CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE FERTILIZER RESEARCH AND EDUCATION PROGRAM (FREP)

2003 Annual and Final Report

Project Title :
The Effect of Nutrient Deficiencies on Stone Fruit Production and Quality

Contract #992278

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Statement of Objective:

1. To induce nutrient deficiencies in full size peach, plum and nectarine trees growing in sand culture in the field and to study the effect of these deficiencies on tree growth, flowering, fruit quality, pest susceptibility and yield.
2. To produce high quality slides and color photos of deficiency symptoms and use these for various educational programs including a laminated field handbook, our stone fruit manual and many extension meetings.

Executive Summary:

This project was initiated in 1999 to study nutrient deficiencies in

mature peach, plum and nectarine trees. Sixty large tanks were installed in the plot, filled with sand and planted with one tree each of Zee Lady peach, Fortune plum and Grand Pearl nectarine (white flesh). Fifteen different fertilization treatments were started in the summer of 2000 and were continued through 2003. This is the final year of this project although the same treatments will continue to be maintained for many years to come.

During 2002 and especially 2003 many differential effects started showing up among the various treatments. Large differences were measured in leaf nutrient levels, deficiency symptoms, vegetative growth, flowering, fruit set, yield, fruit size, fruit defects and various fruit quality parameters. In the interest of keeping this report to a readable length, only those results of real practical value are presented.

Large differences in leaf nutrient levels among individual trees were measured in all the nutrients studied. Some indication of nutrient deficiency was observed for all the nutrients except K, Mn and maybe S. Leaf symptoms and other indications of deficiency are presented. Pictures of deficiency symptoms have been posted to our website. By evaluating the effect of low nutrients on many different parameters, we are able to determine the deficiency threshold for each nutrient. In some cases these values are quite different than those that have been published in the past. These values are presented and discussed.

Flower density varied substantially within the plum trees but much less so within the peaches and nectarines. We concluded that peaches and nectarines tend to flower reasonably well no matter what their nutritional status. For plum, the level of flowering was related somewhat to N level but other nutrients appeared to be involved as well, although the exact nature of this relationship is unclear. Fruit set varied considerably for all three of the varieties studied. As has been demonstrated with many other plants, B definitely played a role in this process and Mg also had an effect, especially in the peach trees.

Fruit weight varied about 2 fold within all three varieties studied. Just about every nutrient that dropped below its deficiency threshold appeared to be involved in determining the final weight of the fruit. The analysis of fruit weight was particularly helpful in establishing deficiency thresholds for each nutrient.

In 2003, a great deal of effort was made to determine fruit firmness and soluble solids content. The end result was quite discouraging as these 2 parameters did not appear to be related to any nutrient in the tree. At harvest the fruit exhibited various disorders such as skin cracks, split pits and internal cavities. On some of the trees these defects were very severe. The role of nutrition in these disorders is not very clear-cut as the results were generally inconsistent. No doubt nutrition plays a role in these fruit quality parameters, but we hypothesize it is complicated.

Vegetative growth, as measured by the increase in trunk cross sectional area, showed tremendous variability across the experiment. Some trees grew very vigorously while others hardly grew at all. While some of these differences can be attributed to N, many other nutrients were involved as well. In fact, just as with fruit weight, practically every nutrient seemed to contribute to total vegetative growth.

The overall conclusion is this: if any nutrient drops below the deficiency threshold, some of which we are suggesting need to be revised, fruit size and vegetative growth will be reduced and the chances of fruit disorders will be increased. Sometimes deficiency occurs without any obvious leaf symptoms, emphasizing the importance of taking leaf samples for nutrient analysis.

Work Description and Results, Discussion and Conclusions:

Task 1: Install tanks in the field.

Over the winter of 1999-2000, sixty large tanks measuring 11'x 8' and 4' deep were placed in 4 trenches in the field, fifteen per trench. Sand was placed under each tank to provide a slight slope towards one end. At the lower end holes were drilled and a manifold system was installed to collect drainage water into a 55-gallon drum buried beside each tank. A 2" pipe extends to the surface from each drum so drainage water can be pumped out. Once the tanks were in place they were filled with sand and the trench around the tanks was backfilled with native soil. A low volume irrigation system was installed with 2 emitters per tank. From 2000 through 2002 emitters of equal volume were used in all the tanks. In 2003, emitters with three different discharge rates were placed in the tanks depending on tree size.

