Proc. Fla. State Hort. Soc. 102:57-60. 1989.

MICROSPRINKLER IRRIGATION SCHEDULING AND PATTERN EFFECTS ON GROWTH OF YOUNG 'HAMLIN' ORANGE TREES

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Additional index words. Citrus sinensis, C. aurantium, canopy, micro irrigation, roots.

Abstract. **Three field experiments were conducted to determine the effects of microsprinkler irrigation at 20 (high frequency), 45 (moderate frequency), and 65% (low frequency) available soil water depletion on one season's growth of 'Hamlin' orange trees [*Citrus sinensis* (L.) Osbeck] on sour orange (*C. aurantium* L.) rootstock. Trunk cross sectional area, and fresh and dry weights were similar for high and moderate frequencies in 2 of 3 years, but were reduced by the low frequency, even though the moderate received about 50% less water than the high frequency. Summer and fall growth flushes were delayed or did not occur at the moderate and low levels. The majority of root growth during the first season was in the top foot of soil and within about 30 inches of the trunk. In related studies, water was applied to 2-year-old trees using either 90 or 180° microsprinklers to test the effect of water distribution pattern on growth of 'Hamlin' orange trees. Tree growth was not affected by irrigation pattern, suggesting that 90° emitters cover enough of the root system to provide adequate tree growth through the second season after planting.**

Water availability has long been a problem in arid and semi-arid regions of the world, but has recently become a major concern in Florida. Seasonal water restrictions have been placed on growers by the water management districts in recent years and one district is considering year-round agricultural irrigation restrictions (1).

The majority of newly-planted citrus is receiving some sort of micro irrigation, and growers are faced with challenging times ahead with regard to water management decisions. Water management district regulations and the necessity of increased efficiency in a competitive industry will govern decisions as growers attempt to maximize tree growth while minimizing water use.

Irrigation requirements for mature citrus trees in Florida were determined by Koo (4) in the 1960s, but requirements for young citrus trees have only recently been studied. Smajstrla et al. (13) used sheltered lysimeters to determine that growth of newly-planted 'Valencia' orange trees was greatest when irrigations were scheduled at 20 cb soil matric potential compared with 40 cb and when the soil around the root zone was maintained weed-free.

Florida Agricultural Experiment Station Journal Series No. N-00050.

Several studies have related mature citrus tree yields to the under canopy surface area wetted by irrigation emitters, suggesting that ground area coverage is perhaps the most important aspect of irrigation management (5,6,12). Some growers believe that emitter coverage should be increased after one season for newly-planted citrus when 90° microsprinkler emitters are used, but no data are available concerning this subject.

The purpose of this study was to determine the level of soil water depletion at which microsprinkler irrigation should be scheduled to maximize growth of newly-planted citrus and to determine the effect of microsprinkler spray pattern on growth of second season trees.

Materials and Methods

Experimental site and plant material. Three experiments were conducted at the Horticultural Research Unit near Gainesville, Florida from 1985-1987. Beds 55 ft wide and 2-2.5 ft high were constructed in March 1985. The Kanapaha sand (loamy, siliceous, hyperthermic, Grossarenic Paleaquults) had 11.3% field capacity and 2.0% permanent wilting point. Two tree rows 25 ft apart were used on each bed with trees set 13 ft apart. Commercially-grown, bare-rooted 'Hamlin' orange/sour orange trees were planted in May 1985 and 1986, and April 1987. All trees were irrigated every two days during an establishment period of 10-14 days. The water table averaged 3.6 ft deep in the tree row during the rainy season (June through Sept.). Between-row bahiagrass ground cover was mowed as needed, and tree rows were maintained weed-free with herbicides. Trees received 4-5 lb. of granular fertilizer (8 N – 2.6 P – 6.6 K – 2 Mg – 0.2 Mn – 0.12 Cu – 0.2 Zn – 1.78 Fe) per season in four to five applications beginning 2 weeks after planting.

Irrigation treatments. The irrigation system was designed to be monitored by flow meters and pressure gauges and controlled by gate valves. Water was supplied to trees through three 0.75 inch black polyethylene tubes per row, one for each treatment. Water was applied by 90°, 10 gallon-per-hour Maxijet™ microsprinklers located ca. 3.25 ft NW of tree trunks.

