HS942

UNIVERSITY OF FLORIDA
IFAS EXTENSION

Effects of Water and Nutrients on the Postharvest Quality and Shelf Life of Citrus[1]

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Introduction

Irrigation and fertilization are important components of commercial citrus production. Irrigation is necessary to adequately replenish soil water lost through evaporation and transpiration. Fertilizers replace nutrients removed during harvest and through leaching. They also maintain tree growth and vigor. Optimum management of both is critical for obtaining maximum yield. Irrigation and fertilization practices can also have significant impacts on fruit quality and shelf life during harvest, packinghouse operations, storage, and distribution. These include effects on fruit color, texture, disease susceptibility, juice composition, and the development of physiological disorders (See Table 1 and Table 2).

Although fruit quality usually improves as soil moisture and nutrients increase from deficient to optimum, levels that produce maximum yield may not always correspond to those that result in the highest fruit quality and maximum quality retention. Further, although the addition of nutrients above optimum levels may not reduce yields, it can have either negative or positive effects on aspects of quality that are not readily apparent. Other critical factors such as rootstock and scion selection, pest management, and environmental conditions will not be discussed in this paper. Much of the information presented below was derived from research conducted more than 15 years ago. Thus, new research is needed to understand irrigation and nutrient effects on fruit quality using the new rootstocks, varieties, cultural practices, etc., that have been adopted since then.

Water

Adequate moisture levels are critical for proper fruit set and to support optimum fruit growth and development through harvest. Moderate water stress in the winter may increase flower bud induction and be a useful management tool, especially during warmer winters with inadequate cold induction. Adequate soil moisture is important early in the season to ensure good fruit set. Water stress during spring fruit set can lead to the setting of a higher percentage of late-bloom fruit of inferior quality. For example, unirrigated trees were reported to produce

1. This document is HS942, one of a series of the Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date: July 2002. Revised publication date: August 2003. This publication is included in SP-281, Water and Florida Citrus. Please visit the EDIS Web site at http:/edis.ifas.ufl.edu.
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up to 79% inferior, late-bloom fruit while irrigated trees had a maximum of only 9% of the late-bloom fruit.

Water stress anytime during the growth and development of citrus fruit can reduce yield and fruit quality compared to that of well-watered trees. Such losses cannot be completely recovered through proper irrigation during the rest of the season. Water stress may result in smaller, lighter fruit with thicker peel and reduced juice content. Excessive rainfall and/or irrigation immediately before harvest results in a dilution of soluble solids whereas drought conditions concentrate soluble solids. Even though fruit from water-stressed trees may have higher total soluble solids and acids per fruit, solids per acre may be reduced because of lower total yields per acre.

Water stress also affects the fruit at harvest, with soft or dehydrated fruit experiencing more plugging (tearing of the peel around the button during harvest). Conversely, irrigation or rainfall near harvest or harvesting with dew on the plant often results in fruit with very turgid rind, susceptible to oleocellosis (rupture of oil cells upon impact). Heavy rains especially after a drought can result in “zebra-skin” (areas of necrotic peel over the raised segments), which occurs mostly in early-season tangerines. Increased irrigation has also been reported to enhance the development of wind scar and scab.

Fruit harvested early in the morning, during rainy periods, or from trees with poor canopy ventilation have a higher risk of postharvest decay (i.e., sour rot, brown rot, and green mold) than fruit from trees on well-drained soils with good canopy ventilation. Conversely, fruit grown in climates that are more arid tend to develop less rot during postharvest handling, transportation, and marketing. If fruit must be harvested from trees during rainy periods, it may be best to avoid fruit from lower branches that may be exposed to more pathogens (i.e., brown rot). Increased irrigation has been reported to decrease postharvest incidence of stem-end rot but increase the incidence of green mold.

Nitrogen

Fruit quality responses to nitrogen (N), phosphorous (P), and potassium (K) appear to be similar for both orange and grapefruit. Among other things, N is an important constituent of proteins and plays a critical role in cells' biochemical machinery. Adequate N is essential for optimal plant growth and development and is the mineral element used most by plants. Citrus fruit quality has traditionally been evaluated at N concentrations between 2-3% of leaf dry weight. In Florida, 2.5-2.7% leaf N is recommended for optimum citrus production. Of all the nutrient elements, N has the largest impact on fruit quality.

Probably the most pronounced effect of higher N levels on orange and grapefruit quality is on delayed time to color-break, and reduced color development at harvest. Low N levels produce more orange colored fruit while high N levels tend to produce greener fruit. Lower levels of N that result in optimum color development may reduce yield. Thus, it is a balancing act to keep N levels high enough for maximum yield, but low enough to allow good color development. Excess N can promote regreening of fruit whereas using less N can reduce re-greening of citrus.

High N levels in young trees can promote coarser fruit with thicker peel, while high N in mature trees can result in more and smaller fruit with thinner peel. Although sometimes inconsistent, fruit grown under higher N levels tend to have lower solids to acid ratio, increased acids, and lower ascorbic acid (vitamin C) content. In oranges, high N has been reported to lower juice content and increase rind staining. Orange fruit quality appears to be best if high N levels are avoided during the summer and fall.

