Flexibility in scheduling is one of the advantages jet and drip irrigation systems have over the sprinkler irrigation system, which should increase the efficiency of irrigation. This was shown in the increase of fruit production with irrigation water applied (Table 5). In 1983 and 1984, jet irrigation produced 46 boxes of fruit per acre for every inch of water applied over no irrigation control as compared to 29 boxes for sprinkler and 24 boxes for drip irrigation, respectively. We feel that the efficiency in drip irrigation would be increased if more drip emitters per tree had been installed. There was no increase in fruit production in jet and drip treatments in 1981 and 1982 probably indicating too much water was being applied. The objective of citrus irrigation is to obtain maximum fruit production with the least quantity of water. All 3 irrigation systems have the potential to reach that goal through design and management. Studies are in progress to achieve optimum coverage and scheduling of irrigation.

Literature Cited

1. Koo, R. C. J. 1967. Effects of soil amendments on soil moisture and growth of young orange trees. Proc. Fla. State Hort. Soc. 80:26-32.
2. Koo, R. C. J. 1969. Evapotranspiration and soil moisture determination as guides to citrus irrigation. Proc. First Intern. Citrus Symp. 3:1725-1730.
3. Koo, R. C. J. 1978. Response of densely planted 'Hamlin' orange on two rootstocks to low volume irrigation. Proc. Fla. State Hort. Soc. 91:8-10.
4. Koo, R. C. J. 1981. The effects of fall irrigation on freeze damage to citrus. Proc. Fla. State Hort. Soc. 94:37-39.
5. Koo, R. C. J. and J. W. Sites. 1955. Results of research and response of citrus to supplemental irrigation. Proc. Soil Sci. Soc. Fla. 15:180-190.
6. Koo, R. C. J. and A. G. Smajstrla. 1984. Effects of trickle irrigation and fertigation on fruit production and juice quality of 'Valencia' orange. Proc. Fla. State Hort. Soc. 97:8-10.
7. Sites, J. W., H. J. Reitz, and E. J. Deszyck. 1951. Some results with irrigation research with Florida citrus. Proc. Fla. State Hort. Soc. 64:71-79.
8. Smajstrla, A. G. and R. C. J. Koo. 1984. Effects of trickle irrigation methods and amounts of water applied on citrus yields. Proc. Fla. State Hort. Soc. 97:3-7.

Proc. Fla. State Hort. Soc. 98: 32-37. 1985.

SHALLOW WATER TABLE FLUCTUATION IN RESPONSE TO RAINFALL, IRRIGATION, AND EVAPOTRANSPIRATION IN FLATWOODS CITRUS

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Additional index words. Low-volume irrigation, upward flux, drainage.

Abstract. **Subsurface soil layers which are restrictive to water flow often give rise to shallow water tables under citrus grown on flatwoods soils. The level at which this water table exists can have a direct influence on the vigor and productivity of bedded citrus trees. In 1984 and 1985, the level and fluctuation of a shallow water table was recorded in a bedded, drip-irrigated citrus grove in the Indian River area. Rainfall amounts as low as 0.15 inches and irrigation amounts as low as 22 gal/tree caused a measureable rise of the shallow water table. Heavy rains brought the water table as high as 14 inches below the top of the beds, and the drainage rate following this was determined to be about 4.5 inches/day. A greater rate of water table decline during the hours of maximum evapotranspiration (ET) suggested that some of the free water was being made available to the citrus trees through upward flux into the root zone. Some current irrigation scheduling models in use in Florida do not take into account water from upward flux. The data collected suggest that this water can contribute significantly to the ET demand of citrus on bedded soils.**

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Most soils in the flatwoods citrus-growing region of Florida are poorly drained due to low land elevation and the existence of a slowly-permeable subsurface layer. This layer can be either argillic or spodic in nature, with saturated hydraulic conductivity often below 0.2 inches/hr (7). Shallow water tables can exist above this layer during periods of consistent rainfall. Citrus grown on flatwoods soils must be planted on raised beds in order to create enough unsaturated soil volume for adequate root growth and development (4).