Irrigation scheduling was based on soil water content as measured by a neutron scattering device (Troxler Model 1255) on four (1985, 1986) or three (1987) randomly chosen trees per treatment. Access tubes were positioned about 14 inches northeast of each tree and 3.25 ft from emitters, and measurements were made daily or as needed during the rainy season. The soil volume around each tree was irrigated to field capacity when a prespecified available soil water depletion (SWD) level was reached (1 ft depth) at any of the four sites in 1985 and 1986. In 1987, irrigations were scheduled when the average of the three neutron probe readings reached the prespecified level. Three irrigation frequencies were designated as high (20% SWD), moderate (45% SWD), and low (65% SWD).

A randomized complete block design with four blocks and six single tree replications per treatment per block was used in 1985 and 1986. The block effect was not significant in these 2 years, thus a completely randomized design with 13 single tree replicates was used in 1987.

The first few irrigations in 1985 were used to determine the irrigation duration needed to return soil to field capacity from each of the three levels of SWD. Soil water content was monitored with the neutron probe at 15 min intervals following an irrigation. By initially varying the length of irrigation time, the approximate irrigation duration needed for each treatment was determined.

Plant measurements. Total plant fresh weight was measured before planting. Trunk diameter was measured in two directions 2 inches above the bud union at planting and in Dec. of each year. Trunk cross sectional area was calculated from the average diameter. Twenty and 21 tree root systems per treatment were excavated using a shovel at the end of the experimental period in 1985 and 1986, and five tree root systems per treatment were excavated in 1987 due to time limitations. The excavation operation was not difficult due to the loose, sandy nature of the soil. Whole plant fresh weight was determined immediately, and dry weight after oven drying at 80° for 1-3 days. Lateral root distribution was determined on 10 (1985) and five (1986, 1987) root systems per treatment. These root systems were separated into three concentric zones (0-16, 16-31, and >31 inches) from the trunk, and lateral distribution on a percentage basis was calculated following oven-drying.

A modification of the trench profile method (2) for root distribution studies was used to determine irrigation effects on vertical root distribution at two distances from tree trunks. Since roots radiate concentrically from trunks, circular trenches were dug by hand around each of three randomly selected trees per treatment in Dec. 1987. Initial trenches were excavated 31 inches from the trunk to a depth of about 20 inches. The profile was smoothed with a shovel, then a thin layer of soil was removed by hand with the aid of a brush to expose roots. Roots were counted at each of four depth increments (0-3.9, 3.9-7.9, 7.9-11.8, and >11.8 inches) and vertical distribution on a percentage basis was calculated. A second circular profile wall was subsequently exposed on the same tree at 16 inches from the trunk and the process repeated.

Trees generally flushed three times during each season. Dates that shoot growth began in each of the three flushes were recorded for each tree at intervals of about seven days throughout the season. The percentage of actively growing trees in each irrigation treatment and at each date was calculated.

Microsprinkler irrigation spray patterns. Two experiments were conducted to test the effect of microsprinkler irrigation spray pattern on 'Hamlin' orange tree growth the second season in the field. Site characteristics were as described previously, except trees were set 11 ft apart in rows. Trees were grown during the first year under 90° microsprinkler irrigation with 20% SWD scheduling. During the second season, 90° and 180° patterns were used. Irrigation water was applied through 23.5 gallon-per-hour Maxijet™ emitters and distributed over about 63 and 100 ft^2 of ground area for the 90° and 180° patterns, respectively. Irrigations were scheduled when 20% SWD was reached in the adjacent irrigation scheduling experiments.

Treatments began in May 1986 in the first experiment on trees planted in May 1985, and in May 1987 in the second experiment on trees planted in May 1986. Both sets of trees were part of ongoing factorial experiments designed to study two types of nursery trees and four types of fertilizer (7). Thirty-two and 16 trees, respectively, were assigned to each spray pattern in the first and second study.

Trunk cross sectional area was measured as described previously. Initial and ending measurements were made on 9 May and 7 Dec. 1986 for the first experiment and 30 April and 18 Dec. 1987 for the second.

Statistical analysis. Whole plant dry weight was analyzed by analysis of variance, whereas whole plant fresh weight and trunk cross sectional area were analyzed by analysis of covariance to standardize differences in initial plant measurements. William's test (14) was used to compare means where treatments differed. This test is useful in cases where curve-fitting and regression analyses are difficult due to a small number of treatment levels.

