AN EVALUATION OF NUTRIENT REMOVAL BY CITRUS FRUITS

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Abstract. In this experiment, Valencia, Parson Brown, Hamlin, and Sunburst cultivars were used which received either 150, 200, or 250 lb N ac⁻¹ yr⁻¹ as broadcast application of dry soluble granular fertilizer. Over three year period the effect of N rate was non-significant on either fruit diameter, dry weight, or fruit N content. The mean fruit diameter and the fruit weight varied from 2.7 to 3.3 inch and 141 to 262 g per fruit, respectively. The Valencia fruits were the largest, while the Sunburst were the smallest among the four varieties. The concentrations of most macronutrients (on dry weight basis) varied marginally among the four varieties. The quantities of nutrients in harvested fruits are those removed from the tree-soil system on an annual basis. The quantity of N in 500 boxes of fruits accounted 67 lb for the Valencia and Sunburst, and were 56 and 53 lb for the Parson Brown and Hamlin varieties, respectively. Most of the micro-nutrients in 500 boxes of fruits were <0.01 lb across all varieties. The interpretations of the nutrients removal in harvested fruits in relation to nutrient budget were discussed.

Review of long-term citrus fertilization experiments from various parts of the world indicated that application of 180 lb N ac⁻¹ yr⁻¹ is sufficient to sustain optimal tree growth, and maintain high fruit quality and production (Dasberg, 1987). The rate, placement, and timing of nutrient application are important to maximize the nutrient uptake efficiency and to minimize nutrient losses. Analyses of leaves and soil can be used to evaluate the nutritional status of the trees and nutrient availability in the soil to supply the trees nutrient requirement (Embleton et al., 1996).

For a perennial tree crop such as citrus, the annual fertilization program should aim to replenish the nutrient removed by the harvested fruits along with adequate consideration to the nutrient requirement for new annual growth and storage, application efficiency, and the concentration of nutrients from recycling of organic residues in the soil. The contribution of nutrients from the organic residue is quite appreciable (Dou et al., 1995) due to the recycling of the dried leaves and turnover of fibrous roots.

In a grafted tree, rootstock can influence tree yield, bearing habit, fruit quality, and leaf mineral nutrient concentrations (Castle, 1980, 1987; Fallahi et al., 1989; Fallahi and Rodney, 1992). Although leaf analysis is an important tool for evaluation of the nutritional status of the trees, an understanding of the major components of the nutrient budget is important for improving the fertilizer recommendations to improve the nutrient uptake efficiency.

The objectives of this study were to evaluate: i) the fruit size and concentrations of various mineral elements in mature fruits, and ii) total mineral element removal in fruits for a given production level per acre of four citrus varieties. The varieties used in this study represent an early, mid-season, and late-season oranges; and a specialty fresh fruit variety.

Materials and Methods

This study was conducted in a commercial citrus grove in Hardee County, Florida, using four citrus varieties, i.e., i) Parson Brown on Bittersweet rootstock (142 trees/acre; planted 1990), ii) Hamlin on Rough lemon (125 trees/acre; planted 1962), iii) Valencia on Swingle citrumelo (142 trees/acre; planted 1989), and iv) Sunburst on Swingle citrumelo (142 trees/acre; planted 1988). The fertilizer treatments included three N rates at 150, 200, and 250 lb N ac⁻¹ yr⁻¹ in four applications, i.e., Jan., Feb./Mar., May, and Sept./Oct. which accounted for 18%, 26%, 28%, and 28% of the annual N rate, respectively. All applications were made in dry granular form broadcasted using a commercial fertilizer spreader. The application of other macro- and micronutrients, and standard production practices as recommended by Tucker et al. (1995) were followed. The experiment was conducted using a randomized block design with three replications.

Fruit sampling and analysis. Each of the 3 yr, 10 fruits were sampled per plot about 2 weeks prior to harvest. The fresh weight of the fruits was measured immediately after sampling. The diameter of the individual fruit was measured using a caliper. Fruits were washed in detergent solution, rinsed in distilled water, sliced, dried at 90°C for 72 hr, and the dry weight was recorded. The dried fruits were ground using a Wilely Mill, and screened through a 40 mesh screen. The concentrations of C and N were determined by using an Elemental An-
alyzer (NA 1500, Fisons Instruments). About 0.5 g sample was ashed in a muffle furnace 550°C for 5 hr. The ash was dissolved in 10 mL 1 M HCl. The concentration of P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu, and Al were analyzed using Inductively Coupled Plasma Argon Emission Spectroscope (ICPAES, Plasma 40, Perkin Elmer).

