THE EFFECT OF NUTRIENT DEFICIENCIES ON STONE FRUIT PRODUCTION AND QUALITY

Project Leader: R. Scott Johnson
Cooperators: Carlos Crisosto
Harry Andris, Kevin Day, Brent Holtz, Bob Beede, Kevin Klassen

Abstract

This project was developed to study nutrient deficiencies in mature peach, plum and nectarine trees. In 1999 sixty large tanks with individual drainage systems were installed in the plot and filled with sand. At the start of the 2000 season, one tree each of Zee Lady peach, Fortune plum and Grand Pearl nectarine (white flesh) was planted in each tank. Differential fertilization treatments were started in the summer of 2000 and continued through the 2001 and 2002 seasons.

The following results were obtained in 2002. There was a 2 to 3 fold difference between the low and high values for each of the nutrients measured in July. Some of the leaf samples tested below the published deficiency thresholds for N, B, Zn and Fe. The remaining nutrients also measured very low on some of the trees, often just above the deficiency threshold. Despite the low leaf nutrient levels, there were surprisingly few leaf deficiency symptoms observed on the trees. Nitrogen deficiency was obvious on many trees, starting right after bloom. Also early in the spring, some zinc deficiency symptoms were apparent, especially on some of the plum trees, but these disappeared as the weather warmed up. By mid summer, other than the yellow and red leaf symptoms of N deficiency, the trees looked very healthy and vigorous. However, there were many other subtle symptoms such as fruit size, fruit color and shoot vigor that were obviously caused by the nutrient treatments.

Flower density varied about 3 fold for both peach and nectarine and much more for plum. The treatments with no nitrogen had distinctly lower flower densities than the other treatments, especially with plum. However, there was generally a very poor correlation between leaf nitrogen content and flower density for all the trees together. Instead, it appears other nutrients such as P, B and Fe may have contributed to flower development as well. Fruit set was dramatically different from one tree to another. A few nectarine trees had good flowering but ended up with virtually no fruit even though some flowers started to develop initially. For peach, the differences in fruit set (both initial and final) correlated well with leaf B content in May. For nectarine, fruit set also correlated with May leaf B but not as strongly as for peach. Other nutrients may have played a role. For example, good correlations were found between initial set and both leaf Ca and Mg, while final set correlated with leaf Cu.

Average fruit weight varied about 2 fold among the various trees of peach, plum and nectarine. Several of the trees had excellent fruit size even with fairly heavy fruit loads. The statistical analysis conducted to this point suggests that just about every nutrient measured had some effect on final fruit size. Generally, those trees with the most balanced nutrition had the best fruit size. As any nutrient started to drop below the optimum level (often well above the deficiency level) fruit size decreased. At harvest several parameters of fruit quality were measured. These included firmness, % red color, % soluble solids content and acidity. As with the other parameters measured there tended to be at least a 2-fold difference from the lowest to the highest values. Firmness and % red color correlated somewhat with leaf N but appeared to reflect maturity of the fruit more than nutritional status of the tree. Fruit acidity showed a high correlation with many different nutrients suggesting it might be affected by P, K, Ca, Mg and B.

Trunk circumference was measured at the end of the season and 2002 growth in trunk cross sectional area was calculated. There was considerable variability in this parameter, with over a 6-fold difference among trees for all 3 varieties. The majority of this variability was explained by nitrogen. However, other nutrients also seemed to play a secondary role. Multiple regression analysis suggests copper and iron could also be involved.

