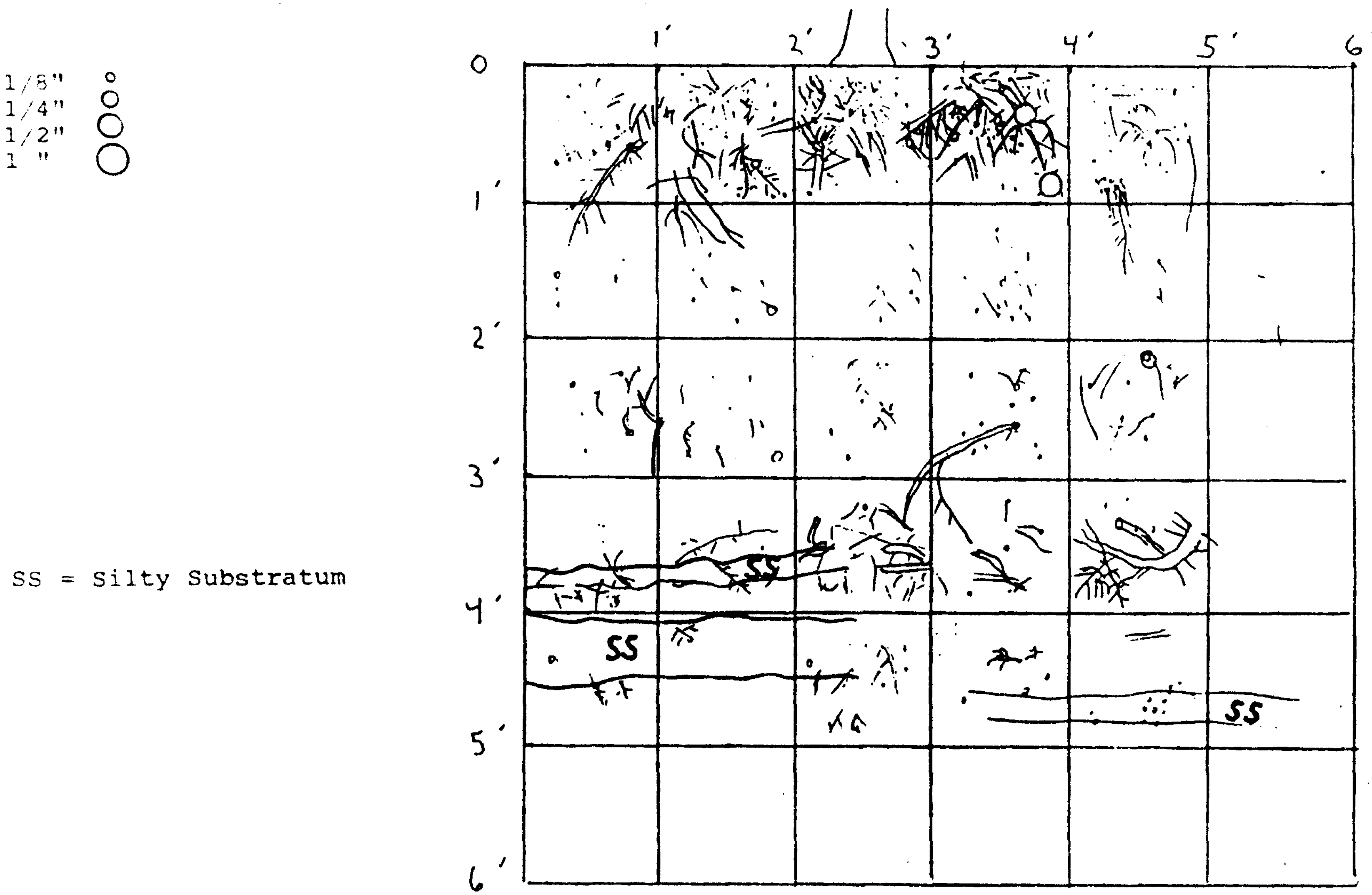

Figure 6. Root distribution of peach tree in trench parallel to row. February 1992. Treatment: T8 (100% ET - Low frequency irrigation). Block 1.

