HS1138

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IFAS Extension

Citrus Tree Stresses: Effects on Growth and Yield [1]

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Introduction

Although Florida is known for its plentiful sunshine and rainfall, commercial citrus can experience stress at certain times of the year whenever growth conditions are not optimal. For example, drought stress can occur whenever soil water is not adequate or whenever the evaporative demand of the air is high. Drought is one of the most formidable stresses. It alters a tree's ability to take up nutrients from soil and changes the way the tree produces roots, shoots, leaves and fruit. To strive for consistently high commercial yields, grove managers must incorporate strategies to minimize the negative effects of drought.

The objectives of this document are to:

a)Explain how citrus trees respond to changes in availability of water and nutrients;

b)Discuss plant-stress situations and their effects on citrus growth and productivity; and

c)Discuss the balance between roots and shoots.

The target audience for this document dealing with citrus responses to drought conditions includes: Certified Crop Advisers, citrus producers, agrochemical and equipment industry representatives, and other parties interested in citrus management practices.

Understanding Citrus Root-to-Shoot Ratios

In any particular environment, the size or volume of a citrus tree's canopy and root system are linked. If there is some root damage or root loss, the root system will be unable to sustain the aerial portion of the tree. In severe situations the tree can be lost; however, citrus trees will often compensate by dropping leaves and reducing the number of shoots. Simply put, there will be too few roots to transport sufficient water and nutrients into the above-ground portion of the tree, the shoots. These adjustments are often described by the use of the root-to-shoot ratio, which is defined as the ratio of below-ground tree parts to above-ground tree parts. Root-to-shoot adjustments also occur when trees are hedged and topped. Removal of a portion of the shoots affects the number of roots and in turn can be reflected in reduced fruit yield.

In citrus trees, there is usually less root dry weight than shoot dry weight. Typically, the root-to-shoot ratio varies from 1:4 to 1:2. Growers seeking higher fruit yields should **minimize changes**

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in the root-to-shoot ratio and **maintain that ratio as low as possible** (e.g., 1:4), favoring the above-ground portion of the plant. Increase above-ground growth by maximizing root health with good water and nutrient management. Leaves produce the photosynthetic sugars that, in turn, can be allocated to additional fruit production. However, maintaining a low root-to-shoot ratio means that the trees must be managed with care to reduce potential root stress that can change the root-to-shoot ratio.

Water and nutrient management effects on root-to-shoot ratio

A key to higher production is to avoid tree stress, which is directly reflected in changes in the root-to-shoot ratio. There can be a number of stresses within the grove that can occur at the same time; for example, drought, salinity, and nutrient deficiency stresses. These stresses can be minimized by good grove management. Moderate **drought** can increase root growth at the expense of top growth, adversely affecting fruit production. Elevated **salinity**, either from excess fertilizers or saline irrigation water, can adversely affect the root-to-shoot ratio, and decrease maximum fruit production. When total dissolved salts (TDS) in the irrigation water are between 1,000 and 2,000 ppm, salinity stress can be observed. Salinity greater than 2,000 ppm TDS is likely to cause reductions in tree growth and yield. The threshold TDS for both orange and grapefruit is similar, approximately 1,200 ppm TDS. When TDS values are above this threshold value, irrigation timing and duration, water blending, and other salt management efforts should be considered. The average yield loss with good management is about 18% every 700 ppm TDS increase. Salinity can be increased by high evapotranspiration during drought conditions because the salts remain in the soil when water is taken up.

In addition to affecting salinity, fertilization can directly affect root-to-shoot ratios. **Low nitrogen** availability tends to increase roots and decrease top growth, whereas **high nitrogen** decreases roots and increases top growth. This effect can be observed when plant nutrients are not sufficient to satisfy the crop nutrient requirements of citrus for that part of the season.

