NITROGEN FERTIGATION OF YOUNG PRUNE TREES AND EFFECTS ON HORTICULTURAL PERFORMANCE: 1996 Final Report

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Abstract

During orchard establishment, young trees must be irrigated, fertilized, and pruned to obtain enough vigorous growth and develop tree structure in the first five to six years while striving to minimize over fertilization, especially with N. In orchards with loam, clay-loam, or sandy-clay-loam soils, adequate soil N may be found for first year growth. Generally, it is contended that young prune and other deciduous fruit trees should be grown in ways that foster the rapid filling of allotted space in the orchard planting. In many instances, to achieve those goals growers frequently apply nitrogen fertilizers to enhance the vegetative growth of young trees. Young trees have limited root systems and, as a result, frequent irrigation and fertilization insures that trees get off to a good start. However, because of these actions and young tree root distribution characteristics, it is likely that significant amounts of water are wasted and nitrogen fertilizers are not efficiently utilized by the tree even though they may be applied to limited soil areas.

In 1991, we established a research plot at the UC Davis Department of Pomology's Wolfskill Orchards to determine the effects of "fertigation" (N [urea] fertilizers applied through drip irrigation) on growth responses and yields of young prune trees (planted February 1991). N was applied to trees at 0, 0.25, 0.5, and 1.0 lbs actual N per tree per year as UN32 with 1/10th of the total amount per application at bi-weekly intervals through the growing season from May until September starting in 1992. Two other treatments were also included: one delivered 0.14 lb N/tree/year if leaf N reached the critical level of <2.3%, and the other delivered 0.5 lb N/tree/year in small amounts at every irrigation through an automated buried drip system. The normal irrigation water contained only trace amounts of nitrate nitrogen. Trees were planted at distances of 14 feet between trees and 17 feet between rows equaling 183 trees per acre. The soil was generally classified as a Yolo clay-loam which represents soils where prunes are typically grown. Whole tree dry weight and N accumulation, leaf N, vegetative growth, and fruit yields were assessed as a function of treatment.

Tree growth was increased by adding nitrogen fertilizer, which tended to improve dry yields per tree. However, we found that the rates of 0.5 lb and 1.0 lb N/tree/year did not significantly increase yields/tree over the 0.25 lb N/tree/year rate in 1994, 1995 or 1996. Fertigation is thought to be one of the most effective techniques by which to insure that fertilizer N is delivered to trees in the most efficient means possible. Even though we used what is considered to be a very efficient fertilizer N delivery system, much of the applied N was not taken up by the trees, as indicated by N

accumulation in tissues. Consequently, there are opportunities for N fertilizer application abuse in young orchards especially during years 2, 3 and 4 at higher N application rates.

In these experiments we are striving to define prudent levels of N fertilizer application through fertigation that minimize N losses (through leaching), while maximizing tree growth and productivity. During this work we have found that young prune tree nitrogen status may be linked to the development of bacterial canker in areas or conditions where bacterial canker is prevalent. Where we have applied low levels or no nitrogen fertilizer for six seasons of growth we have found increased incidence of bacterial canker. Trees fertigated with 0.25 to 1.0 lb N/tree/year have no symptoms of bacterial canker. We have found on this clay-loam soil a dose of 0.25 to 0.5 lb N/tree/year delivered as UN32 regularly through the season by drip irrigation has minimized the incidence of bacterial canker while providing good yields and increased tree growth without a documented extraordinary movement of nitrate nitrogen below the rooting zone of trees.

Introduction

Although there has been a great deal of research with regard to nitrogen fertility in fruit trees, fewer experiments have been conducted with young trees. Generally, it is contended that young fruit trees should be grown in ways that foster the rapid filling of allotted space in the orchard planting. In many instances, to achieve those goals growers irrigate frequently and apply nitrogen fertilizers to enhance the vegetative growth of young trees. Young trees have limited root systems and, as a result, this frequent irrigation and fertilization insures that trees get off to a good start. However, because of these actions and young tree root distribution characteristics, it is likely that significant amounts of water are wasted and nitrogen fertilizers are not efficiently utilized by the tree even though they may be applied to limited soil areas. We know there are many alternatives available to growers when trying to establish an orchard, but no concerted effort has been put forth to develop research based information that would help to make better nitrogen fertilization decisions when developing a prune orchard. It is our intent through these experiments to develop information that should help prune growers make better decisions with regard to nitrogen fertilization of young prune orchards and to demonstrate that techniques and technologies are available today to address some of the public concerns over excessive use of nitrogen in fruit production.

Over the last ten years there has become an increased concern and awareness of nitrate contamination of groundwater. Agriculture has been identified as a contributor to nitrate contamination. Techniques to minimize use of applied nitrogenous materials without impacting tree productivity would help to reduce the public concern over the problem. The use of nitrogenous fertilizers on young trees, especially where fall or winter broadcast applications of nitrogen have been made, could lead to leaching of nitrate into groundwater. Young trees have sparse root systems that do not spread adequately to scavenge applied nutrients. Fertigation is an alternative method of applying nitrogen and other mineral nutrients required by trees through irrigation system water. By delivering nutrients to tree roots in this fashion, in theory, fertilizer can be delivered more efficiently at more beneficial times resulting in greater applied nitrogen use efficiency. There has been little research on nitrogen fertigation throughout the tree fruit industry in California. This is unfortunate because the technology is available and offers opportunities to maximize tree productivity while reducing the excessive use of fertilizers and the problems associated with that use. Research in Israel has demonstrated that yields of many crops can be dramatically increased while the amount of fertilizer use has remained the same and in many cases been reduced.

In 1991, we established a research plot at the UC Davis Department of Pomology's Wolfskill Orchards to determine the effects of "fertigation" (N [urea] fertilizers applied through drip irrigation) on growth responses and yields of young prune trees (planted February 1991). N was applied to trees at 0, 0.25, 0.5, and 1.0 lbs actual N per tree per year as UN32 with 1/10th of the total amount per application at bi-weekly intervals through the growing season from May until September starting in 1992. Two other treatments were also included: one delivered 0.14 lb N/tree/year if leaf N reached the critical level of <2.3%, and the other delivered 0.5 lb N/tree/year in small amounts at every irrigation through an automated buried drip system. The normal irrigation water contained only trace amounts of nitrate nitrogen. Trees were planted at distances of 14 feet between trees and 17 feet between rows equaling 183 trees per acre. The soil was generally classified as a Yolo clay-loam which represents soils where prunes are typically grown. Whole tree dry weight and N accumulation, leaf N, vegetative growth, and fruit yields were assessed as a function of treatment.