The percentage of each treatment population flushing throughout the season was analyzed using linear, quadratic, and cubic regression models. Models with the highest level of significance and best fit for each treatment population were chosen. The three equations within each growth flush were subjected to analysis of covariance for homogeneity to test the hypothesis that they could be used to estimate the same population.

Measurements from the two experiments on microsprinkler spray pattern were analyzed separately. Split-plot analysis was used with the pre-existing treatments as main plots and irrigation patterns as subplots. Analysis of covariance was used to standardize differences in trunk cross sectional area from the beginning of each experimental period.

Results and Discussion

Irrigation amount and frequency. Ten, 13, and 20 gallons of water per tree were needed at each irrigation, respectively, to return the high, moderate, and low frequencies to field capacity. These amounts were applied with durations of 1.0, 1.3, and 2.0 hr for the three treatments. On average, 31 irrigations were required per season for the high frequency, and only 11 and 2 irrigations were required for the moderate and low frequencies, respectively (Table 1). Irrigations were 2-3 days apart in high and 4-6 days apart in moderate frequency during periods of no rainfall. Drying cycles of the low frequency were usually interrupted by rain. Trees in the moderate and low fre-

Table 1. Number of irrigations and cumulative water applied per tree per season for young 'Hamlin' orange trees under scheduling treatments based on soil water depletion (SWD), 1985-1987.[x]

Irrigation frequency[z]	Irrigations per year (no.)	Cumulative amount of water applied per tree per season (inches)[y]	(gal)
High	31	9.2	310
Moderate	11	4.5	151
Low	2	1.2	40

[z]High = 20% SWD, moderate = 45% SWD, low = 65% SWD; based on neutron probe measurements at a 1 ft depth.
[y]Based on area wetted by emitters.
[x]Modified from Marler & Davies (9).

quencies received 49% and 13%, respectively, as much water during the season as those in the high frequency (Table 1).

Growth responses. Final tree size was not different for trees in the high and moderate frequencies in 1985 and 1986 (Table 2). In the low frequency, however, trunk cross sectional area and fresh and dry weight were significantly lower than the high frequency in 1985. Similarly, trunk cross sectional area was less for the low vs the high frequency in 1986. In contrast, both the moderate and low frequencies reduced final plant size when compared with the high frequency in 1987.

The difference in growth response in 1987 may have been due to the generally poorer quality nursery trees used that year. Severe defoliation occurred after transplanting trees from the nursery to the field, inducing a spring flush with an average of 68 shoots per tree. This was more than three times the number of shoots in spring flushes of trees in 1985 (seventeen) and 1986 (sixteen). Since shoot growth is dependent on stored substrates in citrus (11), the growth of so many shoots in the spring of 1987 may have depleted stored reserves. These less vigorous trees responded more to increased irrigation frequency than did the trees in 1985 or 1986.

More than two-thirds of the trees in 1985 initiated their first growth flush the last week in May, and all had begun growth by 25 June (Fig. 1). Initiation of the second flush occurred from 12 July to 19 Aug. Irrigation treatments did not significantly alter the dates of initiation in either flush, although growth of the second flush in some trees in the moderate and low frequencies was slightly delayed. Initiation of the third flush occurred over a longer time period than for flushes one and two. The entire population of trees receiving the high irrigation frequency initiated growth by mid-Oct. Growth of many of the trees receiving the moderate and low frequencies, however, was significantly delayed to later in the season. About 40% of the trees receiving low irrigation frequency did not grow during this fall flush.

Growth patterns were similar to those of 1985 during the two subsequent years (data not shown). The number of trees initiating growth in the moderate and low frequencies was delayed for the second and third growth flushes in 1986 and 1987, causing a significant difference in the shapes of the curves for these flushes. About 25 and 35% of the trees under moderate and low irrigation had not initiated growth of the third flush by the end of the season in 1986. In contrast, trees in all three treatments flushed three times in 1987, probably due to the earlier planting date and longer season.