Even with bedding and artificial drainage, the shallow water table can still exist close enough to the root zone to have a direct influence on the vigor and productivity of citrus trees. Rainfall and subirrigation can have an immediate impact on the level of the shallow water table in the upward direction, while topographical elevation, depth to the restrictive layer, and quality of artificial drainage can have an immediate effect in the downward direction. If the upper boundary of free water remains within the root zone for a period of several days, anaerobic conditions arise and root damage can occur (2). A water table situated just below the root zone will not cause root damage but should be a source of available water for citrus trees through upward capillary movement. This process has been shown to occur in the laboratory with soil cores and in situ with other crops (1, 8). Thus, a matter of a few inches in water level can mean the difference between healthy and unhealthy trees.

Data illustrating the fluctuation of the shallow water table in response to rainfall, irrigation, drainage, and evapotranspiration (ET) are useful in determining the drainage capability of a soil and a suitable citrus irrigation schedule. The objectives of this study were to observe the rise and fall of a shallow water table as affected by the above environmental factors in a mature citrus grove and determine the implications on citrus irrigation in the flatwoods.

Materials and Methods

This study was initiated in March 1984 and terminated in June 1985. The area under observation was a 25-year-old 'Marsh' grapefruit (*Citrus paradisi* Macf.) grove in south-central St. Lucie county. The grove was planted on a 27 ft. (row) by 25 ft. (drill) spacing in single-row beds on Pineda sand (Loamy, siliceous, hyperthermic Arenic Glossaqualf). This soil has a coarse-textured surface underlain by an argillic horizon restrictive layer approximately 45 inches below the crown of the beds. Vertical distance between the crown of the beds and the bottom of the water furrows was approximately 24 inches. The bottom of the root zone existed about 18-24 inches below the soil surface. The soil water characteristic curve measured for the 0-12 inch soil layer is shown in Fig. 1.

Irrigation was provided by a low-volume drip system. One line of poly tubing lay adjacent to the trunk line of each tree row. Turbo-key emitters were spaced every 40 inches along the line (7.5 emitters/tree), and emitter flow rate was 1 gal/hr. Irrigations were scheduled at the discretion of the grove irrigation supervisor with the aid of tensiometers placed at 6 and 12 inches below the top of the beds. Surface drainage was afforded by swale ditches spaced 800 ft apart cut at right angles to the water furrows. Surface water flowed from the water furrows through the swale ditches into a deep lateral dragline ditch which ran parallel to the block.

A Stevens Type F water-level recorder was installed in an interior part of the grove, away from swales or lateral ditches. The instrument was situated at the crown of a bed between two trees. The 5-inch diameter recorder float raised or lowered inside a piece of 6-inch PVC pipe, which had been installed such that its bottom edge rested near the top of the restrictive layer. The entire recorder was covered with a wooden box to prevent damage to the unit and entry of rainfall directly into the PVC pipe.

Neutron probe access tubes were installed close to the water-level recorder at various points in the root zone of a tree. Measurements of volumetric soil water content were made approximately twice per week during the time period of the study.

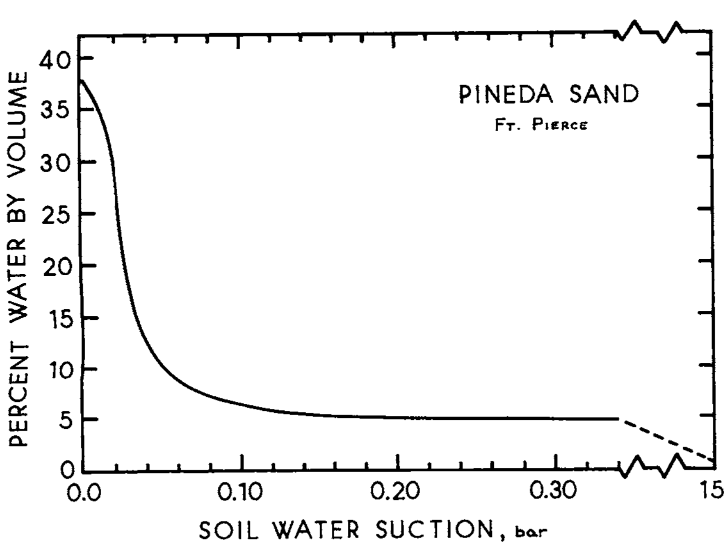

Fig. 1. Soil water characteristic curve for Pineda sand, 0-12 inches.

