Project Concluded: Final Report

Seasonal Variations in N Uptake and Nutrient Concentrations in Mature Field-Grown Citrus

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This constitutes the final report for this project. A few data points are missing due to delays in isotopic analysis, however estimates have been made for the missing points as referenced below. The objectives of this study were to measure seasonal variations in mineral nutrient concentration and mass in vegetative organs and fruit of mature citrus trees, to estimate seasonal variations in nitrogen uptake, and to estimate the amount of nitrogen removed from soil.

Mature Valencia trees at the UC Lindcove Research and Extension Center in Tulare County were sampled six times in a yearly cycle: winter 2003, bloom 2003, drop 2003, color break 2003, maturity 2004, and winter 2004. At each harvest date, entire trees were removed and partitioned into fruit, young leaves (i.e., flushes), mature leaves, small green branches, small brown branches, intermediate branches, large branches, trunk, large roots, medium roots, and fine roots. Roots were extracted from soil using the device designed by Mary Lu Arpaia. This gave a more complete estimate of root mass than would have been obtained otherwise. Note that not all organs were harvested at each date, and fruit alone was harvested in September 2003. For instance, young flushes were not always available.

Fresh weights were taken at the time of harvest. For the canopy, subsamples were taken and total weights of the individual organs estimated from total canopy mass. Subsamples were taken and dried. Dried samples were sent to the DANR lab for mineral analysis. This information combined with the dry weight provides an estimate of the total mineral content of the trees. N uptake was estimated using the stable isotope N^{15}. Isotopic analysis was done at Oregon State University. Saturated soil extracts were made to estimate the isotopic ratio in the soil N.

Some general comments regarding this project should be made. The necessary destructive harvest of the trees increased the overall variability of the various measurements. Repeated harvesting of the same trees would have reduced this, but then sampling of the underground portion of the trees would not have been possible. The study was further complicated by the fact that the trees were Valencias and so for the most part had two crops on them. Therefore, the category “fruit” for winter1 through Valencia harvest included the first year’s crop, while the data for break, maturity, and winter2 included the second year’s crop. The second year’s crop was harvested separately at drop (“immature fruit” in the tables). Fruit was harvested as rinds and juice, with the results combined to represent the whole fruit. Thus, some tables do not show the concentration for fruit (since the concentration units for juice and rind are different) but do show mass.

Sampling also had some issues, as there was a certain amount of subjectivity in separating (for instance) intermediate branches from large branches. This would affect the uncertainty of the individual dry mass measurements more than either the total dry mass (which would be compensated for by the complete sampling) and the elemental masses (due to the extent to which the organs were subsampled). Finally, although every effort was made to thoroughly sample the roots utilizing the root extraction device ('The Beast'), this was not possible in practice. The rootball was extracted out to the skirt of the tree, however some roots extended beyond this and the roots from adjacent trees extended into this volume. There was no way to differentiate between the roots of the sample tree and the adjacent trees. This introduced some more uncertainty into the contribution of the roots, particularly the smaller roots, to the total tree and elemental masses. Moreover, it was impossible to completely extract the smallest roots from the soil due to their minute size and in addition, drying them reduced them to nothingness. Thus the contribution of the smallest roots may be underestimated. However, although the N content was relatively high, the small dry mass of the roots reduces the amount of error introduced.

Regarding the isotopic analysis, the isotope ration of the soil N is usually calculated or estimated based upon other measurements. This is usually done with small potted trees rather than the large mature trees utilized in this study. In order to more accurately quantify the isotope ratio of the soil N, we made a saturated extract. This will increase the accuracy of the contribution of the soil N to the trees. However, the results for this analysis are not available at the time of writing this report. Therefore, the soil N isotope ratio was estimated in the conventional manner. This will probably result in an under-estimation of the contribution of the soil N to tree N. We intend to correct this when the results are available and present the more thorough analysis to the growers via extension publications such as "Topics in Subtropics".

Table 1 shows the dry mass of the various organs sampled. Note that the dry mass of the entire tree is about 300 – 400 lbs. The fruit contribute a substantial portion of the fresh mass to the tree (data not shown), and harvest greatly reduces total tree fresh mass. However, most of the mass of the fruit is juice (or basically water), and the contribution of the fruit to the dry mass of the tree is not that great. There is not much significant variation in dry mass throughout the year. Basically, the tree-to-tree variability, the fact that most carbon assimilation throughout the year goes into fruit growth rather than the tree permanent structure, and the destructive harvest makes it difficult to see seasonal changes here. We believe that most of the differences seen are artifacts of the sampling process, particularly the winter1 harvest, when we were inexperienced with our harvesting procedure.