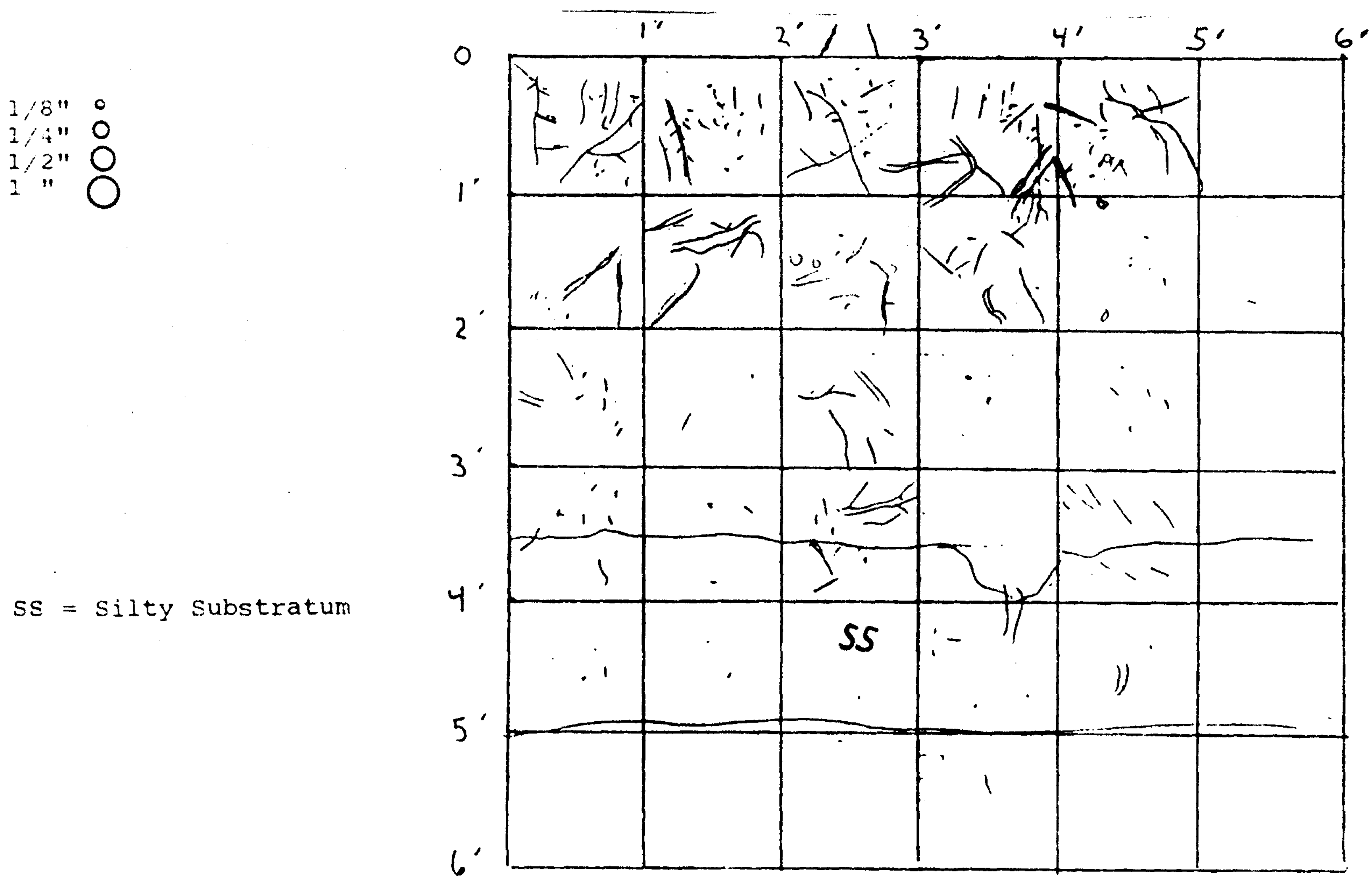

Figure 7. Seasonal patterns of soil water content (%) by irrigation treatment at three depths. Values are means of six replicates. A) 9", B) 1.5', C) 2.5'.