Tree growth was increased by adding nitrogen fertilizer, which tended to improve dry yields per tree. However, we found that the rates of 0.5 lb and 1.0 lb N/tree/year did not significantly increase yields/tree over the 0.25 lb N/tree/year rate in 1994, 1995 or 1996. Fertigation is thought to be one of the most effective techniques by which to insure that fertilizer N is delivered to trees in the most efficient means possible. Even though we used what is considered to be a very efficient fertilizer N delivery system, much of the applied N was not taken up by the trees, as indicated by N accumulation in tissues. Consequently, there are opportunities for N fertilizer application abuse in young orchards especially during years 2, 3 and 4 at higher N application rates.

Objectives:

1. To determine if frequent application of nitrogen through fertigation during the growing season can lead to improved tree growth and productivity while minimizing the excessive use of nitrogen fertilizer.

2. To evaluate leaf analyses as an indicator of whether nitrogen should be applied to young trees and to measure the impact of that strategy on prune tree productivity.

3. To work toward the development of a nitrogen budget (N inputs and losses) approach for managing N fertilization of prune orchards.

4. To assess buried drip irrigation as a potential high-efficiency alternative to above-ground drip irrigation

Materials and Methods

The orchard is a nine acres of French prune trees planted in February 1991 with annual replants as needed. Trees were planted in a randomized complete block design where four blocks of 24 rows per block were randomized so that four rows per block were assigned to each of six treatments. Treatments are replicated four times within the orchard. The two center rows were used for measurement of yield while the adjacent rows (one on either side) were used as guard trees and for removing whole trees to sample tree parts for growth and N partitioning. N was applied to trees at 0, 0.25, 0.5, and 1.0 lbs actual N per year as UN32 with 1/10th of the total amount per application at bi-weekly intervals through the growing season from May until September starting in 1992. Two other treatments were also included: one of which delivered 0.14 lb N/tree/year if % leaf N reached the critical level of <2.3%, and the other that delivered 0.5 lb N/tree/year in small amounts at every irrigation through an automated buried drip system. The normal irrigation water contained only trace amounts of nitrate nitrogen. Trees were planted at distances of 14 feet between trees and 17 feet between rows equaling 183 trees per acre. The soil was generally classified as aYolo clay-loam which represents soils where prunes are typically grown.

Treatments: (performed 1992-end of project)

1. No applied N (control)
2. Frequent N (urea, UN32) application at low rates at bi-weekly intervals through the growing season (May, June, July, August, September, October) via fertigation. Rates:
   a) 1.0 lbs N/tree/year
   b) 0.5 lbs N/tree/year
   c) 0.25 lbs N/tree/year
3. N applied 'as needed' via fertigation in July, August, and September to equal 0.14 lbs N/tree/year. Leaf analyses in July indicate whether or not leaf N is below or about 2.3%. If above 2.3%, no N is applied. If deficient, N is applied.
4. Buried drip irrigation with continuous, low level nutrient injection (N, P), using an automated evaporation device to estimate tree water requirements on an hourly basis. Total N rate of 0.5 lbs N/tree/year were applied through the buried drip system

Fertilizer. Nitrogen fertilizer was applied to the three frequent N fertigation treatments (#2, above) as UN32 (urea) by injection into the drip irrigation system on a bi-weekly basis starting on 5 May 1992 and continuing for 20 weeks each successive year. No additional fertilizers were added to any of the treatments that were irrigated with conventional drip in 1992-94. In 1995 and 1996 potassium was applied to the irrigated area around each tree in all treatments by hand (1995, 3 lb/tree of potassium sulfate) or through the drip emitters (1996 3.3 gal/acre of Tracite® 15% potassium chloride). The buried drip treatment received a small amount of N in the irrigation water (100 ppm) starting in 1992 with every irrigation for a total of 0.5 lbs N/tree as well as a small amount of phosphorous (approx. 25ppm) in the form of phosphoric acid to prevent root intrusion into the buried drip lines.

Irrigation water. Irrigation water was applied twice weekly according to ET estimated from Davis and Zamora CIMIS data. From April to May, 1992 water was applied at 40% ET and then it increased through the growing season and year to year up to 70% to adjust to the increasing canopy size of the young trees. Trunk water potential measurements were made periodically to verify that irrigation schedules were adequate to maintain the trees in a well-irrigated condition through the growing season. Trees in the surface drip irrigation treatments received approximately 17.2 inches

(1995) and 22 inches (1996) of water throughout the growing season and trees in the buried drip treatment received 10.55 inches (1995) and 16.5 inches (1996) of irrigation water. Stem water potential readings were taken each year and did not show significant differences among treatments. Only trace amounts of nitrate nitrogen were present in the irrigation water.

Tree growth, weight of pruned shoots and nutrient content measurements. The 1991 season was used to initiate the experiment. No fertilizer was applied during the season so that actual fertilizer experiments began in 1992 with less interference from residual fertility. At the time of planting, February 1991, three random trees were selected from the population, and they were separated into roots, rootstock, trunk, and branches. They were dried and ground, and dry weights and nitrogen contents of the various parts were determined. Near the end of each successive growing season (mid-October 1991-1995) three selected trees each in the highest and lowest nitrogen treatments were removed from the orchard. Again, trees were separated into roots, rootstock, trunk, branches, and leaves and analyses were performed as above. Trunk measurements indicative of tree growth were made during dormancy on all orchard trees. Weight of pruned shoots was determined in January of each year.

Yield. Trees began bearing lightly in 1994 with increasing production in 1995 and 1996. Fruit was harvested by hand in 1994 and mechanically in 1995-96. Fresh yield was measured from the center two rows of each treatment in each block with subsamples taken to measure size distribution of dried fruit, drying ratio and #/fruit/lb from which estimates of dry yield were made.