Introduction

This project was developed to study nutrient deficiencies in mature peach, plum and nectarine trees. In 1999 sixty large tanks with individual drainage systems were installed in the plot and filled with sand. At the start of the 2000 season, one tree each of Zee Lady peach, Fortune plum and Grand Pearl nectarine (white flesh) was planted in each tank. Differential fertilization treatments were started in the summer of 2000 and continued through the 2001 and 2002 seasons. By 2001 nutrient deficiencies were apparent in some trees. A small amount of fruit was harvested from most of the trees in that year. By 2002 fruit production was substantial on the majority of the trees. Big differences among trees were measured in tree size, flower production, fruit set, fruit size, and fruit quality parameters. Many of these differences were correlated with leaf nutrient levels. In analyzing the relationships between these parameters and trees nutritional status, many interesting results have been obtained. In some cases, a single nutrient seems to explain the variability. In others, multiple nutrients appear to be involved, sometimes in rather complex ways. In addition, this research suggests the conventional mid summer timing of nutrient analyses may be too late for some nutrients. An early spring sampling may be more appropriate in a few cases. This research is also providing preliminary evidence that published critical levels may need to be revised for a few of the nutrients. Overall, this project is producing some very interesting and useful findings and should continue to do so as the trees grow larger and show even greater differences among treatments over time.

Objectives

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.

Project Description

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)

Besides the mixture of salts (based on Hoagland solutions) applied to each treatment, an additional fertilization program was followed in 2002 in order to achieve a wide range of nutrients among individual trees and to help depress the specific nutrient for a given treatment. For instance, extra nitrogen was applied to some treatments (5,7,9 and 12) to stimulate vigorous growth and thus help dilute the specific nutrient not supplied to that treatment. Also heavy applications of competing cations were made to treatments 6,7,8,9,11 and 12 in order to replace the given cation on the soil cation exchange sites. Finally additional applications of P (treatments 6 and 11), B and Fe (treatments 1 and 3 to 12), and Zn (treatments 3,5,7,9 and 12) were made to specific treatments because these nutrients were generally low in all trees in 2001. Leaf samples were collected from all 180 trees in early May and early July 2002. These were sent to the DANR analytical lab for determination of all macro and micronutrients.

In March, 10 shoots per tree were tagged for measurements of flowering and fruit set. In July, fruit were harvested from each tree as they ripened in one or two picks per variety. Total yield and average fruit weight were calculated. Samples of 20 fruit per tree were then taken and analyzed for firmness, % red color, soluble solids content and acidity. In October, trunk circumferences were measured on each tree as an estimate of vegetative growth.

Results and Conclusions

Since the start of this experiment a large mass of data has been collected. This includes thousands of nutrient analyses and hundreds of measurements of flowering, fruit size, fruit quality and vegetative growth. Many different statistical tests have been run. This yearly report will just highlight a few of the most interesting results. In the final year of the project (2003), a more comprehensive report will be submitted.

Leaf Nutrient Levels. Table 1 shows the range of leaf nutrient levels from the July sampling period. There was a 2 to 3 fold difference between the low and high values for each of the nutrients measured. Some of the leaf samples tested below the published deficiency thresholds for N, B, Zn and Fe. The remaining nutrients also measured very low on some of the trees, often just above the deficiency threshold. Almost all the nutrients had both higher and lower values in 2002 compared to the year before. The one exception to this is potassium, which had some very high values but no minimum values as low as those measured in 2001. The other two major cations, calcium and magnesium, had minimum levels that were considerably lower than those achieved in 2001. Overall, the wide range of values and the low levels measured for each nutrient provide a very useful data set for examining nutrient effects on tree and fruit parameters.

Table 1. Range of nutrients from July 2002 leaf samples taken from trees in sand tank experiment. Published deficiency thresholds are shown for comparison.

	Zee Lady Peach			**Grand Pearl Nectarine**			**Fortune Plum**		
Nutrient	**Deficient Below**	**Low**	**High**	**Deficient Below**	**Low**	**High**	**Deficient Below**	**Low**	**High**
N (%)	2.3	1.64	3.27	2.3	1.62	3.60	-	1.08	2.39
P (%)	-	.08	.19	-	.08	.19	-	.11	.25
K (%)	1.0	1.43	3.21	1.0	1.17	2.97	1.0	1.52	3.42
S (ppm)	-	720	1790	-	820	1820	-	850	2070
Ca (%)	-	1.11	3.62	-	.75	3.12	-	1.55	4.72
Mg (%)	.25	.29	.85	.25	.29	.75	.25	.55	1.14
B (ppm)	18	14	37	18	19	36	25	22	48
Zn (ppm)	15	5	19	15	6	19	18	6	26
Mn (ppm)	20	38	121	20	37	121	20	24	90
Fe* (ppm)	60	39	84	60	40	68	-	39	111
Cu (ppm)	-	2.5	6.2	-	3.0	6.0	-	3.3	6.8

*Values for Fe are from May, 2002 leaf sample since deficiency threshold applies to this timing.