The tanks have worked well to support good tree growth and allow for the imposition of nutrient deficiencies. Even though there has been some cracking of the tanks at the surface, the cracks have not extended into the soil and roots have been contained within the tanks (with one possible exception). Frequent pumping of the 55- gallon drums has been required as they fill quickly after heavy rain and with over- irrigation. Generally, the trees have been over-irrigated by 10 to 20% to prevent water stress.

Task 2: Plant trees in the tanks and grow them as vigorously as possible the first year.

In mid February 2000, one tree each of Zee Lady peach, Fortune plum and Grand Pearl nectarine was planted in each tank. Trees were trained to a perpendicular V system with two 8' bamboo poles per tree used to insure uniform tree shape. The irrigation system was set to run automatically each day. The trees started growing well but soon developed some leaf chlorosis. Small amounts of a balanced fertilizer were applied through the irrigation system to keep the trees growing and green. By early May the trees were growing well and looking very healthy so uniform fertilization was cut off for the rest of the season. In late June the first differential fertilization was applied to the sand to begin the various nutrient deficiency treatments.

The trees grew well during the season reaching a height of about 6 feet. There was also good uniformity in growth among the trees across the field. Trunk circumference measurements showed no differences among treatments (data not shown).

Task 3: Initiate nutrient deficiency treatments and measure the effect on tree growth and fruit quality parameters.

Combinations of fertilizer salts were applied to the different tanks in an effort to achieve the following treatments. Each treatment was replicated in 4 tanks.

Treatment 1 - All nutrients
Treatment 2 - No nutrients
Treatment 3 - No nitrogen
Treatments 4 & 5 - No phosphorus
Treatments 6 & 7 - No potassium
Treatments 8 & 9 - No calcium
Treatment 10 - No sulfur
Treatments 11 & 12 - No magnesium
Treatments 13, 14 & 15 - No micronutrients (B, Zn, Mn, Fe, Cu, Mo)

During the 2001 season the trees generally grew well. On several occasions, growth started to slow down due to nitrogen deficiency in many of the trees. Therefore, small amounts of N containing fertilizers were supplied to ensure adequate growth. Even treatments 2 and 3 were given some nitrogen to make sure there was enough shoot growth to carry a crop load in 2002. A few fruit were left on the trees in 2001 so a preliminary evaluation of fruit quality could be made.

One of the goals of this project was to induce a wide range of nutrient levels within the trees, with some individual trees well below the deficiency level and others two to three times higher. By the end of 2001 good progress was made towards accomplishing this goal with many of the nutrients. Deficiency levels were achieved for N, K, B, Zn and Fe, and low levels of P and S are also obvious. Deficiency symptoms of N and Zn were observed.

Task 4: Continue the nutrient deficiency treatments and measure their effect on tree growth, yield, pest susceptibility and fruit quality parameters.

During 2002 and especially 2003 many differential effects started showing up among the various treatments. Large differences were measured in leaf nutrient levels, deficiency symptoms, vegetative growth, flowering, fruit set, yield, fruit size, fruit defects and various fruit quality parameters. In an attempt to make sense of all these data, a great number of graphs have been created, thousands of correlations have been made and hundreds of analyses have been carried out. There are many interesting relationships that could be reported here. However, in the interest of keeping this report to a readable length, only those results of real practical value will be presented. Even though this is the final year of this particular project, the overall experiment will continue for many years and other results will be reported in the future.

Leaf nutrients. Table 1 shows the leaf nutrient levels in July, 2003 for Zee Lady peach (the other 2 varieties had similar trends). Large differences among individual trees were measured in all the nutrients studied. Some indication of nutrient deficiency was observed for all the nutrients except K, Mn and maybe S. All of the treatments except "No Potassium" and "No Sulfur" were successful at achieving deficiencies of the intended nutrient in at least a few trees. The "No Potassium" treatments (#6 and #7) had K levels as low as 1.01% but none below the 1.0% deficiency threshold. Sulfur (S) was highly correlated with N in all three varieties, leading us to the hypothesis that S uptake is tightly controlled by N. Therefore, even though there were very low levels of S, they were only in the low N treatments and don't represent true S deficiency. Deficiencies of micronutrients (except Mn) were measured in individual trees, although not necessarily in treatments 13 - 15. We were particularly successful at achieving very low levels of B and Zn in many trees within the experiment.