Results and Discussion

Effect of rainfall. Figs. 2, 3, 4, and 5 show several examples of shallow water table rise in response to rainfall. An increase in water level was seen with a rainfall amount as low as 0.15 inches. Pineda sand has a low available water-holding capacity in the surface layer (0.50 – 0.75 inches/ft) and cannot hold much rainfall against gravity, thus a large fraction of most rainfall events percolated downward through the soil until the free water zone above the restrictive layer was reached. A downward flux greater than the

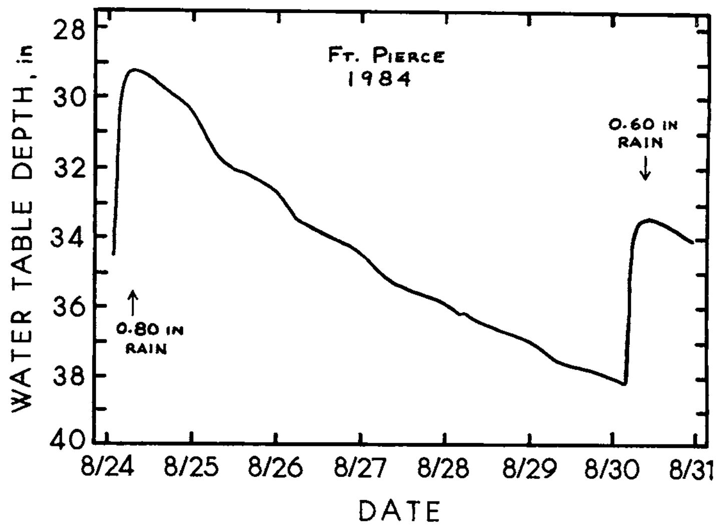

Fig. 2. Shallow water table level vs. time for 24-31 Aug 1984.

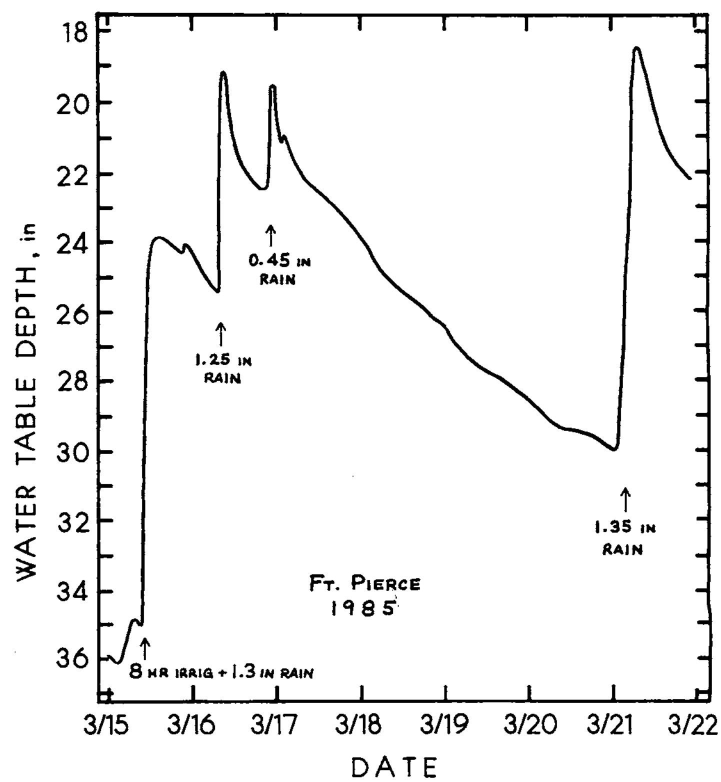

Fig. 3. Shallow water table level vs. time for 15-22 Mar 1985.