**Results and Discussion**

The fruit diameter varied from 2.7 (Sunburst) to 3.3 (Valencia) inch (Table 1). Although the fruit diameter was largely similar for the Hamlin, Parson Brown, and Valencia varieties, the fruit weight was greater for the Valencia compared to the other two varieties. The mineral analysis was done in the total fruit including the peel, pulp, and the juice, to estimate the total mineral contents in the harvested fruits. On dry weight basis, the concentrations of most macronutrient elements were largely similar between the different varieties (Table 1). With respect to the micronutrients, the concentration of Fe and Zn varied from 19 to 40, and 11 to 18 mg/kg, respectively. The reason for high variability in Fe and Zn concentrations between the varieties is not clear. Although the fruits were thoroughly washed before slicing and oven drying, there could be a possibility of some micronutrients residue on the fruit surface, if micronutrient spray was made late in the season for some variety.

These mineral nutrients concentrations and percent dry matter in the fruits were used to calculate the total nutrient contents for an estimated fruit production of 500 boxes per acre (Table 2). It is important to emphasize that the quantities of nutrients shown in Table 2 are simply the total amount of nutrients in 500 boxes of fruits. In other words, a grove which picked 500 boxes of Hamlins in a year removed 52.8, 7.3, and 67.2 lb of N, P, and K, respectively, from an acre during that year. These are generally referred to as the nutrient removal per year and are dependent on the fruit production levels. The removal of P and K are largely similar across all varieties. However, that of N for a given target fruit yield was much greater for the Sunburst, and Valencia compared to that for the other two varieties.

The nutrient removal in fruits is an important data for developing crop nutrient budget, particularly for a perennial crop since there is a large carry over of nutrients from year to year from that stored in the tree. The components of a nutrient budget, is discussed below using an example of N budget:

**Nitrogen Inputs:**

(i) Fertilizer N as either inorganic or organic source is a major input under most conditions. If organic source is used, we need to know the fraction of total

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Fruit wt (g)</th>
<th>Fruit diameter (inch)</th>
<th>Concentration of various mineral elements (% on dry wt basis)</th>
<th>Concentration of various mineral elements (mg/kg on dry wt basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamlin</td>
<td>249 ± 8</td>
<td>3.2 ± 0.0</td>
<td>1.00 ± 0.02, 0.14 ± 0.00, 1.26 ± 0.03, 0.36 ± 0.01, 0.10 ± 0.01, 0.03 ± 0.01</td>
<td>19 ± 1, 3 ± 0, 12 ± 2, 5 ± 0, 19 ± 1</td>
</tr>
<tr>
<td>Parson Brown</td>
<td>221 ± 6</td>
<td>3.0 ± 0.1</td>
<td>1.02 ± 0.02, 0.14 ± 0.00, 1.19 ± 0.02, 0.44 ± 0.02, 0.11 ± 0.02, 0.03 ± 0.02</td>
<td>26 ± 2, 5 ± 0, 13 ± 2, 5 ± 0, 21 ± 1</td>
</tr>
<tr>
<td>Valencia</td>
<td>262 ± 5</td>
<td>3.3 ± 0.0</td>
<td>1.10 ± 0.02, 0.16 ± 0.00, 1.19 ± 0.05, 0.35 ± 0.02, 0.10 ± 0.01, 0.04 ± 0.01</td>
<td>40 ± 5, 4 ± 0, 11 ± 1, 5 ± 0, 16 ± 1</td>
</tr>
<tr>
<td>Sunburst</td>
<td>141 ± 4</td>
<td>2.7 ± 0.0</td>
<td>1.19 ± 0.03, 0.15 ± 0.00, 1.20 ± 0.03, 0.29 ± 0.01, 0.09 ± 0.02, 0.05 ± 0.01</td>
<td>33 ± 4, 4 ± 0, 18 ± 3, 6 ± 1, 15 ± 1</td>
</tr>
</tbody>
</table>

Table 1. Mature fruit weight, diameter, and concentrations of various mineral elements for four citrus varieties. Mean across three years (1994-96).

<table>
<thead>
<tr>
<th>Mineral elements</th>
<th>Pounds in 500 boxes of fruits (fresh wt basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hamlin</td>
</tr>
<tr>
<td>N</td>
<td>52.8</td>
</tr>
<tr>
<td>P</td>
<td>7.3</td>
</tr>
<tr>
<td>P × 2.29 = P₂O₅</td>
<td></td>
</tr>
<tr>
<td>K × 1.20 = K₂O</td>
<td></td>
</tr>
</tbody>
</table>

*These quantities simply refer to the nutrients in 500 boxes of fruits, and NOT the amount of nutrients required per acre to produce 500 boxes of fruits. Please refer to the text for detailed discussion on how to interpret these results.
N available during the first year, and the subsequent years. During multiple application of organic N source, we have to account for the N being made available from that year’s application of organic source and the residue carryover from the past year’s application.