Leaf sampling. Leaf samples were taken each summer from 1993 through 1996 from all treatments and blocks. In 1993 leaf samples were taken on August 8, and in subsequent years sampling occurred in mid July. In 1995 and 1996 leaf samples were also taken in late May, and in 1995 leaf samples were also collected in October. Forty to sixty leaves were taken from throughout the canopy from each sampled tree from a height of about 2m above ground, washed in a dilute detergent solution to remove surface residues, dried, and ground (Leece, 1972). Analysis of total N, NH_4-N, P, K, Mn, S, and Zn were performed by DANR Analytical Laboratory (University of California, Davis, CA). Total N was analyzed using the modified Dumas total N combustion method (Sheldrick, 1986).

Fruit sampling. In 1996 fresh fruit samples (20 randomly selected fruit) were taken from each treatment and block immediately prior to harvest with the pooled 20 fruit sample for each treatment within block analyzed for total N, P, K, Ca, % moisture, firmness, diameter, soluble solids and number of fruit/lb.

Soil sampling. Soil samples were taken every foot from 1 to 5 foot depths in July 1991 throughout the orchard to identify high or low nitrate nitrogen areas. In April 1992, 1993, 1994, and 1995 additional soil samples were taken from each replicate. At each collection site, samples were taken at 0-1, 1-2, 2-3, 3-4, 4-5 (5-6, 6-7, and 7-8 in 1994 and 1995) feet deep from areas within one foot of a drip irrigation emitter. Additionally, in block 3, samples were taken at 5-6, 6-7, and 7-8 feet deep in 1993. All sampling was done with an Oakdale soil tube. Samples were oven dried at 70°C for approximately one week. Samples were analyzed for NO_3-N, NH_4-N and total N. Sampling sites were also characterized for percentages of sand, silt, clay and for soil pH at the different depths.

Results and Discussion:

Tree Growth. In 1992, trees receiving 1.0 lb of fertilizer N were ~16% larger (dry weight) than trees without additional fertilizer and contained ~25% more nitrogen. However, the additional N accumulated by trees receiving 1 lb (453.6 g) of fertilizer N was only 12.2 g compared with trees receiving no fertilizer N. This indicates N fertilizer uptake efficiency of about 2.7%. Uptake efficiency was estimated by calculating the difference in total tree N (excluding fruit N and mineralization) between the 0 N control and 1 lb N treatments and then dividing by the total N applied. In 1993, trees receiving 1.0 lb N/tree were ~22% larger than trees without additional fertilizer and contained 27% more nitrogen; the uptake efficiency was ~ 9.4%. N uptake efficiency was low when trees were young even though fertigation is believed to be one of the most efficient N delivery techniques available to fruit growers. In 1994, trees receiving 1.0 lb N/tree were ~33% larger than trees without additional fertilizer and contained 46% more nitrogen; the uptake efficiency was ~25%. In 1995 trees receiving 1.0 lb N were ~27% larger than trees without additional fertilizer and contained ~44% more nitrogen with N uptake efficiency being about 45%. Uptake efficiency increased markedly as trees approached maturity and fruit bearing age. This is likely due to the increased size of the tree root systems providing a much larger surface area for uptake of N dispersed throughout the soil. It has been common practice for growers to increase N application during tree establishment in order to maximize early tree growth. However, our findings suggest that root systems of young trees may not be large enough to provide efficient uptake of applied N even when fertilization occurs in a localized area around the tree as in drip irrigation. This argues for moderate and localized fertilization of young prune trees until they have developed a more extensive root system.

Treatment comparison of tree growth and nitrogen partitioning averaged over four years and for each individual year demonstrated that trees in the 1lb N treatment had consistently higher dry weights and accumulated nitrogen in the roots, rootstock, branches and the entire tree than the 0 N control (Tables 1a, 1b). N percentage for the 1 lb N treatment was also significantly higher in the roots and whole tree than in the 0 N control (Table 1). Leaf N levels for sampled trees were taken in October of each year just prior to dormancy, and were probably not significantly different because N remobilization had already begun. Tree trunks are by weight mostly non-living tissue, so non significant differences in N accumulation are not surprising. Dry weights and accumulated nitrogen were significantly different among years and increased significantly from year to year for both the 1 lb N treatment and the 0 N control. However, the 1 lb N treatment had steeper increases each year for total accumulated N than the 0 N control, indicating that well fertilized trees accumulate more nitrogen reserves which could translated into more growth and production the following year (Figure 1). Levels of other tree nutrients didn't exhibit any trend that appeared related to N treatment.

Tree growth can also be assessed using trunk measurements. Trunk cross sectional area (TCSA) was significantly greater for the 1 lb N compared to the 0 lb N treatment in 1992, 1993 and 1994 and significantly greater for the 0.5 lb N and 0.25 lb N treatments in 1992 and 1994. In 1993, the 0.25 lb treatment also had significantly greater TCSA than the control (Table 2). Vegetative growth as measured by TCSA was most consistent at higher rates of applied N, suggesting that other factors besides applied N may influence growth of the tree trunk.

Vegetative growth measured by pruning weights can be indicative of tree nitrogen status. Trees have been long pruned throughout this experiment to promote early fruiting. The weight of shoots pruned in 1992 was greatest in the 1 lb N treatment followed by the 0.5, 0.25 and <2.3% leaf N treatments (Table 2). No significant differences among treatments were observed in 1993 for weight of pruned shoots. In 1994 the weight of pruned shoots was significantly higher for trees receiving 1 lb N, 0.5 lb N and 0.25 lb N compared to the 0 N control and other treatments (Table 2). In 1995 no significant differences for weight of pruned shoots were observed among treatments. These results show that only during some years are pruning weights closely associated with applied N, and indicative of tree nitrogen status. Alternate years where no significant differences among treatments occurred may be the result of the previous year's pruning with new vegetative buds needing a year to form and elongate on newer wood before significant differences in pruning weights become apparent. On certain sites, where vegetative growth is not excessive, this could argue for pruning only very lightly or not at all in alternate years to preserve potentially bearing shoots.