DryMass	Winter1	Bloom	Drop	ValHarvest	Break	Maturity	Winter2
immature fruit	*	*	11.2	*	*	*	*
fruit	38.0 a	34.7 ab	28.8 b	28.4 b	17.6 cd	19.7 c	12.7 d
young leaves	0.00 b	1.2 b	0.9 b	*	0.6 b	0.0 b	9.7 a
mature leaves	63.0 a	53.2 b	40.4 bc	*	57.8 a	51.7 ab	28.5 c
small green branches	31.7 c	56.6 ab	50.8 ab	*	63.0 a	51.0 ab	45.3 ab
small brown branches	2.2 b	12.1 a	7.7 ab	*	12.9 a	0.9 b	14.6 a
intermediate branches	29.2 b	58.5 a	53.8 a	*	61.9 a	62.5 a	49.8 a
large branches	47.0 b	54.9 ab	61.5 ab	*	70.3 a	63.5 ab	53.2 ab
trunk	18.1 ns	22.1 ns	14.8 ns	*	14.4 ns	18.8 ns	18.1 ns
large roots	72.7 a	59.3 b	48.3 b	*	55.3 b	54.4 b	54.1 b
medium & small roots	9.6 ab	11.8 a	11.1 a	*	12.9 a	7.4 b	7.1 b
total	311.5	375.2	329.3	*	366.7	329.9	293.1
total - fruit	273.5	340.5	289.3	*	349.1	310.2	280.4

Table 1. Dry mass of organs of mature 'Valencia' trees over the course of a year. Statistical separations are within organ using Duncan's multiple range test (alpha = 0.05).

The percentage of total N in the various organs would not be affected as much by tree-to-tree variability as the mass. Nonetheless, there was not much seasonal variation in N concentration in most organs (Table 2). In most organs, there appeared to be a slight increase in total N concentration at bloom. However, N concentrations in the leaves dropped at bloom. This may have been a case of the mature leaves exporting N to support the flush. However, flush N concentration was lower than expected. Possibly this was due to the flushes not yet being fully established. The increase in percentage total N in the permanent structure may have represented a mobilization of soil N, with it not yet arriving to the new growth or fruits. However, this does not appear to be the case based upon the estimation of the proportion of organ N being due to soil uptake (Table 4). The bloom sampling represents the only significant seasonal change in total N concentration and so it is also possible that this sampling was anomalous for some unknown reason.

%TotalN	Winter1	Bloom	Drop	ValHarvest	Break	Maturity	Winter2
immature fruit	*	*	2.05	*	*	*	*
fruit	*	*	*	*	*	*	*
young leaves	*	1.76 c	2.87 bc	*	2.50 bc	*	3.98 a
mature leaves	2.22 b	1.03 c	2.62 a	*	2.36 b	2.18 b	2.15 b
small green branches	1.03 ms	1.52 ns	1.24 ns	*	1.08 ns	1.11 ns	1.06 ns
small brown branches	0.70 ns	0.90 ns	0.74 ns	*	0.78 ns	0.82 ns	0.78 ns
intermediate branches	0.52 b	1.80 a	0.59 b	*	0.66 b	0.70 b	0.58 b
large branches	0.48 b	0.88 a	0.59 b	*	0.54 b	0.58 b	0.49 b
trunk	0.47 b	0.99 a	0.62 b	*	0.59 b	0.59 b	0.52 b
large roots	0.56 b	1.60 a	0.69 b	*	0.69 b	0.62 b	0.59 b
medium & small roots	1.05 b	1.72 a	1.44 ab	*	1.37 ab	1.27 ab	1.13 ab

Table 2. Change in percent of total N in organs of mature ‘Valencia’ trees over the course of a year. Statistical separations are within organ using Duncan’s multiple range test (alpha = 0.05).

Total N mass in the various organs was estimated using the total N concentration and organ masses (Table 3). It is interesting that total N in the trees was only 3 – 5 pounds. The largest single contribution to total tree N were the leaves. Most of the leaf contribution was from mature leaves. This is due to the much smaller mass of the flush leaves. The N associated with the fruit was not very high, and at harvest only about 0.5 lb of N were removed from the tree. Most of the N in the fruit is actually in the rind (data not shown). Table 1 and Table 3 show the alternate bearing that these trees exhibited. Most of the remainder of the N was found in the actively growing portions of the canopy. The woody portions of the permanent structure do not represent a large N sink. Table 4 shows the contribution of the soil N to the N content of the various organs, and Table 5 shows the actual mass of N contributed from the soil N.