(ii) N is also contributed from the decomposition of leaf litter and turn over of fibrous roots. This includes all of the tree vegetation parts returned to the soil. This contribution increases with age of the trees. In a hedging and topping program, if the small branches and foliage cut from the tree is chopped into small pieces and spread under the canopy, this could contribute substantial amount of nutrients after decomposition.

(iii) Atmospheric deposition. This is basically any gaseous forms of N contained in the atmosphere which is dissolved in the rain water and is returned to the soil. This contribution in a non-industrial area is rather negligible, often <5 lbs/acre/year.

(iv) N-fixation. This refers to mostly non-symbiotic fixation of N. This contribution is also quite small, often <5 lb/acre/year.

_Nitrogen Removal:_

(i) N in the fruits. For a perennial tree this is a major component of removal, since this is the only portion which is removed from the tree-soil system on an annual basis. The current study provides the data for this component for various nutrients on the basis of fruit analysis over three years.

(ii) N required for annual regrowth of leaf and root flush. The annual regrowth occurs in two distinct flushes, i.e., spring and summer flush. A portion of the annual nutrients applied will be utilized by the annual regrowth.

(iii) Towards stored N. During flowering and fruit setting, a portion of N is derived from tree storage which has to be replenished by the annual application.

(iv) Gaseous loss. In a well-drained soil generally no anaerobic condition is created, although there are possibilities of some localized anaerobic microsites. Therefore, the gaseous loss of N by denitrification is often negligible in well drained Ridge soils. This could occur in the Flatwoods soils, since these are poorly drained soils with fluctuating water table which can rise within 6 to 12 inch seasonally. However, in the well-drained Ridge soils with high pH, volatilization loss can account for 10 to 15% of NH₄⁻ nitrogen applied on the soil surface on an annual basis. High temperature and surface application of ammonium form of N, with no incorporation, provide ideal conditions for volatilization loss of N. When using dry granular form of N, it is beneficial to run a light irrigation soon after broadcasting the fertilizer. This helps to solubilize the N and place it slightly below the soil surface, which can minimize the volatilization loss.

(v) N leached below the rootzone. Sandy soils and poorly distributed rainfall provide ideal conditions for leaching of N below the rootzone, which decreases the N uptake efficiency substantially. One of the aims of best management practice is to minimize this loss.

In addition to the above components, we should also consider the application efficiency in determining the actual amount of N that is necessary to be applied for any given application method.

Using the above information, we can calculate the percent efficiency of N for a given situation. This is an important guideline for adjusting the fertilizer program for the subsequent years.

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Table 2. Total contents of mineral elements in 500 boxes of fruits of four citrus varieties. Mean across three years (1994-96). *a*

<table>
<thead>
<tr>
<th>Mineral elements</th>
<th>Pounds in 500 boxes of fruits (fresh wt basis)</th>
<th>Hamlin</th>
<th>Parson Brown</th>
<th>Valencia</th>
<th>Sunburst</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td></td>
<td>67.2</td>
<td>65.9</td>
<td>71.7</td>
<td>69.5</td>
</tr>
<tr>
<td>Ca</td>
<td></td>
<td>19.9</td>
<td>24.5</td>
<td>21.4</td>
<td>16.7</td>
</tr>
<tr>
<td>Mg</td>
<td></td>
<td>5.2</td>
<td>5.9</td>
<td>5.9</td>
<td>5.0</td>
</tr>
<tr>
<td>Fe</td>
<td></td>
<td>0.10</td>
<td>0.15</td>
<td>0.19</td>
<td>0.17</td>
</tr>
<tr>
<td>Mn</td>
<td></td>
<td>0.017</td>
<td>0.028</td>
<td>0.023</td>
<td>0.022</td>
</tr>
<tr>
<td>Zn</td>
<td></td>
<td>0.158</td>
<td>0.187</td>
<td>0.158</td>
<td>0.197</td>
</tr>
<tr>
<td>Cu</td>
<td></td>
<td>0.025</td>
<td>0.029</td>
<td>0.034</td>
<td>0.034</td>
</tr>
<tr>
<td>Al</td>
<td></td>
<td>0.099</td>
<td>0.098</td>
<td>0.097</td>
<td>0.083</td>
</tr>
</tbody>
</table>

*P × 2.29 = P₂O₅
K × 1.20 = K₂O*

*These quantities simply refer to the nutrients in 500 boxes of fruits, and NOT the amount of nutrients required per acre to produce 500 boxes of fruits. Please refer to the text for detailed discussion on how to interpret these results.*
Literature Cited