Understanding Citrus Tree Composition and Potential Water Requirements

A typical citrus tree is composed of approximately 60% water and 40% dry matter. The dry matter portion averages approximately 95% carbon-based compounds, 2% calcium, 1% nitrogen, and smaller amounts of many other nutrients. Specifically, leaves and roots contain approximately 70% water, while fruit contains about 85% water. The woody portions of the tree, including the trunk, limbs, and branches, contain about 50% water. In addition, all plants transpire far more water from leaves to the air than the water they contain. To ensure that this large water requirement to support transpiration is met, growers should consider both **rainfall and irrigation sources** as needed replacements for lost water.

The average annual rainfall received in the Florida peninsula is often sufficient so that if rain were distributed throughout the year to match the tree's requirements, water stress would be minimal with little irrigation. Comparing rainfall and evapotranspiration requirements (Figure 1), the months of April, May, October, and November have higher average evapotranspiration than rainfall, indicating that insufficient rainfall is available to replace water used by the trees, particularly during periods of high temperature. These months are prime candidates for supplemental use of irrigation in Florida citrus groves.

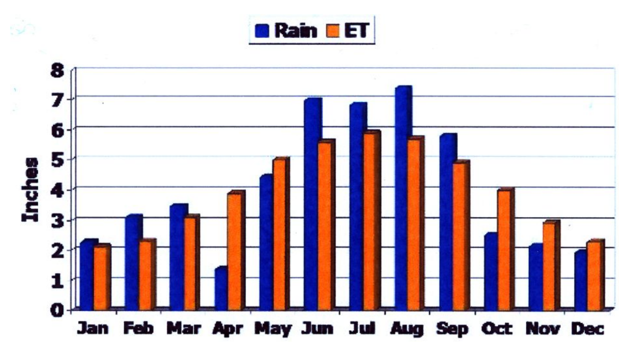

Figure 1. Average monthly rainfall and evapotranspiration (ET) at Lake Alfred, FL (Courtesy of T.A. Obreza from historical records from FAWN)

Root compensation

The development of new roots at the expense or delay of additional shoot or top growth is one way a tree can recover from stress. For example, when nutrients in the soil are insufficient, the tree may produce more root growth than shoot growth. In effect, the tree is “exploring” additional soil volume in an attempt to satisfy overall nutrient demand. A similar effect can occur during drought stress, when shoot and fruit growth are curtailed more than root growth so root growth appears to occur first followed by shoot growth. Thus, moderately drought-stressed roots tend to explore more soil volume than well watered roots. Once roots have re-established the root-to-shoot ratio for existing conditions, new shoots can produce additional photosynthates, and shoot and fruit growth will resume. Good water management, therefore, minimizes root growth so as to promote shoot growth and optimize yield.

Using Irrigation Effectively

Irrigation is important for proper growth and maintenance of roots. Healthy roots must be present to supply water and nutrients to the shoots. Since the root-to-shoot ratio must be within the proper range to produce high quality fruit, effective irrigation management is critical. The effects of proper irrigation on various yield and fruit quality parameters are shown in Table 1.

Root loss

The relationship between roots and shoots also can be affected by root loss from flooding, pests, disease or root pruning from tillage . When 50% of a citrus tree's roots were intentionally pruned, sugars were transported to the roots, rapidly stimulating new root growth. During the time when new roots were being produced, shoot growth stopped. This finding underscores the need for tillage practices that minimize root loss, providing a balanced proportion of functional roots to support shoot and fruit growth for commercial production.

Flooding

Flooding effects and drought stress can have similar responses in citrus. In a flooded soil (Figure 2), citrus roots will begin to die after 72 hours because they are unable to take up oxygen. The reduced root system can only take up a portion of the water and nutrients that was originally available to the entire healthy root system. This root loss first triggers leaves to close their stomata to reduce transpirational water loss. If the reduced flow of water and nutrients to the upper part of the tree persists, then leaves and shoots will begin to wilt and die. Once damaged by flooding, roots also may become more susceptible to feeding by root weevils and/or *Phytophthora* root rot infection, further impairing root function and reducing both shoots and fruit yield.