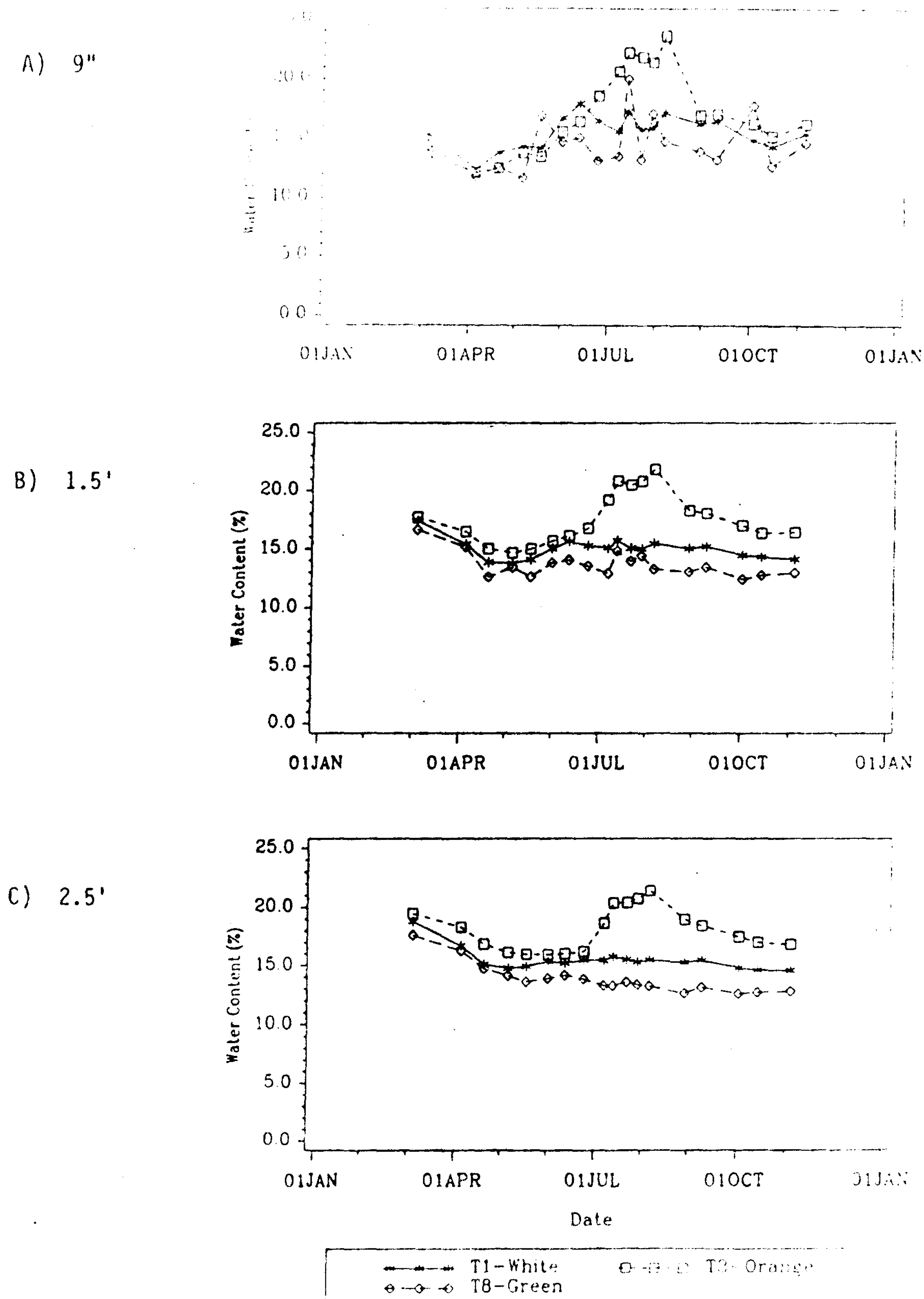

Figure 8. Seasonal patterns of soil water content % by irrigation treatment. Means are averages of six replicates. A) 3.5′, B) 4.5′, C) 5.5′.

A) 3.5'

B) 4.5'

C) 5.5'