By the spring of 2003 leaf deficiency symptoms were showing up for several nutrients. N deficiency symptoms of light green leaves with red highlighting and spotting were obvious from the start of the experiment. At least one tree exhibited P deficiency, although it showed no distinct leaf symptoms other than greatly reduced growth and leaf reddening similar to N deficiency. Ca deficiency, which has never been reported for field grown trees, had leaf symptoms of marginal necrosis, similar to symptoms reported for peach seedlings grown in hydroponic culture. Trees low in Mg showed very minor symptoms of tip and marginal chlorosis that are characteristic of Mg deficiency. Some trees also exhibited a splotchy leaf water soaked symptom, which has also been associated with Mg deficiency. Zn deficiency symptoms of smaller, pointed leaves with wavy margins and interveinal chlorosis were apparent on many plum and peach trees. Pictures of these deficiency symptoms have been posted to our website at http://www.uckac.edu/uckac/people/faculty%20descriptions/johnson.html. Some of the other nutrients showed no obvious leaf symptoms but were considered deficient because of the effect they had on fruit set, fruit size or fruit quality parameters.

Table 1. Leaf nutrient levels for Zee Lady peach taken in July 2003 [illegible] ank experiment among treatments by Duncan's Multiple Range Test, at p = [illegible]

By evaluating the effect of low nutrients on many different parameters, we are able to determine the deficiency threshold for each nutrient. In some cases these values are quite different than those that have been published in the past. The results presented here should be considered preliminary since 4 or 5 years of consistent data are needed to change an "official" deficiency threshold. For the nutrients N, K, S, Mn and Fe we have no new information to add because our data points are too inconsistent or not low enough. P deficient trees exhibited reduced growth, smaller fruit size and some leaf symptoms at leaf levels below about 0.12%. Trees low in Ca had many fruit quality problems such as skin cracking, split pits and air pockets, especially in the plums. However, there was not a clear enough picture to set a definite threshold. With additional years of data, a threshold somewhere between 1.0 and 2.0% should become clear. Low Mg levels led to poor fruit set, fruit quality problems and some minor leaf symptoms. Most of these defects occurred well above the published deficiency threshold of 0.25%. Therefore, this value will need to be revised to at least 0.3 to 0.4%, and maybe even higher.

For the micronutrients, B and Zn have shown a fairly clear and consistent pattern of deficiency. Peach and nectarine trees low in B exhibited no obvious leaf deficiency symptoms, but had low fruit set and reduced fruit size. These problems occurred at leaf B levels well above the published value of 18 ppm. Therefore, the threshold will need to be revised to a value closer to 25 or 30 ppm. Since B toxicity can easily be induced in peach trees by over fertilization, there is a need to study this nutrient in greater detail. Zinc deficiency symptoms appeared in quite a few peach and plum trees in both 2002 and 2003. In all cases, the symptoms were only present in trees with leaf Zn levels below 10 ppm. Fruit size was also reduced in peach and nectarine trees below 10 ppm Zn. The published threshold for Zn is 15 ppm, so this is one nutrient that may need to be revised down instead of up. Finally, trees with leaf Cu values lower than 5.0 ppm showed reduced fruit size. Over the next few years we will continue to refine these thresholds in the sand tanks and evaluate them in field grown trees.

Yield, fruit quality and vegetative growth. In 2003, large differences among treatments were found in all the parameters of productivity, fruit quality and vegetative growth (Table 2). Again, in the interest of brevity, only those relationships of practical significance will be discussed in this report.

Table 2. Range of flowering, fruit set, fruit size, fruit quality parameters and vegetative growth from sand tank experiment in 2003.

	Zee Lady Peach		Grant Pearl Nectarine		Fortune Plum	
Parameter	**Low**	**High**	**Low**	**High**	**Low**	**High**
Flowering Density ([illegible])	.22	.47	.12	.39	5	7.0
Initial Fruit Set (% of flowers)	34	96	31	95	--	--
Final Fruit Set (% of flowers)	16	86	11	61	0	4.7
Fruit Weight (g/fruit)	91	216	61	143	65	138
Fruit Firmness (lb)	9.9	17.5	7.5	18.2	7.4	10.8
Fruit Soluble Solids Content (%)	12.9	16.3	16.4	22.8	12.4	16.5
Skin Cracks (%)	0	46	7	81	0	39
Split Pits (%)	0	3	0	27	0	36
Internal Cavity (%)	0	0	0	0	0	92
Trunk Cross Sectional Area Growth (cm2)	0	27.0	1.8	25.7	1.5	29.0

Plum flowering density in units of #/cm

Flower density varied substantially within the plum trees but much less so within the peaches and nectarines (Table 2). In fact, the peach trees showed no significant difference among treatments for this parameter. The conclusion is that peaches and nectarines tend to flower reasonably well no matter what their nutritional status is (unless a nutrient becomes deficient enough to cause dieback). For plum, the level of flowering was related somewhat to N level (N deficient trees had less flowers) but other nutrients appeared to be involved as well, although the exact nature of this relationship is unclear. Fruit set varied considerably for all three of the varieties studied. As has been demonstrated with many other plants, B definitely played a role in this process and Mg also had an effect, especially in the peach trees. N deficient peach and nectarine trees tended to have higher fruit set values than other treatments.