Fertigation is thought to be one of the most efficient techniques by which to insure that fertilizer N is being delivered to trees in the most efficient means possible. Even though we have been using what is considered to be a very efficient fertilizer N delivery system, prior to 1996 much of the applied fertilizer N had not been taken up by the trees. This is likely due to the relatively limited root systems of younger trees. Consequently, there are great opportunities for N fertilizer application abuse and losses due to leaching in young orchards. In 1996 soil nitrate levels in treated plots were similar to those in the untreated control for all but the highest treatment rate. This suggests that as tree root systems expand with age, trees can more effectively utilize applied N. Our data also suggest that the high incidence of bacterial canker observed in some treatments is correlative with low N (Table 3). A strong linkage can thus be made for low N status leading to higher incidence of bacterial canker in prune trees growing in areas or conditions otherwise favorable to bacterial canker. The recommendations made above to apply N via fertigation at 0.25-0.5 lb N/tree/year are consistent with good orchard practice to minimize tree loss to bacterial canker and maintain adequate tree growth and production. In areas where no other stresses occur which may predispose prune trees to infection by bacterial canker, fertilizer rates could be lowered below commonly used rates and applied only to the root zone during early tree establishment.

Yield. Dry yield per tree in 1996 was significantly greater for the 1 lb, 0.5 lb and 0.25 lb N treatments compared to the 0 lb N control and buried drip treatments (Table 4). In 1995 dry yield was not significantly different among treatments In 1994, trees began bearing with only the 0 N control and buried drip treatment yielding significantly less fruit than the other treatments. Overall yields were good (2.5-5.5 dry lb/tree in 1994, 11.0-17.6 dry lb/tree in 1995, and 20-35.5 dry lb/tree in 1996). In all years, tree growth and vigor was increased by adding nitrogen fertilizer. This was reflected in greater yields/tree in 1994 and 1996 for trees receiving N, although neither the rates of 1 lb N/tree/year or 0.5 lb N/tree or the use of leaf analyses as a guide for N fertilizer application led to higher yields/tree compared to the 0.25 lb N/tree rate. 1995-96 were the first years these trees bore a good crop, and the data would support a recommendation to fertilize with N in the second through fourth growing season with 0.25 lb N/tree on Yolo clay-loam or similar soils if no history or symptoms of bacterial canker or other problems associated with low N are observed. Higher rates of 0.5 lb N/tree are recommended on bacterial canker prone sites where fertigation is practiced. The orchard density in this experiment is 183 trees/acre, thus 0.25 lb N/tree equals approx. 46 lb N/acre. Slightly higher doses of N fertilizer may stimulate more shoot growth, but not necessarily lead to higher yields. Using leaf analyses to guide the grower in the fertilizer application making decision process should prove to be useful, although a grower might be better served to apply N somewhat before trees reach the critical level of 2.3% leaf N.

Leaf sampling. Midsummer % leaf N averaged across blocks for the 0 lb N control was significantly lower than the leaf N level for the 1 lb N treatment in 1992, 1994, 1995 and 1996, and also for the 0.5 lb N and 0.25 lb N treatment in 1992, 1994 and 1996 (Table 5). Theses results demonstrate that midsummer levels of leaf N are directly related to applied N during most years. Levels of leaf N for different treatments increased as level of applied N increased except for the buried drip, which was slightly lower most years than one would expect based on amount of N applied (Table 5). The 0 lb N treatment had deficient levels of leaf N (below 2.3%) during every year except 1992 when one could assume that natural occurring soil N was sufficient. The <2.3% leaf N treatment was deficient in leaf N or bordered on being deficient each year, requiring application of N in July or August. This once a year application of N resulted in dry fruit yields that were lower, but not significantly different from the higher N treatments. However, this low level of applied N may be associated with increased incidence of bacterial canker which became prevalent only in the 0 N control and the <2.3% leaf N treatment. Greater yields and less likelihood of bacterial canker could possibly be achieved by increasing the rate of applied N in the <2.3% leaf N treatment and/or by applying N before leaf N reaches the critical 2.3 % level. With higher yields, this treatment could be more cost effective since it would require fewer N applications than the treatments requiring 10 fertigations per year. All other treatments had adequate levels of leaf N (Table 5).

Levels of other leaf nutrients showed an apparent trend that would suggest a relationship between higher levels of applied N with lower levels of leaf P and K (Table 6). Table 6 contains 1995 and 1996 data, which is representative of this trend. The greater growth and fruit production associated with higher applied N likely contributes to reduced levels of other nutrients that are in limited supply in the soil. Therefore, under high production conditions, other limited nutrients besides N need to be supplemented as needed. Leaf analysis could serve as a good tool for determining overall nutrient needs of an orchard. However, allowing nutrient levels to reach or fall below the current 'critical levels' may not be the best management practice for maintaining tree health, vigor and yields at acceptable levels. Leaf samples taken during May and October as well as July revealed similar relationships between applied N and leaf N levels (data not shown). Treatments which were low in applied N and leaf N early, late and mid-season tended to exhibit N deficiency symptoms the entire season, and developed greater incidence of bacterial canker. Clearly, leaf analysis could be used at any time during the growing season to ascertain tree nutrient status and take action to potentially avoid problems associated with poor tree nutrition.

Fruit Sampling. Total fruit N levels in 1996 for the 0 N and <2.3% leaf N treatments were significantly lower than the 1 lb N treatment (Table 7). Levels of fruit P were significantly lower for only the 0.5 lb N treatment compared to the control, but none of the other treatments were significantly different from the control. No significant differences among treatments were found for fruit K, Ca or % soluble solids. Lowest average fruit diameter was found in the buried drip and <2.3% leaf N treatments, while the 0.5 lb N treatment had fruit of significantly larger diameter (Table 7). Fruit firmness differed significantly between the 0 lb N (softest) and 0.5 lb N (firmest) treatments (Table 7). Applied N rates of 0.25 to 1 lb resulted in good fruit size and appeared to delay maturity and increase firmness compared to the 0 N control. These data suggest that measurement of fruit N correlates with leaf N, but the sensitivity of fruit analysis to N fertility may not be as great as leaf analysis.