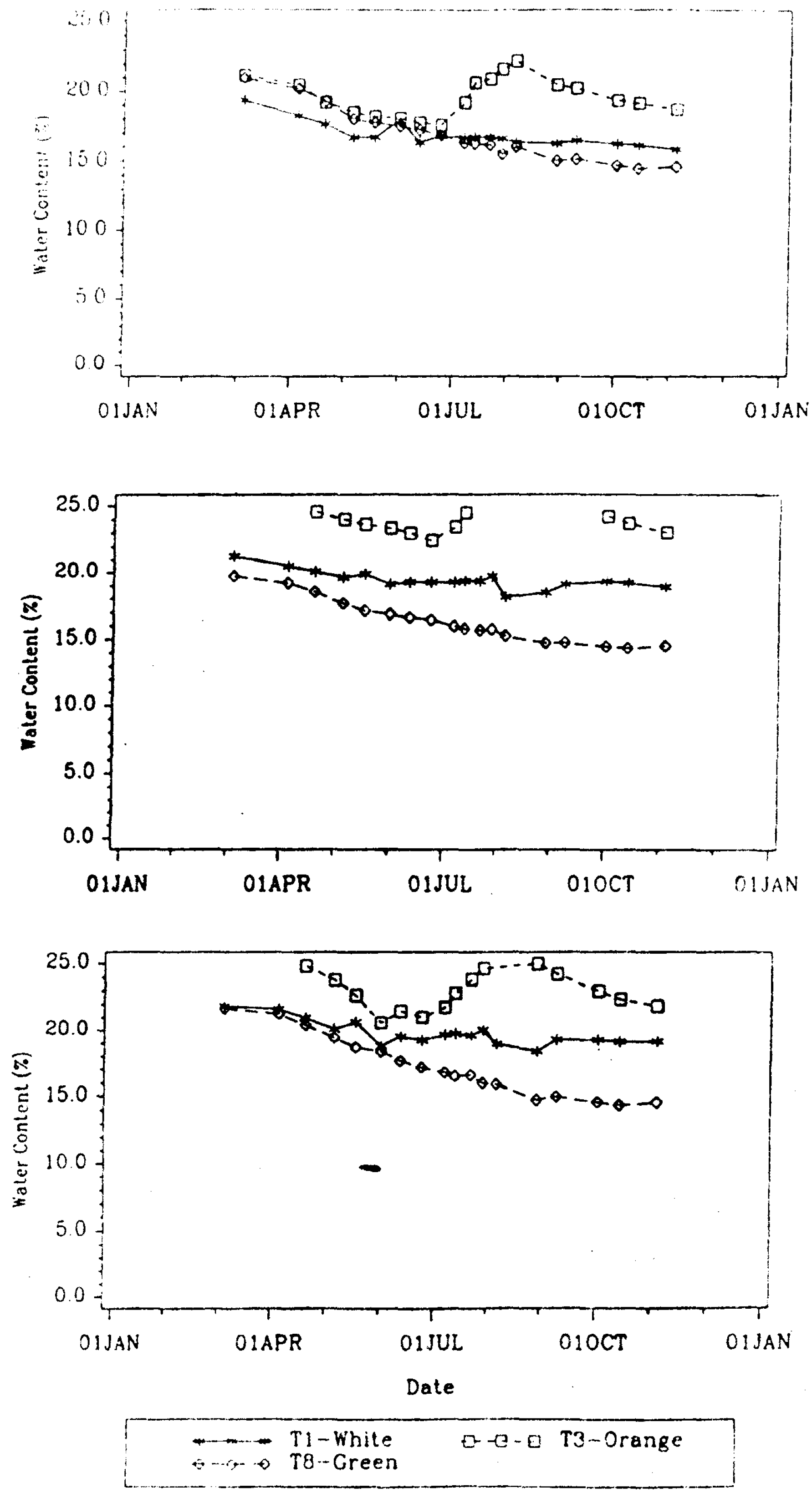

Figure 9. Seasonal patterns of midday peach stem water potential (SWP). Means of six replicates, each replicate the mean of 2 leaves from 2 trees.

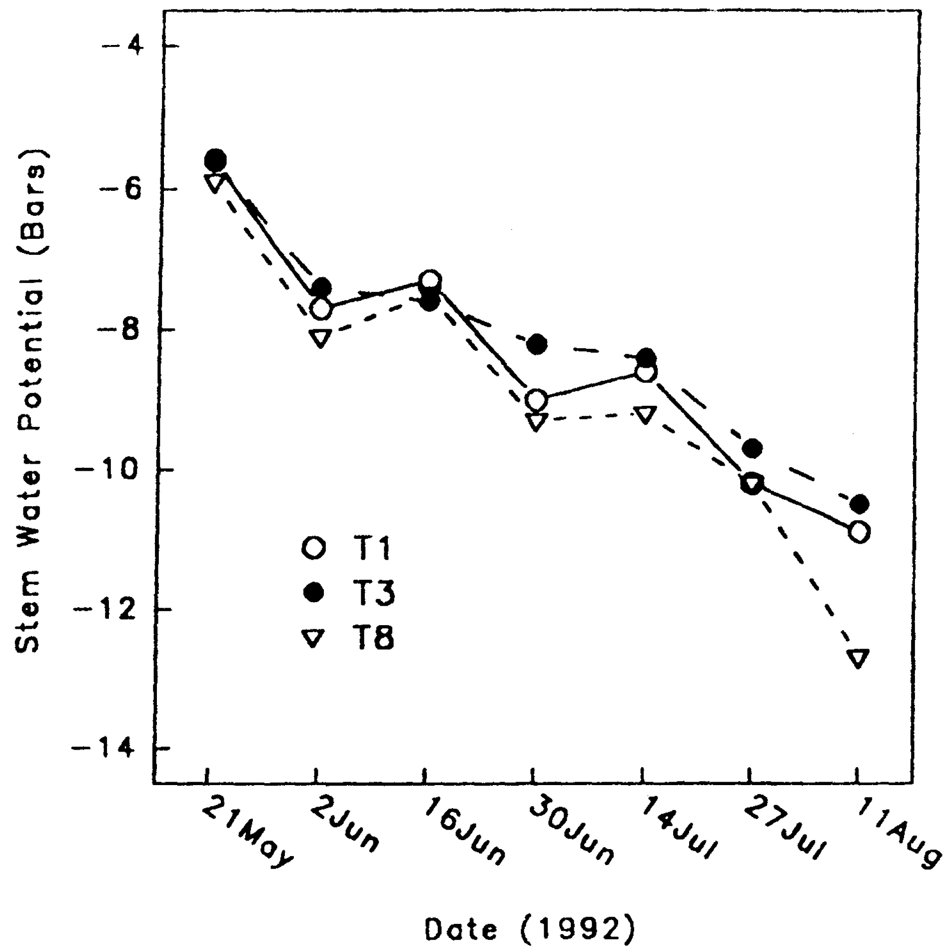

Figure 10. Seasonal patterns of NO_3 -N concentration in soil moisture extracted from 12," 30," 48," and 72," by irrigation treatment. Each value is the mean of 6 replications, and each replicate is the mean of 2 sites.