Figure 2. Citrus trees can withstand flooding for only short durations and can start to lose roots when exposed to flooding more than 72 hours. (Photo courtesy of Dr. R. E. Rouse, UF/IFAS – SWFREC)

Defoliation due to freezes

A healthy tree will survive and recover from a freeze better than a stressed tree. If the root-to-shoot ratio was appropriately balanced before the freeze-induced leaf loss, the relatively large post-freeze root system will make leaf regeneration much easier for the tree. During a freeze in the 1980s, an irrigated grove was observed to have sustained only 20% defoliation, while an adjacent non-irrigated grove suffered 90% leaf losses (Figure 3). The non-irrigated trees had been in drought stress before the freeze, and suffered more freeze damage than the non-stressed trees. Nonetheless, the previously drought stressed trees suffered less drought stress during recovery because of the larger root-to-shoot ratio than the well watered trees.

Figure 3. A freeze caused 90% defoliation in this non-irrigated grove.

Established canopy pruning (hedging and toping)

Trees that are pruned have increased root-to-shoot ratios. If pruning is particularly severe, it can result in some root loss as the tree adjusts. For example, pruning one third of the canopy in August stopped root growth and some roots died, but root growth started again within 60 days. New roots often have higher conductivity than older roots. Thus, additional water and nutrients can be made available to quickly regrow shoots and reestablish the balance between roots and shoots.

Water, carbon, and nutrient budgets

From the trees' perspective, shoot development is the first priority, followed by the root growth to support shoot growth. Only after these two priorities are balanced, will the third most important priority, fruit yield and quality, be met. The balance among roots, shoots, and fruit with respect to water, carbon, and nutrient resources can be thought of as a budget (Figure 4). These three resources are taken up, allocated, and lost by the tree. Any changes in either the roots or the shoots will affect the availability of water, carbon, and nutrients to the tree. If there is a budget deficit, the tree responds by ensuring that leaves and shoots are available (first priority) to produce photosynthate, then roots are available to transfer water and nutrients to the shoots. Only after both roots and shoots are balanced does the carbon energy of the tree end up in the fruit. Since fruit production with high quality is the goal of growers, keeping the root-to-shoot ratio within normal limits by reducing water and nutrient stresses should be a high priority when making management decisions.

Factors that directly affect crop load, such as fruit removal during harvesting, can also affect the root-to-shoot ratio. After harvest, roots, especially fine roots, can proliferate since carbon once allocated to fruit can be reallocated to roots. Monitoring root growth is impractical for grove management decisions, but knowing that the tree will respond to fruit loss with a root growth flush can be beneficial. For example, when trees are properly irrigated, root growth after harvest can precede a shoot flush.

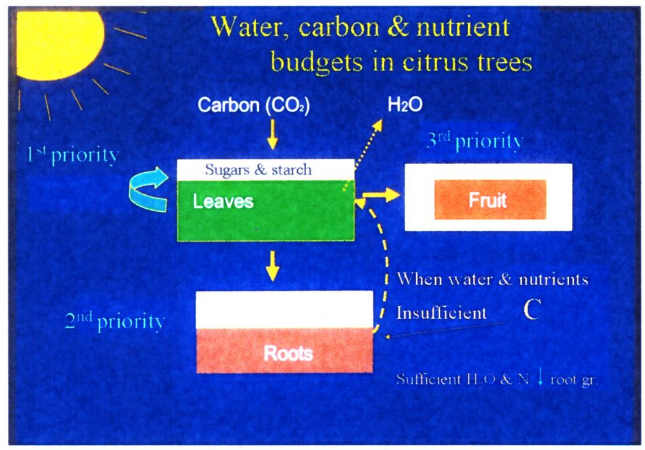

Figure 4. Schematic representation of citrus tree root-to-shoot adjustments based upon inputs of water and nutrients from soil and carbon (C) from CO_2 in the air.