Nmass	Winter1	Bloom	Drop	ValHarvest	Break	Maturity	Winter2
immature fruit	*	*	0.23	*	*	*	*
fruit	0.45 bc	0.70 a	0.58 ab	0.54 ab	0.28 cd	0.31 cd	0.22 d
young leaves	0.00 b	0.03 b	0.02 b	*	0.02 b	0.00 b	0.39 a
mature leaves	1.40 a	0.54 c	1.06 b	*	1.36 ab	1.13 ab	0.62 c
small green branches	0.33 c	0.81 a	0.63 ab	*	0.67 ab	0.56 bc	0.47 bc
small brown branches	0.02 ab	0.11 a	0.06 ab	*	0.11 a	0.00 ab	0.12 a
intermediate branches	0.15 c	0.55 a	0.32 abc	*	0.40 ab	0.44 ab	0.29 bc
large branches	0.23 b	0.52 a	0.37 ab	*	0.38ab	0.37 ab	0.26 b
trunk	0.08 a	0.27 a	0.09 a	*	0.08 a	0.11 a	0.09 a
large roots	0.41 b	0.97 a	0.34 b	*	0.39 b	0.34 b	0.32 b
medium & small roots	0.10 bcd	0.19 a	0.16 abc	*	0.18 ab	0.09 cd	0.08 d
total	3.17	4.69	3.86	0.54	3.87	3.35	2.86
total - fruit	2.72	3.99	3.05	0.00	3.59	3.04	2.64
total - (fruit + leaves)	1.32	3.42	2.42	0.00	2.21	1.91	1.63

Table 3. Change in mass of total N in organs of mature Valencia trees over the course of a year. Statistical separations are within organ using Duncan's multiple range test (alpha = 0.05).

Prop	Winter1	Bloom	Drop	ValHarvest	Break	Maturity	Winter2
Immature Fruit	*	*	6.86	*	*	*	*
Fruit	0.00 c	0.12 c	2.91 b	2.04 bc	4.28 b	7.10 a	8.56 a
Young leaves	*	0.13 b	8.98 a	*	5.05 ab	*	6.84 a
Mature leaves	0.00 c	0.00 c	4.85 ab	*	3.04 bc	4.39 ab	7.63 a
Small Green branches	0.00 c	0.03 c	2.58 b	*	2.61 b	3.15 b	6.06 a
Small Brown Branches	0.00 c	0.01 c	1.49 bc	*	1.69 bc	8.10 a	4.31 b
Intermediate branches	0.00 c	0.00 c	1.70 b	*	1.57 b	2.38 b	4.11 a
Large branches	0.00 b	0.00 b	0.014 a	*	1.52 a	1.44 a	1.58 a
Trunk	0.00 c	0.00 c	1.82 a	*	0.77 b	1.54 a	1.64 a
Large Roots	0.00 b	0.00 b	1.36 a	*	0.55 b	1.53 a	1.52 a
Medium & Small roots	0.00 b	0.00 b	3.54a	*	1.78 ab	3.57 a	3.48 a

Table 4. Change in proportion of total N derived from soil N in organs of mature Valencia trees over the course of a year. Statistical separations are within organ using Duncan's multiple range test (alpha = 0.05).

NmassFert	Winter1	Bloom	Drop	ValHarvest	Break	Maturity	Winter2
immature fruit	*	*	0.016	*	*	*	*
fruit	0.000 c	0.009 c	0.016 ab	0.010 b	0.012 b	0.021 a	0.017 ab
young leaves	0.000 b	0.000 b	0.003 a	*	0.001 b	0.000 b	0.026 a
mature leaves	0.000 b	0.000 b	0.050 a	*	0.038 a	0.044 a	0.037 a
small green branches	0.000 b	0.000 b	0.016 a	*	0.016 a	0.018 a	0.029 a
small brown branches	0.000 b	0.000 b	0.001 ab	*	0.003 a	0.000 b	0.005 a
intermediate branches	0.000 d	0.000 d	0.005 c	*	0.006 bc	0.011 ab	0.001 a
large branches	0.000 b	0.000 b	0.005 a	*	0.005 a	0.005 a	0.004 a
trunk	0.000 c	0.000 c	0.002 a	*	0.001 a	0.002 a	0.001 a
large roots	0.000 c	0.000 c	0.004 a	*	0.002 b	0.005 a	0.004 a
medium & small roots	0.000 b	0.000 b	0.005 a	*	0.003 a	0.003 a	0.003 a
total	0.000	0.009	0.121	0.010	0.085	0.109	0.127
total - fruit	0.000	0.000	0.089	0.000	0.073	0.088	0.110

Table 5. Change in mass of total N derived from soil N in organs of mature Valencia trees over the course of a year. Statistical separations are within organ using Duncan's multiple range test (alpha = 0.05).