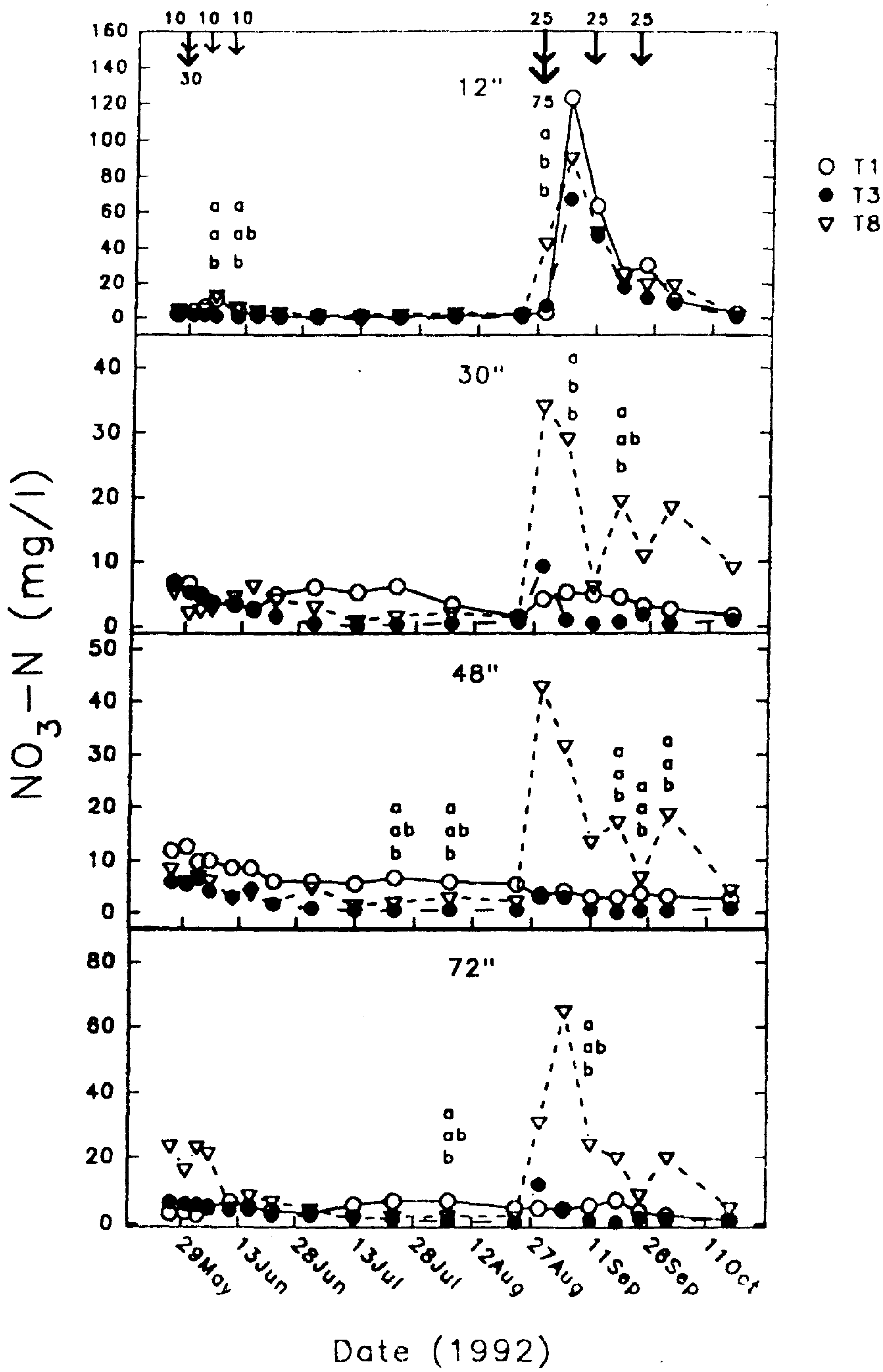

Figure 11. Seasonal patterns of NO_3-N concentration in soil moisture extracted from 12," 30," 48," and 72," by N fertilization treatment. Each value is the mean of 9 replications, and each replicate is the mean of 2 sites.
0 "Slug" treatment ● "Split" treatment