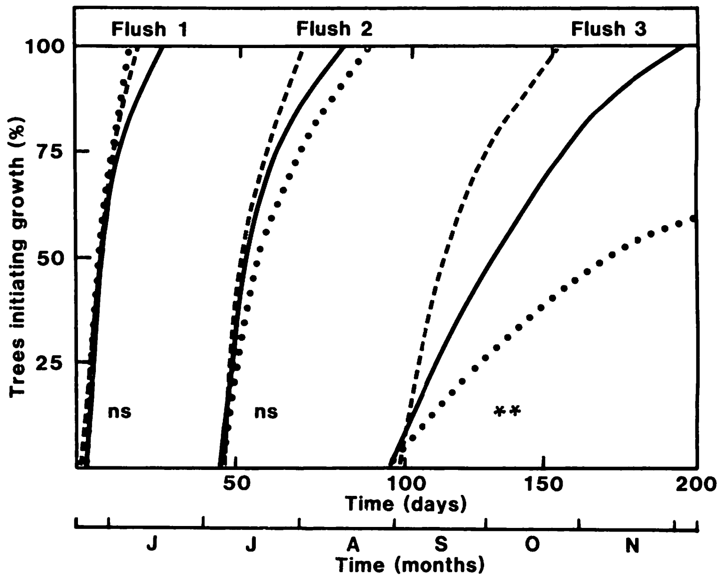

Fig. 1. Cumulative percentage of trees in three irrigation treatments initiating growth within each of three flushes throughout the 1985 season. High frequency, 20% SWD (---), moderate frequency, 45% SWD (—), low frequency, 65% SWD (• • •); ns, ** indicates nonsignificance or significant at the 1% level, respectively, according to analysis of covariance test of homogeneity of the three equations. From Marler & Davies (9).

Table 2. Trunk cross sectional area (TCA) and whole plant fresh and dry weight of young 'Hamlin' orange trees as influenced by irrigation based on soil water depletion (SWD), 1985-1987.

Irrigation frequency[z]	TCA (inch²)[y]	Fresh wt (lb.)	Dry wt (lb.)
	1985		
High	0.79	4.80	1.70
Moderate	0.76	4.39	1.67
Low	0.65**	3.63**	1.40**
	1986		
High	0.76	4.84	1.59
Moderate	0.74	4.84	1.59
Low	0.65**	3.94	1.24
	1987		
High	0.73	4.09	1.44
Moderate	0.59*	2.61*	0.94*
Low	0.51*	2.31*	0.86*

[z]High=20% SWD, moderate=45% SWD, low=65% SWD; based on neutron probe measurements at a 1 ft depth.
[y]From Marler & Davies (9).
*,**Response is significant when compared with the 20% SWD treatment by the William's method, 5% and 1%, respectively.

Cooper et al. (3) suggested prolonged quiescence periods between growth flushes of citrus commonly occurs in response to drought. This delay in growth may result from decreased levels of available reserves since a considerable reduction in CO_2 assimilation occurs with decreased soil water content (8). Perhaps a critical level of available reserves must be met before subsequent shoot growth begins, and this critical level is reached more quickly under high frequency irrigation.

Root dry weight decreased with increased distance from tree trunks (Fig. 2). More than 90% of the roots were within 31 inches of the trunk under these growing conditions in Gainesville, although maximum lateral root spread averaged about 50 inches. Circular trench profiles corroborated these findings in that root concentrations and root length density were more than three times greater at 16 than at 31 inches from the trunk (7).

There is considerable controversy over the optimum microsprinkler irrigation pattern to use for young citrus trees. In this study the zone of maximum root spread occupied an area of about 56 ft² on average, with 65% covered by the 90° emitters. Furthermore, 96% of the roots on a dry weight basis were within the wetted zones, indicating that 90° microsprinkler emitters placed 3.25 ft from the tree cover the majority of the young tree's roots after one season.

More than 85% of the roots were located in the top foot of soil (Fig. 3), with most being located between 3.9