Rootstock effects

Rootstocks have a major effect on the root-to-shoot ratio. Vigorous rootstocks (e.g., rough lemon) have greater root growth compared to intermediate (e.g. Carrizo citrange) or low-vigor rootstocks. Although selection of rootstocks is a decision made when establishing a grove or selecting resets, it's helpful to understand how the existing rootstocks will affect the root-to-shoot ratio and subsequently fruit production.

Sheepnosing

Sheepnosing is a fruit abnormality that commonly occurs in grapefruit due to accelerated growth at the stem-end of the fruit (Figure 3). Although predisposition to sheepnosing can be determined in the flower, it is worse if fruit set is low. In low fruit set situations, the prioritization of shoot, then root, then fruit growth predicts that conditions will be favorable for rapid fruit growth because of the greater availability of resources. By withholding irrigation, you can slow fruit growth and thus reduce sheepnosing. This example demonstrates that drought stress can have beneficial effects, so long as that stress is moderate and not persistent.

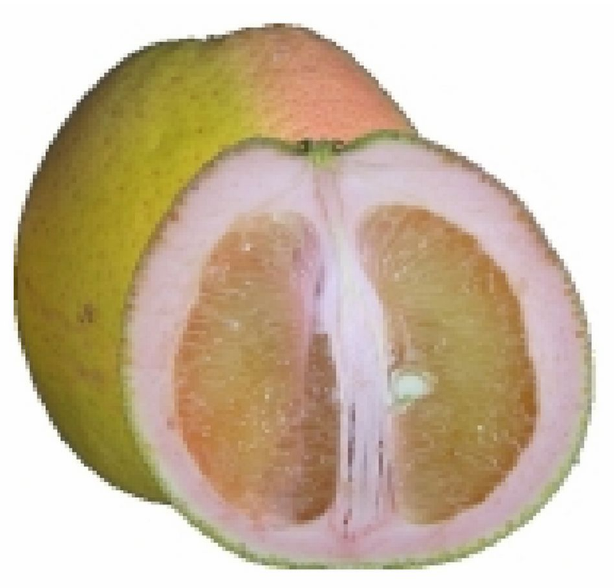

Figure 5. An example of sheepnosing in grapefruit.

During winter, drought can result in decreased vegetative growth, which enhances cold hardiness, another beneficial effect of moderate drought stress. In addition, drought stress can also substitute for cold temperatures to increase flower induction. Wetting of just a portion of the roots is being studied in Florida and in other citrus-growing areas with much drier climates than Florida, to determine if well-timed partial root zone drying can increase flowering and improve juice quality. There is also ongoing research using intensive management strategies to enhance root growth in irrigation-wetted areas while limiting root growth in non-irrigated areas. This research will determine if this strategy can lead to more rapid canopy development and earlier yields.

Conclusions

Keeping in mind that citrus trees give first priority to leaves and shoots, second priority to roots, and third priority to fruit, managers should carefully manage irrigation and fertilization practices as the best way to maintain a low root-to-shoot ratio (1:4). Drought and flood stresses reduce shoot growth and root growth, respectively, causing the tree to have to re-establish the balance between roots and shoots. Thus, fluctuations in root-to-shoot ratio can decrease yield and quality of citrus. Since rootstocks affect the water, carbon, and nutrient budget of the entire tree, proper rootstock selection is important for the conditions within the individual grove. During winter, moderate drought stress can be beneficial because drought can increase flower induction. In addition, appropriately controlled drought stress may be of use to manipulate root and shoot growth to favor fruit growth and yield.

Additional Information

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Table 1.

Measurement	Effect of proper irrigation
Juice content	**Increased**
Soluble solids	**Decreased**
Acid	**Decreased**
Soluble solids to acid ratio	**Increased**
Color	No Effect
Solids per box	**Decreased**
Solids per acre	**Increased**
Fruit size	**Increased**
Fruit weight	**Increased**
Green fruit	**Increased**
Peel thickness	**Decreased**