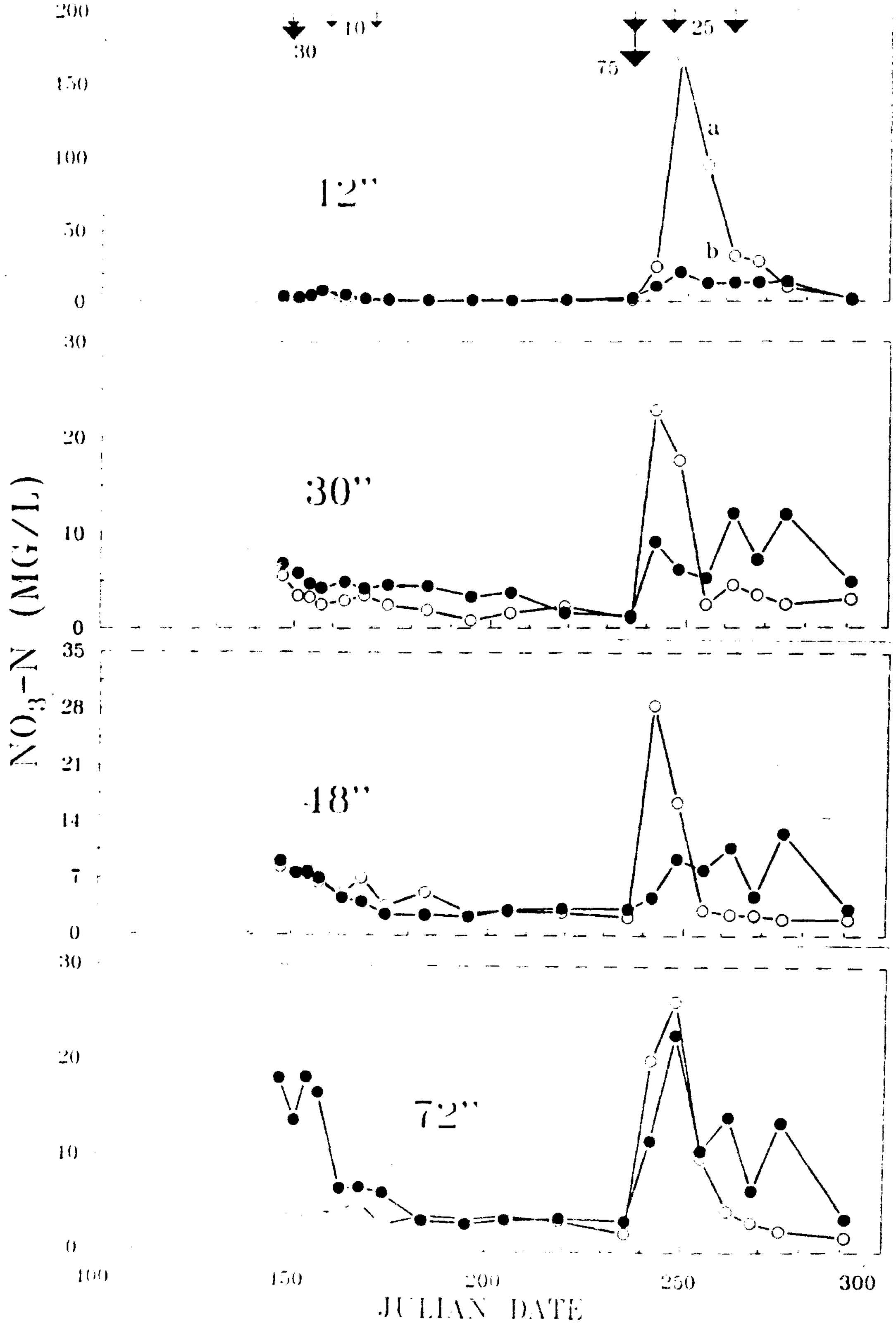

Table 1. Irrigation and nitrogen treatments for plot study of irrigation and fertilization management.

Irrigation Treatments

Treatment	Percent of ET (4/1-6/15)	Percent of ET (6/15-8/15)	Percent of ET (8/15-10/1)	Frequency of Irrigation (After X inches loss from lysimeter)
T-1	100	100	100	.21
T-3	100	150	100	.21
T-8	100	100	100	1.26

Nitrogen Treatments

Treatment	Blocks	Spring Application lbs N/acre	Spring Application Date	Fall Application lbs N/acre	Fall Application Date
A	1-3	30	May 29	75	July 30
B	4-6	10	May 29 June 5 June 10	25	Aug. 29 Sept. 10 Sept. 24

Table 2. Soil NO_3-N (ppm on dry soil weight basis) value in early April, 1992, at SSAT sites, according to irrigation treatments. Values are means of 3 replicates, each replicate an average of 2 sites.

	T-1	T-3	T-8
12"	3.79	2.95	3.91
30"	2.43	2.39	2.47
48"	2.83	2.43	2.35
72"	5.74	4.03	2.55

Table 3. Leaf nitrogen values (%N), July 9, 1992, by irrigation treatment. Values are means of 40 leaves from each of 6 replicates.

Treatment	Total Leaf N (%)
T1	2.94 ab
T3	2.72 b
T8	3.06 a

Table 4. Number of fruit per tree, yield (total fresh fruit weight per tree), and mean fruit weight of O'Henry peach trees as affected by irrigation treatment.

Lysimeter Peaches
Harvest Summary - 1992

Treatment	# Fruit per tree	Total fresh weight/tree (Kg)	Mean weight/fruit (g)
T-1	293 a	57.96 a	199 a
T-3	260 b	51.13 b	203 a
T-8	280 ab	56.06 a	201 a

APPENDIX I
LABORATORY PROCEDURES FOR NITRATE ANALYSIS

Laboratory analysis of soil water solutions for nitrates will be performed using the Alp-Chem Rapid Flow Analyzer RFA300 at the USDA Water Management Laboratory in Fresno, CA. The analyzer is equipped with a module for nitrate measurement using cadmium reduction of nitrate to nitrite. Nitrite concentrations are measured before and after reduction, the difference giving nitrate concentration. The diazo coupling procedure is used and nitrite is measured colorometrically.

USDA Water Management Lab Nitrate Testing Protocol

1) Groups of 24 samples are measured. Before each group 5 nitrate standards are measured and a standard curve prepared.

2) Before each group a cadmium reduction efficiency check is run using nitrite standards.

3) The first 10 samples are measured, then calibration is checked by rerunning the mid-standard for nitrate. The nitrite efficiency is checked by rerunning the mid-standard for nitrite.

4) The next 10 samples are measured and the calibration check is redone.

5) The next 4 samples are run and the calibration check is redone.

6) This procedure is repeated for each group of 24 samples.