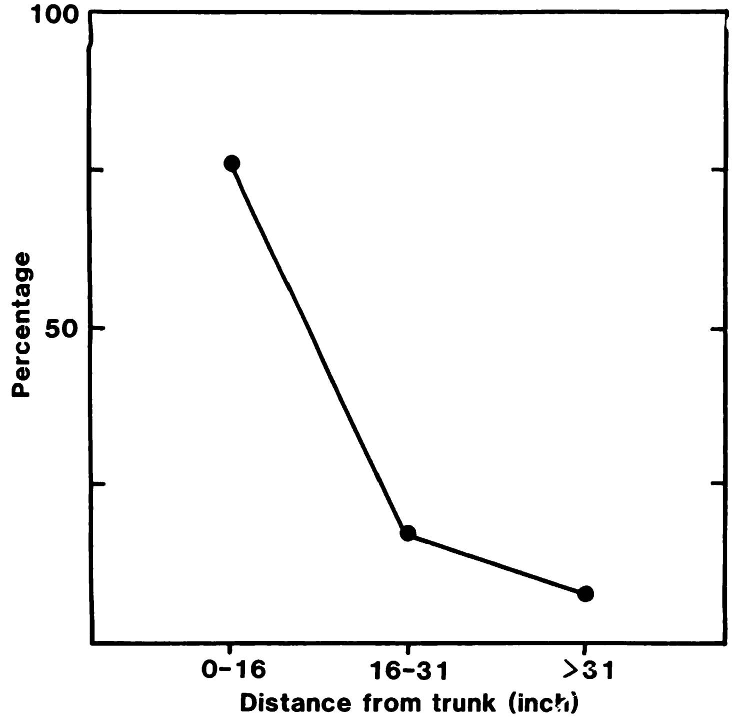

Fig. 2. Percentage of 'Hamlin' orange/sour orange root dry weight in three lateral zones. Mean of three irrigation treatments (20, 45, and 65% SWD) and 3 years (1985-1987).

and 11.8 inches. The limited root growth in the top 3.9 inches could be due to periodic supraoptimal soil temperatures particularly during the summer or to lack of moisture resulting from evaporational losses.

The concentration of roots in the top foot after one season of growth suggests that when soil moisture monitoring is used for irrigation scheduling, measurements should be concentrated in this zone. Furthermore, irrigation times should be limited to replenish soil moisture only in these shallow zones. Irrigations of short duration are adequate when using systems which direct applications to a small area in sandy soils.

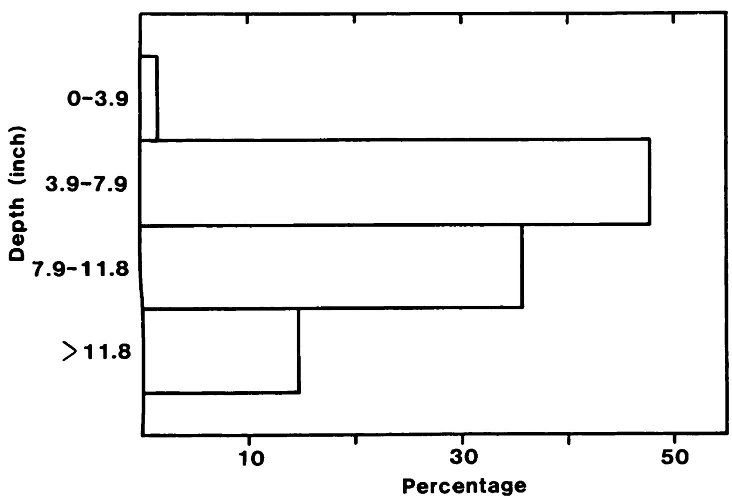

Fig. 3. Percentage of 'Hamlin' orange/sour orange total root number in four depth zones. Mean of three irrigation treatments (20, 45, and 65% SWD) and two distances from the trunk (16 and 31 inches), 1987.

Microsprinkler spray patterns. Distributing irrigation water over 63 and 100 ft^2 by using 90° and 180° spray patterns during the second growing season did not affect the final trunk cross sectional area, which averaged about 1.75 $inch^2$. When beginning with 90° spray patterns, there appears to be no advantage in changing from a 90° to 180° pattern after the first season in the field under the conditions tested in this study. By directing more water on tree trunks, 90° patterns are more efficient than broader patterns for freeze protection (10). Using 90° emitters for irrigation more than one season allows this more efficient system to be used throughout a second winter season for freeze protection.

Conclusions

The optimum level of irrigation in this study was between 20 and 45% SWD, suggesting that microsprinkler irrigation every 4-6 days at 45% SWD is as effective as irrigating every 2-3 days at 20% SWD. More frequent irrigations, however may be beneficial for trees of poor vigor. Based on root location and measurement of soil water replenishment after irrigations, durations of 1-2 hr are adequate to replenish soil water in the root zone for this soil type when microsprinkler systems are properly used. Based on root location and second season tree growth in response to 90° and 180° spray patterns, 90° emitters are adequate for up to two seasons in the field.

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