Soil sampling. In 1991, before nitrogen treatments had begun, no significant differences in level of soil nitrates were found among blocks or among depths from 1 to 5 feet (data not shown). However, significant differences among blocks and depths were found for NH4-N, total N, phosphorous, exchangeable potassium pH and percentages of sand, silt and clay. These were inherent differences across the orchard location, and were accounted for by using a block factor in all analyses. From 1992 through 1996 we found significant differences in soil nitrate among treatments and among different depths with a range of 0.63 to 11.59 ppm (Table 8). However, we found no areas in the orchard block where soil NO_3-N down to 8 feet deep was alarmingly high prior to or during treatment. Nitrate levels below 45 ppm are considered safe in drinking water (Weinbaum, personal communication). In 1992, 1993 and 1995, the buried drip treatment exhibited the highest levels of nitrate leaching while the 1 lb N treatment had highest nitrate levels in 1994 and 1996 (Table 8). This suggests that those two treatments may possibly increase the potential for nitrate leaching during some years. The normal irrigation water contained only trace amounts of NO_3-N. Although approximately 70% of prune roots are found within the first three feet of the soil profile and some roots reach up to six feet deep or more depending on soil type (Begg, 1981), nitrates and other analyzed forms of nitrogen were not found to move substantially below the rooting zone of trees where sampling was performed down to eight feet in 1995 and 1996 (Figures 2, 3). In 1995, neither the 1 lb N or 0.25 lb N treatments exhibited significantly higher soil nitrate levels than the 0 N control at any depth (Figure 2). The 0.5 lb N, buried drip and <2.3 % leaf N treatments had significantly higher soil nitrate levels than the control at several depths, but not overall. The 1 lb N, buried drip and < 2.3% leaf N treatments had significantly higher soil nitrate levels than the control at several depths in 1996, while all other treatments were not significantly different. In 1992 and 1995, level of N applied was not obviously linked to level of measured soil nitrate except for the buried drip treatment (Table 8). For 1994 and 1996, 1 lb N appeared to be in excess of what the trees could effectively remove from the soil profile. High levels of soil nitrate in the buried drip treatment might be explained by inability of surface feeder roots to effectively access applied N at the 18 inch depth of the buried system. This could have allowed for more accumulation of nitrate below the buried drip treatment. For the <2.3% leaf N treatment, higher nitrate levels in the first two feet of the soil profile during 1996 might be due to the less extensive root systems of the trees in this lower N treatment (Figure 3). Both the 0.5 and 0.25 lb N treatments appear to deliver adequate levels of N for good tree growth and production without increasing the potential for nitrate leaching.

PROJECT SUMMARY

During orchard establishment, young trees must be irrigated, fertilized, and pruned to obtain enough vigorous growth and develop tree structure in the first five to six years while striving to minimize over fertilization, especially with N. In orchards with loam, clay-loam, or sandy-clay-loam soils, adequate soil N may be found for first year growth. Generally, it is contended that young prune and other deciduous fruit trees should be grown in ways that foster the rapid filling of allotted space in the orchard planting. In many instances, to achieve those goals growers frequently apply nitrogen fertilizers to enhance the vegetative growth of young trees. Young trees have limited root systems and, as a result, frequent irrigation and fertilization insures that trees get off to a good start. However, because of these actions and young tree root distribution characteristics, it is likely that significant amounts of water are wasted and nitrogen fertilizers are not efficiently utilized by the tree even though they may be applied to limited soil areas.

In these experiments we are conducting in Winters, we are striving to define prudent levels of N fertilizer application through fertigation that minimize N losses (through leaching), while maximizing tree growth and productivity. During this work we have found that young prune tree nitrogen status may be linked to the development of bacterial canker in areas or conditions where bacterial canker is prevalent. Where we have applied low levels or no nitrogen fertilizer for six seasons of growth we have found increased incidence of bacterial canker. Trees fertigated with 0.25 to 1.0 lb N/tree/year have no symptoms of bacterial canker. We have found on this clay-loam soil a dose of 0.25 to 0.5 lb N/tree/year delivered as UN32 regularly through the season by drip irrigation has minimized the incidence of bacterial canker while providing good yields and increased tree growth without a documented extraordinary movement of nitrate nitrogen below the rooting zone of trees.

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Table 1a. Cumulative tree growth and nitrogen partitioning in different prune tree parts over four years (1992-1995) for a 1 lb N/tree/year treatment and a 0 N control						
Tree Part	Dry Weight (g)		% Nitrogen		Average Accumulated N (g)	
	0 lb N	1lb N/tree/yr	0 lb N	1lb N/tree/yr	0 lb N	1lb N/tree/yr
Leaves	1565.2 a[x]	1950.3 a	1.84 a	2.17 a	26.6 a	38.9 a
Branches	**8119.6 a**	**12278 .4 b**	0.68 a	0.80 a	**54.5 a**	**96.5 b**
Trunk	2626.9 a	2997.3 a	0.41 a	0.40 a	10.4 a	11.4 a
Rootstock	**1100.5 a**	**1407.4 b**	0.50 a	0.52 a	**5.2 a**	**6.9 b**
Roots	**4741.6 a**	**6161.1 b**	**1.01 a**	**1.38 b**	**38.9 a**	**74.9 b**
Total	**18153.9 a**	**24794.7 b**	**0.89 a**	**1.05 b**	**135.6 a**	**228.6 b**

[x] Different letters within rows and within the categories Dry weight, % Nitrogen and Total Nitrogen are significantly different by Duncan's Multiple Range Test, 5 % level.