APPENDIX II

SURVEY OF SAN JOAQUIN VALLEY STONE FRUIT GROWERS USE OF WATER AND NITROGEN FERTILIZER

Name___________________________________ **(Optional)**
Address_______________________
Phone No. _____________________

GENERAL SURVEY

1. **What is the approximate acreage of all your stone fruit orchards?**

_____1 to 20 ACRES
_____21 to 50 ACRES
_____51 to 100 ACRES
_____101 to 250 ACRES
_____251 to 500 ACRES
_____501 to 1000 ACRES
_____>1000 ACRES

2. **Approximately what % of your stone fruit acreage is irrigated by each method listed below:**

_____FURROW/FLOOD
_____LOW VOLUME (drip or micro-sprinkler)

3. **How many different varieties of peaches, plums, and nectarines are you growing?**

_____1
_____2 to 5
_____6 to 10
_____11 to 20
_____> 20

4. **What are the two most important sources of information <u>that you use</u> for scheduling irrigations? Indicate (1) and (2).**

_____ GROWER EXPERIENCE (condition of trees, weather, variety)
_____ SOIL MOISTURE (neutron probe, tensiometer, soil probe, etc.)
_____ EVAPOTRANSPIRATION DATA (from CIMIS, newspaper, etc.)
_____ CONSULTANT (PCA, irrigation consultant, field person, etc.)
_____ OTHER (please specify)________________________________

5. **How often do you have the following done?**

	ANNUALLY	EVERY 2 YEARS	OCCASIONALLY
a) SOIL ANALYSIS	______	______	______
b) LEAF ANALYSIS	______	______	______
c) IRRIGATION WATER TEST	______	______	______

Please comment on the usefulness of these tests.

____
____
____
____
____

6. **What are the two most important sources of information <u>that you use</u> for determining the amount of nitrogen to apply? Indicate (1) and (2).**

_______ GROWER EXPERIENCE (condition of trees, variety, soil, etc.)
_______ CONSULTANT (PCA, field person, fertilizer salesperson, etc.)
_______ SOIL ANALYSIS
_______ LEAF ANALYSIS
_______ OTHER (please specify)____________________________

7. **Do you use cover crops?**

_____ NONE (skip to question 10)

_____ NATURAL COVER) (answer questions 8 and 9)
_____ SEEDED COVER CROP)

8. **What do you consider to be the two most important benefits of cover crops? Indicate (1) and (2)**

_______ INCREASE IN SOIL ORGANIC MATTER
_______ IMPROVEMENT OF WATER INFILTRATION
_______ PEST MANAGEMENT
_______ IMPROVED ORCHARD ACCESS
_______ TO SUPPLY NITROGEN TO TREES
_______ OTHER (Please specify)

9. **How does the use of cover crops affect your irrigation and nitrogen fertilization practices?**

a) Do you supply extra water for the cover crop? _____ YES _____ NO
b) Do you supply extra nitrogen for the cover crop? _____ YES _____ NO

10. **What is the average amount of nitrogen fertilizer that you supply to your stone fruit orchards?**

a) _______ Pounds of nitrogen per acre from chemical fertilizers

11. **How have you changed your nitrogen fertilization practices (timing and rates) in the last 10-20 years and what were the reasons for these changes?**

____
____
____
____
____
____
____

12. **Do you change your nitrogen fertilizer rates based on any of the following?**

_____EARLY VS. LATE VARIETIES
_____LEAF ANALYSIS
_____SOIL ANALYSIS
_____SOIL TYPE
_____WATER ANALYSIS
_____TREE VIGOR

ADDITIONAL COMMENTS____
____
____

SURVEY OF SINGLE EARLY SEASON ORCHARD

For these questions please select one block of bearing early peaches, plums or nectarines.

I. DESCRIPTION OF FIELD

1. a. Type of Fruit____________________
   b. Variety Name____________________
   c. Approximate Harvest Date__________
   d. Spacing _____ ft. between rows _____ ft. between trees in row
   e. Age______________
   f. Acreage_______ acres
   g. Location (nearest town)________________________

2. What is the major soil texture in this orchard?

____FINE (CLAY TO CLAY-LOAM)
____MEDIUM (LOAM TO SANDY-LOAM)
____COARSE (SANDY-LOAM TO SAND)

II. IRRIGATION

Depending on the type of irrigation system in this field, answer A or B below.

A. FURROW/FLOOD

3. **What is approximate flow rate into this field?**

_____ In GPM or _____ In CFS (cubic feet per second)

3a. **In how many sets do you irrigate this field?** ____________

B. LOW VOLUME

4. **Which type of low volume system do you use?**

_____ MICROSPRINKLER
_____ DRIP EMITTERS

5. **What is the volume of delivery in gallons per tree per hour?** ___________

6. Please fill in the following blanks regarding irrigation scheduling.

MONTH	NO. OF IRRIG.	HRS PER IRRIG.	MONTH	NO. OF IRRIG.	HRS PER IRRIG.
JANUARY	___	___	JULY	___	___
FEBRUARY	___	___	AUGUST	___	___
MARCH	___	___	SEPTEMBER	___	___
APRIL	___	___	OCTOBER	___	___
MAY	___	___	NOVEMBER	___	___
JUNE	___	___	DECEMBER	___	___

SURVEY OF SINGLE LATE SEASON ORCHARD

For these questions please select one block of bearing early peaches, plums or nectarines. Use the same type of fruit (peaches, plums, or nectarines) which you used for the EARLY SEASON ORCHARD, above.