As stated above, these proportions may underestimate the contribution of soil N to the tree N. However, the seasonal changes and relationships between the organs would have the same general patterns. As demonstrated in Table 4, little fertilizer N was evident in the trees in winter1 and bloom. This is consistent with the concept that there is little uptake of soil nutrients during the cold winter months and that active uptake does not start until spring, when soil temperatures are higher and roots more active. Soil N was preferentially transported in the actively growing portions of the canopy, with lesser proportions going into the permanent structure. Soil not being transported into the trees from the soil would be supplied by the permanent structure via remobilization. The fact that relatively small amounts of N are supplied by the soil N and that total N mass of the tree does not vary much during the season are consistent.

Most of the macro- and micro-elements were assessed at each harvest. Both concentration and mass were significantly influenced by both sampling date and organ sampled, and in all except two cases, by the interaction. However, even statistically significant differences were not very large and probably do not have a lot of practical implications. Because of the large mass of data acquired, it is difficult to assess completely. Because of this and space considerations, not all of it is shown in this report. It will be made available upon request and presented in appropriate forums.

As an example of the type of data collected, Table 6 shows the concentrations and masses of the elements at break. This particular sampling date was selected because it is the closest to the accepted tissue sampling date for nutritional analysis of citrus. The results are simplified by being rounded to the nearest hundredth of a pound. Thus, a value shown of 0.00 indicates that there isles than 0.005 lb of the element in the tree, not that this element is absent from the tree. As can be seen, masses of all elements are quite low in an entire tree. Only Ca and K are present in masses of more than one pound. So, the actual mineral needs of the tree are quite low.

Break	immature fruit	fruit	young leaves	mature leaves	small green branches	small brown branches
K_%	*	*	0.96	0.50	0.26	0.17
K_lb	*	0.22	0.01	0.29	0.16	0.02
P_%	*	*	0.16	0.09	0.05	0.04
P_lb	*	0.03	0.00	0.05	0.03	0.00
S_ppm	*	*	1970	2010	1055	636
S_lb	*	0.02	0.00	0.11	0.07	0.01
B_ppm	*	*	39	44	18	13
B_lb	*	0.00	0.00	0.00	0.00	0.00
Ca_%	*	*	2.67	5.17	2.98	1.81
Ca_lb	*	0.21	0.02	2.99	1.90	0.24
Mg_%	*	*	0.29	0.35	0.25	0.13
Mg_lb	*	0.03	0.00	0.20	0.15	0.02
Na_ppm	*	*	71	272	61	77
Na_lb	*	0.00	0.00	0.02	0.00	0.00
Cl_%	*	*	0.01	0.03	0.02	0.02
Vl_lb	*	0.01	0.00	0.01	0.01	0.00
Zn_ppm	*	*	15	54	109	77
Zn_lb	*	0.00	0.00	0.00	0.01	0.00
Mn_ppm	*	*	12	20	11	7
Mn_lb	*	0.00	0.00	0.00	0.00	0.00
Fe_ppm	*	*	66	119	105	94
Fe_lb	*	0.00	0.00	0.01	0.01	0.00
Cu_ppm	*	*	24	37	86	71
Cu_lb	*	0.00	0.00	0.00	0.01	0.00
Mo_ppm	*	*	0.23	0.10	0.10	0.10
Mo_lb	*	*	0.00	0.00	0.00	0.00

Table 6 (Part one). Concentrations and masses of macro- and micro-elements in organs of mature Valencia orange trees at color break in 2003.