Table 1b. Tree growth and nitrogen partitioning in different prune tree parts in each of four years (1992-1995) for a 1 lb N/tree/year treatment and a 0 N control

Date	Tree Part	Dry Weight (g)		% Nitrogen		Total Nitrogen (g)	
		0 lb N	1lb N/tree/yr	0 lb N	1lb N/tree/yr	0 lb N	1lb N/tree/yr
10/29/92	Leaves	462.7 a[x]	450.5 a	2.09 a	2.53 a	9.9 a	11.4 a
	Branches	1318.4 a	1708.4 a	0.70 a	0.81 a	8.9 a	13.0 a
	Trunk	1392.5 a	1490.8 a	0.42 a	0.44 a	5.8 a	6.5 a
	Rootstock	636.5 a	988.8 a	0.63 a	0.71 a	3.9 a	6.7 a
	Roots	580.6 a	576.1 a	1.29 a	1.95 a	7.9 a	11.1 a
	Total	4390.8 a	5214.8 a	1.03 a	1.29 a	36.5 a	48.7 a
10/13/93	Leaves	1649.5 a	1997.6 a	2.32 a	2.47 a	37.6 a	49.7 a
	Branches	**7899.6 a**	**10759.8 b**	0.52 a	0.57 a	**41.7 a**	**59.6 b**
	Trunk	2512.1 a	2742.0 a	0.38 a	0.39 a	9.3 a	10.6 a
	Rootstock	953.4 a	1013.9 a	0.53 a	0.60 a	5.1 a	6.0 a
	Roots	**1573.9 a**	**2239.7 b**	1.32 a	1.37 a	21.1 a	31.4 a
	Total	**14588.5 a**	**18735.0 b**	1.01 a	1.08 a	**114.7 a**	**157.4 b**
10/13/94	Leaves	2648.5 a	2836.4 a	1.26 a	1.54 a	32.6 a	41.0 a
	Branches	6460.6 a	11445.5 a	0.84 a	1.02 a	55.4 a	117.5 a
	Trunk	2119.7 a	2804.5 a	0.46 a	0.41 a	9.5 a	11.6 a
	Rootstock	628.8 a	763.6 a	0.43 a	0.34 a	2.8 a	2.6 a
	Roots	5195.5 a	7728.8 a	0.66 a	0.87 a	33.2 a	72.8 a
	Total	**17053.0 a**	**25578.8 b**	0.73 a	0.84 a	133.5 a	245.5 a
10/15/95	Leaves	1500.0 a	2516.7 a	**1.69 a**	**2.14 b**	**26.3 a**	**53.5 b**
	Branches	16800.0 a	25200.0 a	**0.67 a**	**0.78 b**	112.0 a	196.0 a
	Trunk	4483.3 a	4970.0 a	0.38 a	0.34 a	16.8 a	16.8 a
	Rootstock	2183.3 a	2863.3 a	0.42 a	0.42 a	9.1 a	12.2 a
	Roots	11616.7 a	14100.0 a	**0.79 a**	**1.33 b**	93.4 a	184.4 a
	Total	36583.3 a	49650.0 a	**0.79 a**	**1.00 b**	**257.7 a**	**462.9 b**

[x] Different letters within rows and within the categories Dry weight, % Nitrogen and Total Nitrogen are significantly different by Duncan's Multiple Range Test, 5 % level.

Table 2. Effect of N fertigation on trunk cross-sectional area (TCSA), and weight of pruned shoots from 1992 through 1995.

Treatment	1992		1993		1994		1995	
	TCSA (cm2)	Pruning weight(lb)	TCSA (cm2)	Pruning weight(lb)	TCSA (cm2)	Pruning weight(lb)	TCSA (cm2)	Pruning weight(lb)
1 lb N/tree	25.8 a[x]	6.63 a	62.7 a	4.52 a	66.9 a	4.60 a	84.9 a	20.2 a
0.5 lb N/tree	24.5 ab	6.03 b	57.9 ab	4.56 a	62.8 a	4.80 a	84.5 a	22.8 a
0.25 lb N/tree	25.6 a	5.74 c	61.4 a	4.93 a	65.8 a	4.5 ab	81.6 a	21.5 a
buried drip	19.4 d	3.38 e	52.0 b	3.55 a	56.8 b	4.4 ab	81.8 a	21.6 a
<2.3% leaf N	23.6 bc	5.29 d	57.5 ab	4.01 a	61.3 ab	4.3 ab	83.0 a	21.2 a
0 N Control	22.6 c	5.15 d	52.7 b	3.68 a	56.0 c	3.60 b	80.9 a	17.2 a

[x] Mean separation by Duncan's Multiple Range Test, 5% level.

Table 3. Incidence of bacterial canker and level of leaf nitrogen averaged across blocks for different nitrogen fertigation treatments, July, 1995-96.

Treatment	Bacterial Canker Rating (0-4 scale)[Y]		% Leaf Nitrogen	
	1995	1996	1995	1996
1 lb N/tree/year	0.0 a[x]	0.0 a	2.45 a	2.53 a
0.5 lb N/tree/year	0.0 a	0.0 a	2.31 ab	2.47 a
0.25 lb N/tree/year	0.0 a	0.0 a	2.17 bc	2.41 ab
buried drip (0.5 lb N)	0.04 a	0.0 a	2.37 ab	2.38 ab
<2.3% leaf N (0.14 lb N)	0.36 b	0.41 b	2.15 bc	2.32 ab
0 lb N control	0.76 c	1.04 c	1.96 c	2.19 b

[x] Mean separation within columns by Duncan's Multiple Range Test, 5% level.
[Y] 0 to 4 scale: 0(no symptom), 1(chlorotic leaves), 2(twig die-back, cankers), 3(major scaffolds affected/removed), 4(tree dead or near death)

Table 4. 1994-96 Effects of different N fertigation treatments on Dry yield, # dry fruit/lb and dry-away averaged across blocks.

Treatment	Dry yield/tree (lbs)			# Dry fruit/lb			Dry Ratio		
	1994	1995	1996	1994	1995	1996	1994	1995	1996
1 lb N	5.5 a	17.4 a	35.5 a	47.4 a	50.1 ab	39.0 a	2.4 a	2.7 a	2.5 a
0.5 lb N	3.7 ab	14.5 a	34.3 a	46.6 a	48.8 bc	39.0 a	2.3 a	2.7 a	2.6 a
0.25 lb N	5.0 a	11.0 a	33.6 a	46.5 a	45.5 cd	38.0 a	2.3 a	2.6 a	2.5 a
buried drip (0.5 lb N)	2.5 b	11.8 a	20.1 b	50.4 a	53.0 a	41.0 a	2.4 a	2.6 a	2.5 a
<2.3% leaf N (0.14 lb N)	3.6 ab	14.5 a	29.9 ab	49.0 a	46.5 bc	39.0 a	2.4 a	2.6 a	2.6 a
0 N control	2.5 b	17.4 a	20.0 b	50.1 a	42.5 d	37.0 a	2.3 a	2.5 a	2.5 a

[x] Mean separation within columns by Duncan's multiple range test, 5% level.