Despite the low leaf nutrient levels measured in July, there were surprisingly few leaf deficiency symptoms observed on the trees. Nitrogen deficiency was obvious on many trees, starting right after bloom. Also early in the spring, some zinc deficiency symptoms were apparent, especially on some of the plum trees, but these disappeared as the weather warmed up. By mid summer, other than the yellow and red leaf symptoms of N deficiency, the trees looked very healthy and vigorous. However, there were many other subtle symptoms such as fruit size, fruit color and shoot vigor that were obviously caused by the nutrient treatments.

Zinc leaf levels measured in this experiment are particularly perplexing (similar results were obtained in 2001). Just about all the trees had leaf levels well below the published deficiency threshold of 15 ppm for peaches and nectarines and 18 ppm for plums (Table 1). Some trees were as low as 5 or 6 ppm, which suggests severe deficiency. However, none of these trees exhibited the typical “little leaf" symptoms associated with Zn deficiency. Perhaps the deficiency threshold for Zn will need to be revised in the future. In addition, perhaps the timing of sampling for Zn may need to be revised as well. Those treatments that were given extra Zn fertilizer had quite high levels in May (data not shown) but these dropped substantially by the July sampling period. Since zinc is often associated with actively growing tissues, it may be necessary to sample early in the spring when tissues are actively growing. This approach will be investigated in 2003.

The correlation between the May and July samples was generally quite high for most of the nutrients. For instance, N, K, Ca and Mg all had correlation coefficients of about 0.80 for all 180 trees. On the other hand, several nutrients including B, Fe, and Cu did not correlate at all between the two dates. Therefore the standard July sampling period may not reflect nutrient levels at other times of the year. This emphasizes the need for sampling close to the time when a given physiological process is occurring. Since many critical processes such as bud break, flower set, fruit cell division and shoot growth occur early in the spring, a sampling method needs to be developed for this time period. Also, even though N correlated well between the two dates, the levels dropped substantially between May and July. In fact, some trees dropped below the deficiency threshold even though they showed no symptoms of deficiency. For instance, the control nectarine trees had May leaf N levels of 3.61%, which decreased to 2.22% in July (deficiency is below 2.3%). The trees looked healthy and continued to grow vigorously throughout the season. The conclusion that can be drawn from this is that the early season sample appears to be more indicative of the true status of the tree rather than the standard mid-season timing.

It is also interesting to note that the levels of some nutrients in the peach and nectarine leaves were quite different from the plum leaves. For instance, calcium was always substantially higher in the plum leaves than the other two (Table 1). This happened even though all three trees were together in each tank, receiving the same fertilization, and were all on the same rootstock (nemaguard). Perhaps there are physiological differences between these two species that affect the demand for certain nutrients such as calcium.

Flowering and Fruit Set. Flower density varied about 3 fold for both peach and nectarine and much more for plum (Table 2). The treatments with no nitrogen (2 and 3) had distinctly lower flower densities than the other treatments, especially with plum. However, there was generally a very poor correlation between leaf nitrogen content and flower density for all the trees together. Instead, it appears other nutrients such as P, B and Fe may have contributed to flower development as well. There was also some moderate water stress in some of the trees during 2001 that may have affected flowering (irrigation amounts and soil water status were monitored much more carefully in 2002 to make sure no stress occurred).