Table 6 (Part two), continued.

	intermediate branches	large branches	trunk	large roots	medium & small roots	total
K_%	0.15	0.14	0.18	0.13	0.53	
K_lb	0.10	0.10	0.03	0.09	0.07	1.06
P_%	0.03	0.02	0.02	0.02	0.05	
P_lb	0.02	0.02	0.00	0.01	0.01	0.17
S_ppm	481	384	366	435	1263	
S_lb	0.03	0.03	0.01	0.02	0.02	0.32
B_ppm	10	7	8	10	17	
B_lb	0.00	0.00	0.00	0.00	0.00	0.00
Ca_%	1.49	0.72	0.98	0.43	1.49	
Ca_lb	0.73	0.51	0.14	0.30	0.19	7.23
Mg_%	0.08	0.05	0.05	0.03	0.13	
Mg_lb	0.05	0.03	0.01	0.02	0.02	0.53
Na_ppm	139	174	200	118	309	
Na_lb	0.01	0.01	0.00	0.01	0.00	0.05
Cl_%	0.01	0.02	0.01	0.01	0.05	
Cl_lb	0.01	0.01	0.00	0.01	0.01	0.07
Zn_ppm	41	25	40	15	102	
Zn_lb	0.00	0.00	0.00	0.00	0.00	0.01
Mn_ppm	5.00	3.00	4.00	10.00	93.00	
Mn_lb	0.00	0.00	0.00	0.00	0.00	0.00
Fe_ppm	98	101	159	257	1366	
Fe_lb	0.01	0.01	0.00	0.01	0.02	0.07
Cu_ppm	43	32	51	26	58	
Cu_lb	0.00	0.00	0.00	0.00	0.00	0.01
Mo_ppm	0.10	0.10	0.10	0.23	0.63	
Mo_lb	0.00	0.00	0.00	0.00	0.00	0.00

Tables 7 – 10 show an example of the seasonal changes of a macro-element, K, and a micro-element, Zn. There is some variation throughout the season, but even when statistically significant it is not very large in an absolute sense. As noted above, the bloom harvest has the greatest number of puzzling data points. Total masses of even the macro-elements are not very large and in the case of the micro-elements they are almost vanishingly small. However, it should be remembered that this does not mean that these elements are not vitally important in the physiological functioning of the tree. Quite the contrary. Note that the concentration of Zn diminishes during the winter, producing the common winter transient deficiency commonly seen in California. In most cases, the leaves were the dominant sink for the elements.

K_pct	Winter1	Bloom	Drop	ValHarvest	Break	Maturity	Winter2
immature fruit	*	*	0.20	*	*	*	*
fruit	*	*	*	*	*	*	*
young leaves	*	0.72 b	0.14 c	*	0.96 b	*	1.69 a
mature leaves	0.39 a	0.39 a	0.10 c	*	0.50 a	0.34 b	0.28 b
small green branches	0.32 ab	0.57 a	0.05 b	*	0.26 b	0.22 b	0.28 b
small brown branches	0.17 b	0.32 a	0.03 c	*	0.17 b	0.14 bc	0.10 bc
intermediate branches	0.12 b	0.80 a	0.02 b	*	0.15 b	0.14 b	0.08 b
large branches	0.11 b	0.28 a	0.02 c	*	0.14 b	0.08 bc	0.07 bc
trunk	0.09 bc	0.33 a	0.02 c	*	0.18 b	0.11 bc	0.11 bc
large roots	0.15 b	0.68 a	0.02 b	*	0.13 b	0.11 b	0.11 b
medium & small roots	0.35 bc	0.83 a	0.05 c	*	0.53 ab	0.55 ab	0.39 bc

Table 7. Change in percentage of K in organs of mature Valencia trees over the course of a year. Statistical separations are within organ using Duncan's multiple range test (alpha = 0.05).

K_lb	Winter1	Bloom	Drop	ValHarvest	Break	Maturity	Winter2
immature fruit	*	*	*	0.02	*	*	*
fruit	0.42 a	0.42 a	0.23 b	*	0.22 b	0.22 b	0.17 b
young leaves	0.00 b	0.01 b	0.00 b	*	0.01 b	0.00 b	0.16 a
mature leaves	0.24 ab	0.21 b	0.04 c	*	0.29 a	0.17 b	0.08 c
small green branches	0.10 bc	0.29 a	0.02 c	*	0.16 b	0.11 bc	0.12 bc
small brown branches	0.00 b	0.04 a	0.00 b	*	0.02 a	0.00 b	0.02 b
intermediate branches	0.03 b	0.26 a	0.01 b	*	0.10 b	0.09 b	0.04 b
large branches	0.05 bc	0.16 a	0.01 c	*	0.10 b	0.05 bc	0.04 c
trunk	0.02 b	0.09 a	0.00 b	*	0.03 b	0.02 b	0.02 b
large roots	0.11 b	0.41 a	0.01 b	*	0.07 b	0.06 b	0.06 b
medium & small roots	0.03 bc	0.09 a	0.01 c	*	0.07 ab	0.04 bc	0.03 bc
total	1.00	1.98	0.33	0.02	1.07	0.76	0.88

Table 8. Change in mass of K in organs of mature Valencia trees over the course of a year. Statistical separations are within organ using Duncan's multiple range test (alpha = 0.05).