Table 5. Effects of different N fertigation treatments on midsummer level of leaf N from 1992-96.

Treatment	1992	1993	1994	1995	1996
1 lb N	2.61 a[x]	2.41 a	2.66 a	2.45 a	2.53 a
0.5 lb N	2.54 a	2.36 a	2.58 ab	2.31 ab	2.47 a
0.25 lb N	2.48 a	2.41 a	2.69 a	2.17 bc	2.41 ab
buried drip (0.5 lb N)	2.24 b	2.36 a	2.60 ab	2.37 ab	2.38 ab
<2.3% leaf N (0.14 lb N)	2.25 b	2.37 a	2.32 bc	2.15 bc	2.32 ab
0 N control	2.40 ab	2.29 a	2.27 c	1.96 c	2.19 b

[x] Mean separation within columns by Duncan's Multiple Range Test, 5% level.

Table 6. July, 1995-96, levels of various leaf nutrients averaged across blocks for different nitrogen treatments.

Treatment	Leaf P (%)		Leaf K (%)		Leaf Mn (ppm)		Leaf S (ppm)		Leaf Zn (ppm)	
	1995	1996	1995	1996	1995	1996	1995 (SO_4-S)	1996 (S)	1995	1996
1 lb N	0.22 b[x]	0.36 b	1.91 b	3.08 ab	118 a	105 ab	425 a	1750 a	11.50 ab	13.5 a
0.5 lb N	0.25 b	0.37 ab	2.03 b	3.09 ab	118 a	104 ab	388 b	1687 b	12.25 ab	13.5 a
0.25 lb N	0.23 b	0.39 ab	2.07 b	3.23 a	117 a	88 bc	380 b	1538 b	14.00 a	12.3 a
buried drip (0.5 lb N)	0.34 a	0.35 b	2.34 a	2.81 b	105 a	106 a	385 b	1605 b	11.50 ab	12.5 a
<2.3% leaf N (0.14 lb N)	0.31 a	0.44 a	2.38 a	3.19 a	108 a	93 ab	390 b	1573 b	11.00 ab	13.3 a
0 N control	0.34 a	0.42 ab	2.32 a	2.92 ab	101 a	80 c	368 b	1478 b	10.75 b	12.8 a

Mean separation within columns by Duncan's multiple range test, 5% level.

Table 7. 1996 Preharvest levels of various fruit quality measurements and nutrients averaged across blocks for different nitrogen treatments.

Treatment	Diameter (mm)	% Soluble solids	Firmness (lb)	Fruit N %	Fruit P %	Fruit K %
1 lb N	38.27 ab[x]	24.4 a	3.72 ab	0.544 a	0.123 ab	1.08 a
0.5 lb N	38.48 a	24.4 a	3.86 b	0.494 ab	0.112 b	1.03 a
0.25 lb N	37.34 ab	24.9 a	3.54 ab	0.502 ab	0.117 ab	1.04 a
buried drip (0.5 lb N)	37.19 b	24.5 a	3.5 ab	0.465 ab	0.115 ab	1.00 a
<2.3% leaf N (0.14 lb N)	37.21 b	25.1 a	3.36 ab	0.453 b	0.130 ab	1.04 a
0 N control	37.91 ab	25.5 a	3.24 a	0.448 b	0.132 a	1.04 a

[x] Mean separation within columns by Duncan's multiple range test, 5% level.

Table 8. Effects of different N fertigation treatments on soil nitrate levels (NO_3 ppm) averaged from depths of 1 to 5 feet in 1992-94 and from 1 to 8 feet in 1995 and 1996.

Treatment	1992	1993	1994	1995	1996
1 lb N	6.29 b[x]	4.63 a	11.59 a	4.93 ab	2.06 a
0.5 lb N	5.85 c	3.85 b	8.07 b	5.68 ab	1.01 b
0.25 lb N	5.69 c	4.85 a	5.96 c	4.45 ab	0.63 b
buried drip (0.5 lb N)	8.89 a	5.10 a	8.54 b	6.50 a	1.12 b
<2.3% leaf N (0.14 lb N)	6.80 b	4.12 b	5.69 c	5.53 ab	0.89 b
0 N control	6.56 b	3.89 b	4.40 d	4.20 b	0.73 b

[x] Mean separation within columns by Duncan's Multiple Range Test, 5% level.

Figure 1.