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

	Zee Lady Peach		**Grand Pearl Nectarine**		**Fortune Plum**	
Parameter	**Low**	**High**	**Low**	**High**	**Low**	**High**
Flowering Density (#/cm)	.18	.50	.10	.32	.06	1.91
Initial Fruit Set (% of flowers)	44	100	26	93	-	-
Final Fruit Set (% of flowers)	4	71	0	58	-	-
Fruit Harvested (#/tree)	17	103	1	68	0	83
Fruit Weight (g/fruit)	123	248	80	163	60	123
Fruit Firmness (lb)	6.2	14.2	4.0	15.3	6.1	9.7
Fruit Red Color (%)	58	97	46	98	-	-
Fruit Soluble Solids Content (%)	10.0	17.8	13.1	25.4	11.9	16.8
Fruit Acidity	.63	1.05	.24	.38	.27	.74
Trunk Cross Sectional Area Growth (cm^2)	3.0	19.8	4.7	31.1	3.6	24.6

Fruit set was dramatically different from one tree to another (Table 2). A few nectarine trees had good flowering but ended up with virtually no fruit even though some flowers started to develop initially. The peach trees were not quite as extreme but still had some trees with fruit set as low as 4%. On the other hand, some peach and nectarine trees had 200-300 fruit per tree before thinning. Fruit set was not measured on the plum trees but total fruit load showed the same extremes as the peach and nectarine trees. For peach, the differences in fruit set (both initial and final) correlated well with leaf B content in May (Figure 1). Since many of the tanks received an application of B in April, only those tanks that were not thus fertilized were used for this analysis. For nectarine, fruit set also correlated with May leaf B but not as strongly as for peach. Other nutrients may have played a role. For example, good correlations were found between initial set and both leaf Ca and Mg, while final set correlated with leaf Cu. Again, sample timing is probably a key factor in this relationship (July leaf B showed no correlation with set) so an earlier sample should show a better correlation. In 2003, samples will be taken at bloom and analyzed for nutrients. Fruit set in the plum trees did not seem to be related to any nutrients. Often, fruit set in young plum trees is more a function of variable pollination.

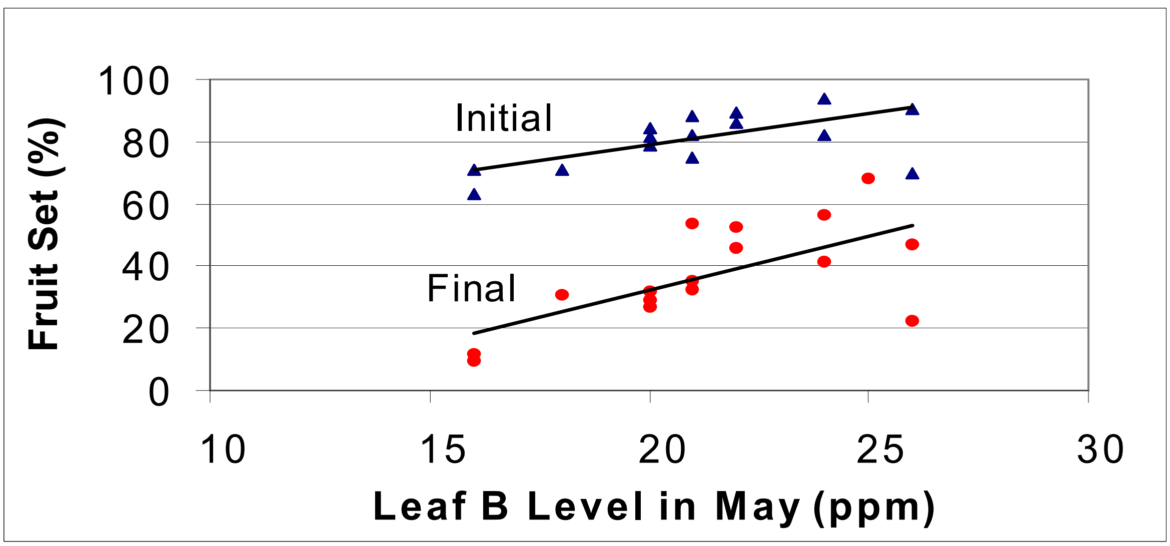

Figure 1. Fruit set of Zee Lady peach as related to leaf boron level in May 2002. Initial fruit set indicates all fruit that started to grow after petal fall. Final fruit set indicates just those fruit that were still growing at hand thinning time in mid April.