On the other hand, higher levels of N can result in increased total soluble solids, soluble solids per box and per acre, juice color, grapefruit juice content, and observed reductions in the development of peel blemishes such as wind scar and russetting. Rind plugging during harvest also appears to be reduced with higher rates of N. Effects of N on creasing (collapse of the peel forming irregular grooves) have been inconsistent.

Although high N has often been associated with increased postharvest decay in other commodities, very little is known about its effects on citrus quality retention during storage and marketing. The only reports thus far suggest that higher N may reduce the development of stem-end rot and green mold during storage.

Phosphorous

Phosphorous is an important component of many plant compounds, including DNA, cell membranes, and energy-yielding intermediates of photosynthesis and respiration. Rates of P studied for fruit quality range between 0.10 and 0.21% of leaf dry weight, with the optimum for Florida citrus being between 0.12 and 0.16%. While P deficiencies are rare, when deficiencies do occur, they often result in fruit with hollow cores, high acids in the juice, or good external color, but thick peels.

High P levels have been reported to result in less color development and more problems with re-greening. Such fruit often have lower acids and vitamin C content. Creasing can also become more of a problem as leaf levels rise between 0.10 and 0.14 percent. On the other hand, higher P can lead to fruit with thinner peels, better peel texture and higher sugar to acid ratio. There have been inconsistent reports that increased P sometimes decreases fruit size and total soluble solids but increases juice content. There have been no reports of different rates of P affecting postharvest diseases (e.g. stem-end rot, green mold, or sour rot) and quality retention during citrus storage and marketing.

Potassium

Potassium plays many important roles, including osmotic (water potential) regulation of cells and the activation of different enzymes in photosynthesis and respiration. In citrus, most research relating to K nutrition on fruit quality has been conducted within the range of 0.3 and 1.7% of leaf dry weight. Optimum K levels for Florida citrus are between 1.2 and 1.7%. For orange and grapefruit, one of the greatest negative effects of increasing K is a decrease in sugar to acid ratio. High levels of K can delay the time to legal maturity in grapefruit up to 83 days compared to fruit grown with low rates of K. Also associated with low K is delayed time to color-break and an increase in the number of green fruit at harvest. Re-greening of oranges may also be enhanced at higher K rates. Higher levels of K can reduce fruit total soluble solids, juice content, and juice color; increase acidity; and often, but not always, increase peel thickness and coarseness.

However, increasing K leads to increased fruit size, weight, and vitamin C content and reduces the incidence of creasing. At harvest, fruit from trees with higher K tend to experience less plugging. Foliar K applications have recently been reported to increase size by 0.1 to 0.2 inches without decreasing sugar to acid ratios, Brix, acid or juice contents, and with no increase in peel thickness. Other than one report suggesting that higher K may slightly decrease stem-end rot, there are no reports of it affecting other postharvest diseases (e.g., green mold, sour rot, etc.). Low levels of K have been associated with increased fruit splitting and fruit drop.

Calcium (Ca), Magnesium (Mg), and Micronutrients

Although Ca deficiency in other commodities commonly results in disorders (e.g., bitter pit of apple), Ca deficiency in citrus is very rare. Unlike many other commodities, there have been no reports of additional Ca enhancing fruit quality or quality retention during storage and marketing.

Magnesium usually has negative effects on fruit quality only if leaf tissue is deficient. In this case, increasing Mg can increase fruit size and weight, decrease peel thickness, and increase total soluble solids, sugar to acid ratio, solids per box, and solids per acre.

Micronutrient deficiencies usually do not impact fruit quality except for boron, which can result in brownish gum pockets in peel and pith areas.

Table 1. Effects of mineral nutrition on fruit quality ("+" = increase, "-" = decrease, "?" = unknown, and "O" = no change).

	Parameters	**N**	**P**	**K**
External quality	Fruit Size	-	0 or -	+
	Fruit Weight	-	0	+
	Green fruit	+	+	+
	Peel thickness	-[a]	-	+
	Plugging	-	?	-
Jucie quality	Juice content	+ or -	0 or +	-
	Soluble solids (SS)	+	0 or -	-
	Acid	+	-	+
	SS:acid ratio	-	+	-
	Color	+	0	-
	Solids/box	+	0	-
	Solids/acre	+	+	+

[a]Fruit from young trees may have a thicker peel

Source: Adapted from D. P. H. Tucker, A. K. Alva, L. K. Jackson, and T. A. Wheaton, 1995, Nutrition of Florida Citrus Trees, Univ. Fla. Coop. Ext. Serv. Publ. Sp 169.

Table 2. Effects of mineral nutrition and irrigation on postharvest diseases ("+" = increase, "-" = decrease, and "O" = no change).

Parameter		Stem-end rot	Green mold	Sour rot
Macro Nutrients	N	-	-	0
	P	0	0	0
	K	-	0	0
Irrigation		-	+	0

Source: Koo, R.C.J. 1988. Fertilization and Irrigation Effects on Fruit Quality. p. 35-41. In: J.J. Ferguson and W.F. Wardowski (eds.). Factors Affecting Fruit Quality, Citrus Short Course Proceedings.