Fruit weight varied about 2 fold within all three varieties studied (Table 2). Just about every nutrient that dropped below its deficiency threshold appeared to be involved in determining the final weight of the fruit, which makes a lot of sense physiologically. Whether a nutrient is involved in photosynthesis, or in sugar transport, or in membrane permeability, or directly in the process of fruit growth, a deficiency will generally mean less sugar availability for fruit growth. The analysis of fruit weight was particularly helpful in establishing deficiency thresholds for each nutrient, as discussed above.

In 2003, a great deal of effort was made to determine fruit firmness and soluble solids content. At each of 2 or 3 harvests for each variety, a 20 fruit sample was taken from every tree for analysis. Firmness was measured on both cheeks of every fruit and individual soluble solids content was read on 5 to 10 fruit per tree. The end result was quite discouraging, as these 2 parameters did not appear to be related to any nutrient in the tree. Even though there was considerable variation among the trees (Table 2), this variability was more associated with factors other than nutrition. Since firmness and soluble solids content have been shown to be strongly influenced by factors such as maturity, light environment, crop load and canopy location, we conclude that these factors are much more important than nutrition in determining these two quality parameters.

The fruit exhibited various disorders in 2003 such as skin cracks, split pits and internal cavities (Table 2). On some of the trees these defects were very severe. For instance, on one nectarine tree 81% of the fruit were cracked. Other trees had high quality fruit with very few defects. The role of nutrition in these disorders is not very clear-cut as the results were generally inconsistent. For instance, in Zee Lady peach, one of the "No Magnesium" treatments had extensive cracking in all 4 of the reps.

However, the nectarine trees in the same tanks (with similar leaf nutrient levels) showed very little cracking. The plum trees in this treatment had excellent fruit quality. No doubt nutrition plays a role in these fruit quality parameters, but we hypothesize it is complicated. Probably several nutrients interact, together with various genetic, physiological and environmental factors to bring about the symptoms. We will continue evaluating these disorders (and others, such as corking) in the future in hopes of being able to relate them more definitively to nutrition.

Vegetative growth, as measured by the increase in trunk cross sectional area, showed tremendous variability across the experiment (Table 2). Some trees grew very vigorously while others hardly grew at all. While some of these differences can be attributed to N, many other nutrients were involved as well. In fact, just as with fruit weight, practically every nutrient seemed to contribute to total vegetative growth. The overall conclusion is this: if any nutrient drops below the deficiency threshold, some of which we are suggesting need to be revised, fruit size and vegetative growth will be reduced and the chances of fruit disorders will be increased. Sometimes deficiency occurs without any obvious leaf symptoms, emphasizing the importance of taking leaf samples for nutrient analysis.

Task 5: Document deficiency symptoms on leaves and fruit with high quality photos and slides and use these in various educational programs.

During the spring and summer of 2003, about 500 digital pictures were taken of nutrient deficiencies observed on trees in the sand tank experiment. These have been used for numerous educational events during 2003 and early 2004. These have included several field days at the site, FREP conference, two Nutrient Conferences, two grower meetings, Plant and Soil Conference and two out-of -state fruit meetings.

Outreach Activities Summary: Extensive outreach activities were carried out in the last year of this project. The following table lists all the meetings where a nutrition talk based on the sand tank experiment was given.

Presentations on Stone Fruit Nutrition (Based on Sand Tank Experiment Results)

Meeting	Date	# in Attendance
Pomology Extension Continuing Conference	3/21/03	30
Stone Fruit Workgroup Meeting	4/17/03	12
Tree Fruit Pest Management Meeting	5/7/03	20
Stone Fruit Fieldmen Seminar	10/21/03	20
Nutrient Conference - Fresno	11/4/03	75
Nutrient Conference - Woodland	11/5/03	40
FREP Annual Meeting	11/20/03	30
Winter Tree Fruit Meeting	12/3/03	170
Cling Peach Seminar	12/10/03	60
Mid Atlantic Fruit & Vegetable Convention	1/28/04	80
Plant and Soil Conference	2/3/04	70
Ontario Fruit & Vegetable Convention	2/19/04	100