Fruit Size. Average fruit weight varied about 2 fold among the various trees of peach, plum and nectarine (Table 2). Several of the trees had excellent fruit size even with fairly heavy fruit loads. The statistical analysis conducted to this point suggests that just about every nutrient measured had some effect on final fruit size. Generally, those trees with the most balanced nutrition had the best fruit size. As any nutrient started to drop below the optimum level (often well above the deficiency level) fruit size decreased. However, the extent of fruit size reduction varied from one nutrient to another. For instance, the “no nitrogen” treatment was obviously chlorotic with weak shoot growth, yet it did not have the smallest fruit size. For Zee Lady peach, the treatment with the smallest fruit was “no potassium” even though it showed no deficiency symptoms. This confirms earlier studies that identified potassium as a critical element for good fruit growth. For Grand Pearl nectarine, the smallest fruit occurred in the “no calcium” treatment. July leaf levels of Ca for this treatment were about 1%. Additional data from the 2003 season will allow us to confirm these relationships and determine the relative importance of the various nutrients with regard to fruit growth.

The peach and nectarine trees tended to show similar results in their relationship of fruit size to leaf nutrients. However, fruit on the plum trees appeared to follow a somewhat different pattern. Most notably, calcium seemed to play a major role in fruit size with some of the “no calcium” trees having noticeably larger fruit than many of the other treatments. These trees had leaf Ca levels around 2%, which is far from deficient and, in fact, is about the same level as that found in the peach and nectarine trees with the largest fruit. Therefore, it may just be a case of many of the plum trees having excessive Ca levels (some were as high as 4.72% - see Table 1), which could depress fruit size. Hopefully in 2003, leaf Ca levels will drop as low as 1% in some of the plum trees, similar to levels observed in the peach and nectarine trees. We are still hopeful that we can develop a single fruit size model that will apply to all 3 of the varieties being tested in this experiment.

Fruit Quality. At harvest several parameters of fruit quality were measured. These included firmness, % red color, % soluble solids content and acidity. As with the other parameters measured there tended to be at least a 2-fold difference from the lowest to the highest values (Table 2). Firmness and % red color correlated somewhat with leaf N but appeared to reflect maturity of the fruit more than nutritional status of the tree. Fruit % soluble solids content did not show a significant correlation with any nutrient. In 2003, a more extensive sampling technique will be used since there tends to be a lot of fruit-to-fruit variability in this parameter. Fruit acidity showed a high correlation with many different nutrients suggesting it might be affected by P, K, Ca, Mg and B. In 2003, there will be substantially more fruit on the trees, so multiple harvests will be employed to ensure more uniform maturity among treatments.

Vegetative Growth. Trunk circumference was measured at the end of the season and 2002 growth in trunk cross sectional area was calculated (Table 2). There was considerable variability in this parameter, with over a 6-fold difference among trees for all 3 varieties. The majority of this variability was explained by nitrogen. However, other nutrients also seemed to play a secondary role. Multiple regression analysis suggests copper and iron could also be involved.

Plans for 2003. 2003 will be the final year of the project so an aggressive fertilization and extensive sampling program will be followed to ensure the original objectives are met. The “no nitrogen” treatment should be severely deficient and ample nitrogen will be supplied to the other treatments to make sure nitrogen is not generally limiting. As in 2002, large doses of competing cations will be supplied to the “no calcium”, “no potassium” and “no magnesium” treatments and micronutrients will be regularly supplied to many of the treatments. This strategy should assure a wide range of all leaf nutrient levels. At harvest, a more comprehensive evaluation will include multiple picks, storage tests, disease susceptibility and various fruit disorders such as corkiness, cracking and discoloration. Finally, a more extensive sampling protocol will include flower and leaf samples at bloom for nutrient analysis.