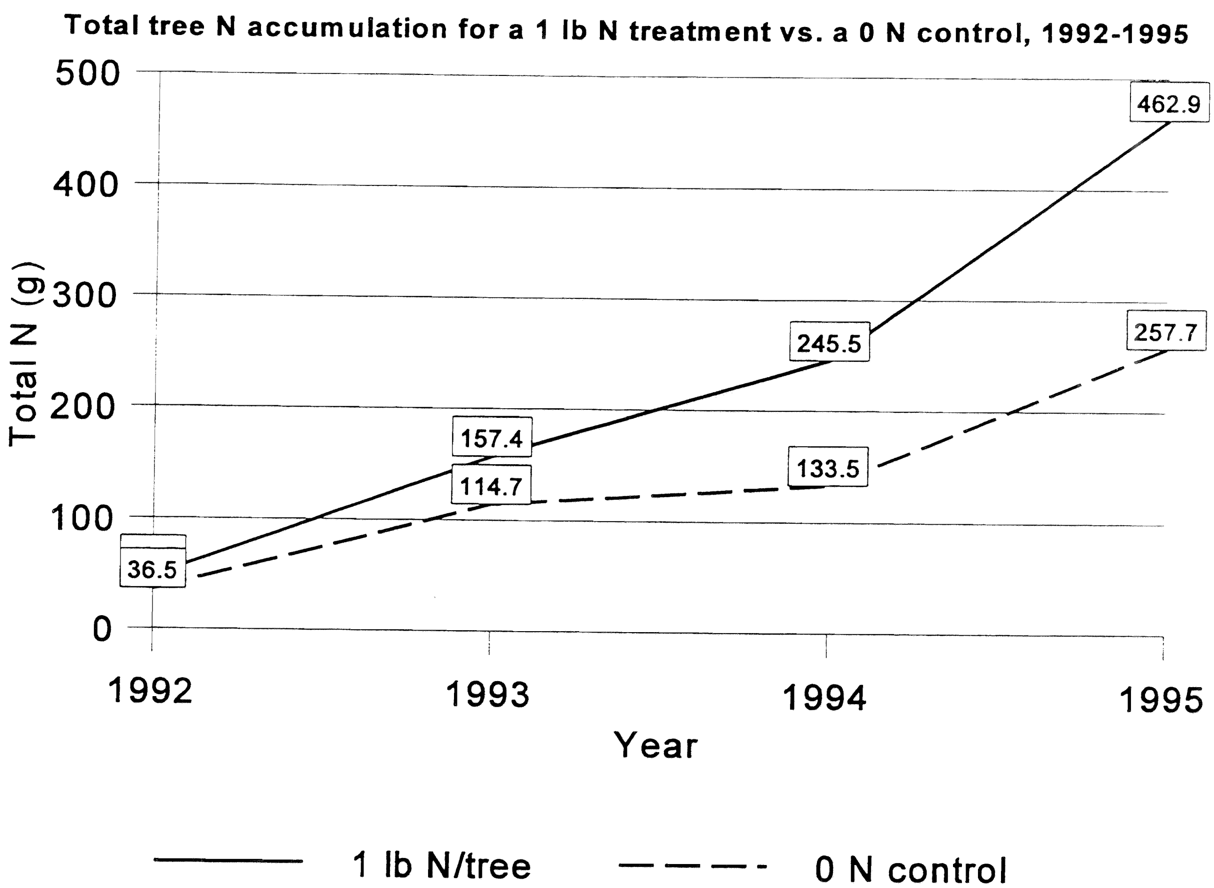
Total tree N accumulation for a 1 lb N treatment vs. a 0 N control, 1992-1995
500
400
300
200
100
0
Total N (g)
462.9
257.7
245.5
157.4
133.5
114.7
36.5
1992
1993
1994
1995
Year
1 lb N/tree
0 N control

Figure 2. 1995 Soil NO_3 Levels at Depths 1 to 8 Ft. for 6 Nitrogen Treatments

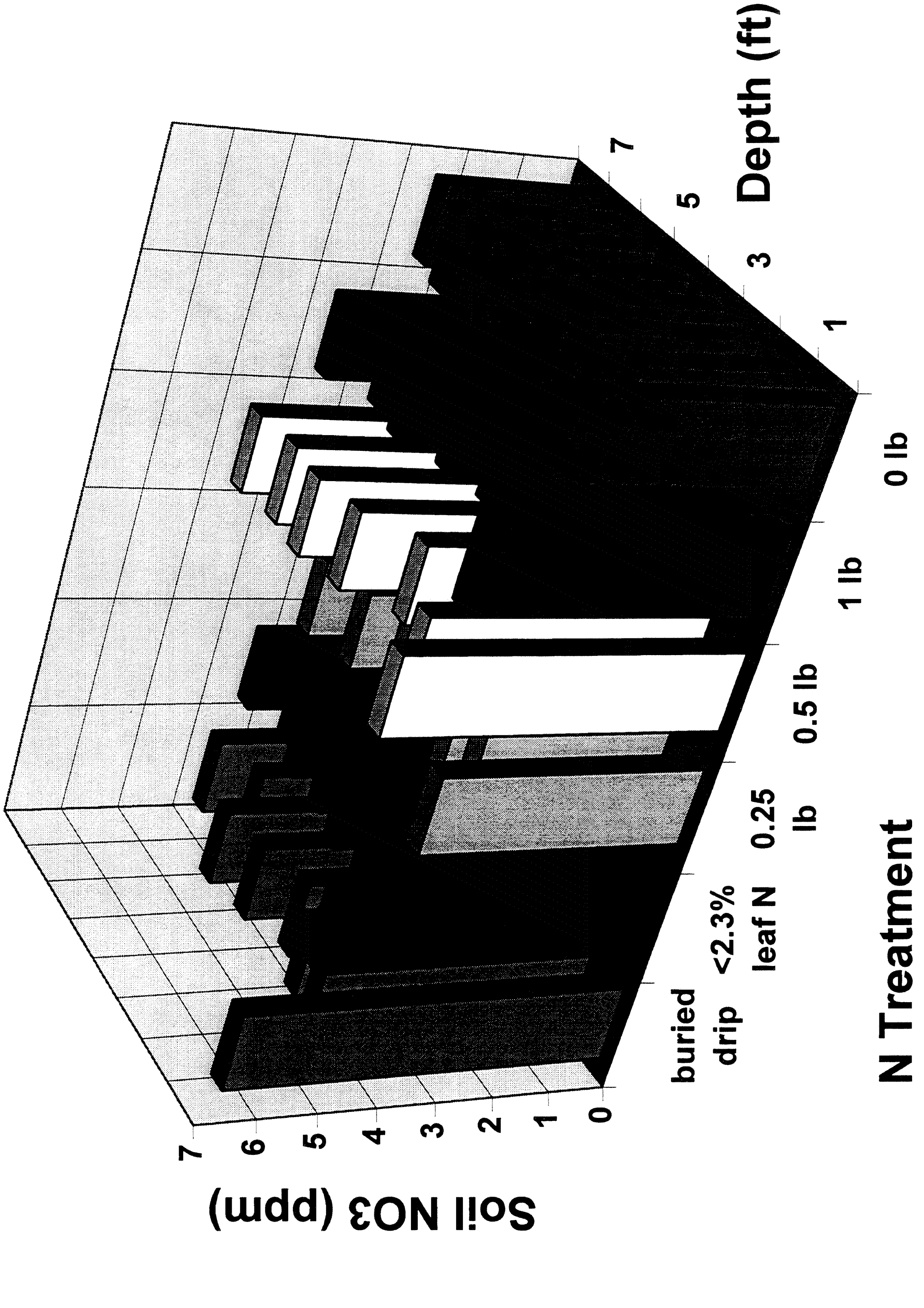

Figure 3. 1996 Soil NO_3 Levels at Depths from 1 to 8 Feet for Six Nitrogen Treatments