Zn_ppm	Winter1	Bloom	Drop	ValHarvest	Break	Maturity	Winter2
immature fruit	*	*	*	19	*	*	*
fruit	*	*	*	*	*	*	*
young leaves	*	75 a	29 b	*	15 b	*	35 b
mature leaves	110 ab	119 a	92 abc	*	54 bc	61 abc	37 c
small green branches	83 bc	108 b	192 a	*	109 b	124 b	58 b
small brown branches	60 ns	172 ns	121 ns	*	77ns	77 ns	83 ns
intermediate branches	29 cd	74 a	49 bc	*	41 bcd	57 bc	22 d
large branches	14 b	32 a	34 a	*	25 ab	16 b	16 b
trunk	21 c	57 a	66 a	*	40 b	39 b	30 bc
large roots	10 b	91 a	36 ab	*	15 b	9 b	10 b
medium & small roots	85 ns	91 ns	100 ns	*	102 ns	111 ns	68 ns

Table 9. Change in concentration of Zn in organs of mature Valencia trees over the course of a year. Statistical separations are within organ using Duncan's multiple range test (alpha = 0.05).

Zn_lb	Winter1	Bloom	Drop	ValHarvest	Break	Maturity	Winter2
immature fruit	*	*	0.0002	*	*	*	*
fruit	0.0008 b	0.0036 a	0.0009 b	0.0007 b	0.0007 b	0.0004 b	0.0003 b
young leaves	0.0000 c	0.0001 b	0.0000c	*	0.0000 c	0.0000 c	0.0003 a
mature leaves	0.0069 a	0.0056 ab	0.0037 bc	*	0.0032 c	0.0032 c	0.0010 c
small green branches	0.0026 c	0.0064 b	0.0099 a	*	0.0070 ab	0.0063 b	0.0024 c
small brown branches	0.0001 ns	0.0023 a	0.0010 a	*	0.0015 ns	0.0001 ns	0.0013 ns
intermediate branches	0.0009 c	0.0044 a	0.0027 abc	*	0.0023 abc	0.0035 ab	0.0010 c
large branches	0.0007 d	0.0018 ab	0.0022 a	*	0.0017 abc	0.0010 bcd	0.0009 cd
trunk	0.0004 b	0.0014 a	0.0010 ab	*	0.0006 b	0.0007 ab	0.0005 b
large roots	0.0007 b	0.0052 a	0.0015 b	*	0.0008 b	0.0005 b	0.0005 b
medium & small roots	0.0009 ab	0.0011 ab	0.0011 a	*	0.0012 a	0.0008 ab	0.0005 b
total	0.0140	0.0309	0.0242	0.0007	0.0202	0.0153	0.0087

Table 10. Change in mass of Zn in organs of mature Valencia trees over the course of a year. Statistical separations are within organ using Duncan's multiple range test (alpha = 0.05).

SUMMARY

Overall, this project has provided data and background for assessing seasonal trends in nutrient dynamics in citrus. Although some seasonal trends are evident in all elements, the actual changes in both concentration and particularly mass of the elements are relatively small. In the case of N, removal of the fruit will remove only about 0.5 lb of N from the tree (about 50 lb per acre at common commercial spacing), and of this only a few percent appears to be derived from soil N. As stated above, these estimates might be somewhat low but will be corrected in subsequent presentations of the data.

Fertilization needs are probably somewhat greater than the raw numbers suggest. This is due to the effect of concentration on uptake from the soil and the effects of various soil factors on uptake. This study does not provide a framework for a long-term evaluation of nutritional dynamics of citrus. It would be expected that early in the life of the tree, the soil contribution would have to be relatively higher than in these mature trees, simply because there would be less tree N to be remobilized. Furthermore, although there is only a small increase in tree dry mass over the course of the year, over a 20-year production life the increase in mass and hence the need for nutrients would be quite significant. This data should be considered in light of these kinds of factors.