I. DESCRIPTION OF FIELD

1.
- a. Type of Fruit____________________
- b. Variety Name____________________
- c. Approximate Harvest Date__________
- d. Spacing ____ ft. between rows _____ ft. between trees in row
- e. Age________________
- f. Acreage_______ acres
- g. Location (nearest town)_________________________

2. What is the major soil texture in this orchard?

____FINE (CLAY TO CLAY-LOAM)
____MEDIUM (LOAM TO SANDY-LOAM)
____COARSE (SANDY-LOAM TO SAND)

II. IRRIGATION

Depending on the type of irrigation system in this field, answer A or B below.

A. FURROW/FLOOD

3. What is approximate flow rate into this field?

_____ In GPM or _____ In CFS (cubic feet per second)

3a. In how many sets do you irrigate this field? ___________

B. LOW VOLUME

4. Which type of low volume system do you use?

_____ MICROSPRINKLER
_____ DRIP EMITTERS

5. What is the volume of delivery in gallons per tree per hour? ___________

6. Please fill in the following blanks regarding irrigation scheduling.

MONTH	NO. OF IRRIG.	HRS PER IRRIG.	MONTH	NO. OF IRRIG.	HRS PER IRRIG.
JANUARY	____	____	JULY	____	____
FEBRUARY	____	____	AUGUST	____	____
MARCH	____	____	SEPTEMBER	____	____
APRIL	____	____	OCTOBER	____	____
MAY	____	____	NOVEMBER	____	____
JUNE	____	____	DECEMBER	____	____

III. FERTILIZATION

7. What is your average annual application of nitrogen fertilizer to this orchard in units of N per acre?

_______ Lbs. of N per acre

8. Indicate the number of units of N normally applied in each month.

JANUARY	____	MAY	____	SEPTEMBER	____
FEBRUARY	____	JUNE	____	OCTOBER	____
MARCH	____	JULY	____	NOVEMBER	____
APRIL	____	AUGUST	____	DECEMBER	____

9. How many separate fertilizer events occur during the year?

_____1
_____2
_____3-5
_____6-10
_____11-15
_____>15

10. On what do you base the timing and number of applications of fertilizer? (convenience, efficiency, environmental concerns, fruit quality, tree response, etc.)

____

____

____

11. How do you apply nitrogen to this orchard?

_____ BROADCAST
_____ BAND APPLICATION
_____ THROUGH LOW-VOLUME SYSTEM
_____ FOLIAR SPRAY
_____ LIQUID BANDED
_____ OTHER (Please specify)______________________

12. What forms of nitrogen do you normally use? Check all that apply.

_____ CAN 17
_____ AMMONIUM NITRATE
_____ AMMONIUM SULFATE
_____ CALCIUM NITRATE
_____ OTHER (Please specify)______________
_____ UREA
_____ UN32 (Urea Ammonium Nitrate)
_____ MIXED FERTILIZERS

13. What is your rationale for using this form(s)? (cost, availability, fruit quality, soil, etc.)

____

____

____

14. How many tons of manure/compost do you apply during the year?

_____0
_____1-2
_____3-5
_____6-10
_____>10

III. FERTILIZATION

7. What is your average annual application of nitrogen fertilizer to this orchard in units of N per acre?

_______ Lbs. of N per acre

8. Indicate the number of units of N normally applied in each month.

JANUARY	_____	MAY	_____	SEPTEMBER	_____
FEBRUARY	_____	JUNE	_____	OCTOBER	_____
MARCH	_____	JULY	_____	NOVEMBER	_____
APRIL	_____	AUGUST	_____	DECEMBER	_____

9. How many separate fertilizer events occur during the year?

_____1
_____2
_____3-5
_____6-10
_____11-15
_____>15

10. On what do you base the timing and number of applications of fertilizer? (convenience, efficiency, environmental concerns, fruit quality, tree response, etc.)

____

____

____

11. How do you apply nitrogen to this orchard?

_____ BROADCAST
_____ BAND APPLICATION
_____ THROUGH LOW-VOLUME SYSTEM
_____ FOLIAR SPRAY
_____ LIQUID BANDED
_____ OTHER (Please specify)______________________

12. What forms of nitrogen do you normally use? Check all that apply.

_____ CAN 17
_____ AMMONIUM NITRATE
_____ AMMONIUM SULFATE
_____ CALCIUM NITRATE
_____ OTHER (Please specify)_______________
_____ UREA
_____ UN32 (Urea Ammonium Nitrate)
_____ MIXED FERTILIZERS

13. What is your rationale for using this forms? (cost, availability, fruit quality, soil, etc.)

____

____

____

14. How many tons of manure/compost do you apply during the year?

_____0
_____1-2
_____3-5
_____6-10
_____>10