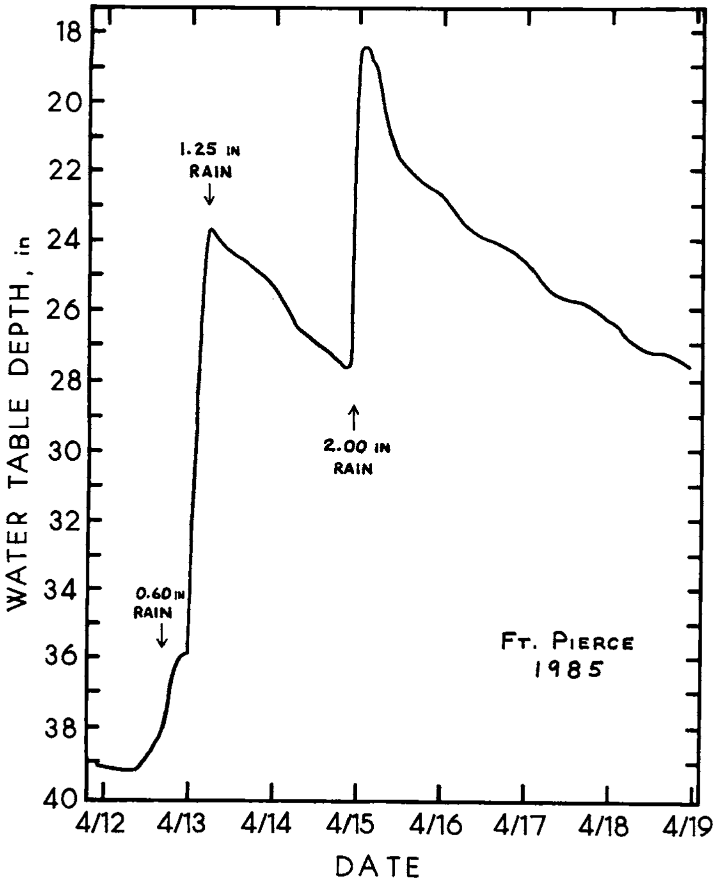

Fig. 4. Shallow water table level vs. time for 12-19 Apr 1985.

rate of drainage off of the restrictive layer caused the level of free water to build up above it. Drainage off of the shallow water table was primarily due to lateral seepage of the swales and dragline ditches which were cut as deep or deeper than the top of the restrictive layer.

It would be desirable to know the relationship between volume of rainfall and shallow water table level increase, but this would be difficult to establish because the partitioning of rain water into infiltration and surface runoff is partially determined by the rate at which rain falls. Shallow water table rise would best be correlated with infiltration amount rather than total rainfall amount. To develop this, a relationship between rainfall rate and infiltration amount would be required.

There were several instances when the free water surface rose into the citrus tree root zone as a result of heavy rainfall. A total of 3.85 inches of rain fell between 13 Apr. and 15 Apr. 1985, which raised the shallow water table from 39 inches to 18 inches below the top of the bed (Fig. 3). A period of heavy rainfall in July 1984 raised the water table level to 14 inches below the bed surface. Free water existing at these levels has the potential to damage roots if it remains stagnant. The drainage rate measured following high water levels was approximately 4.5 inches/day. Ford (3) indicated that adequate and inadequate drainage rates of average water table drawdowns are 6 and 2 inches/day, respectively. Thus, the drainage rate of the grove under observation was probably sufficient to prevent significant root damage.

Effect of irrigation. Figs. 5, 6, and 7 show several examples of shallow water table rise in response to low-volume irrigation. An increase in water level was seen with an irrigation amount as low as 22 gal/tree, based on 7.5 emitters/tree. Due to the hydraulic properties of the surface soil, water from the drip emitters percolated down to the shallow water table with very little horizontal movement. This was confirmed by the neutron soil moisture probe. Data

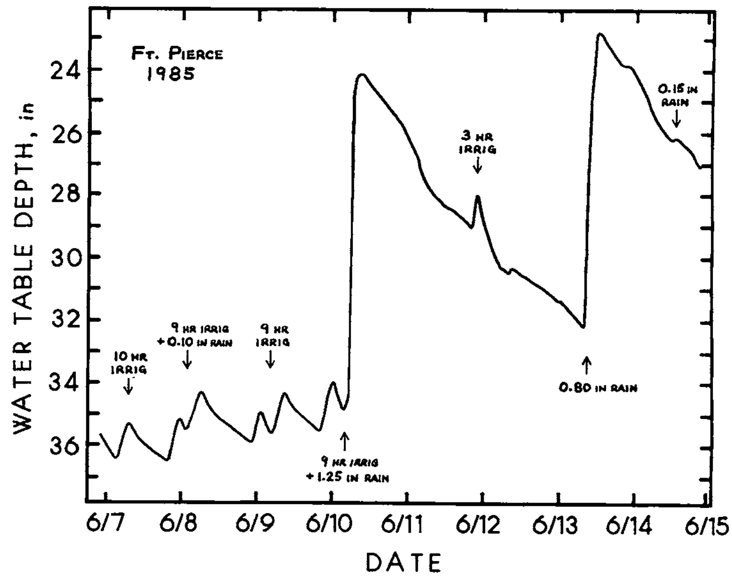

Fig. 5. Shallow water table level vs. time for 7-15 Jun 1985.

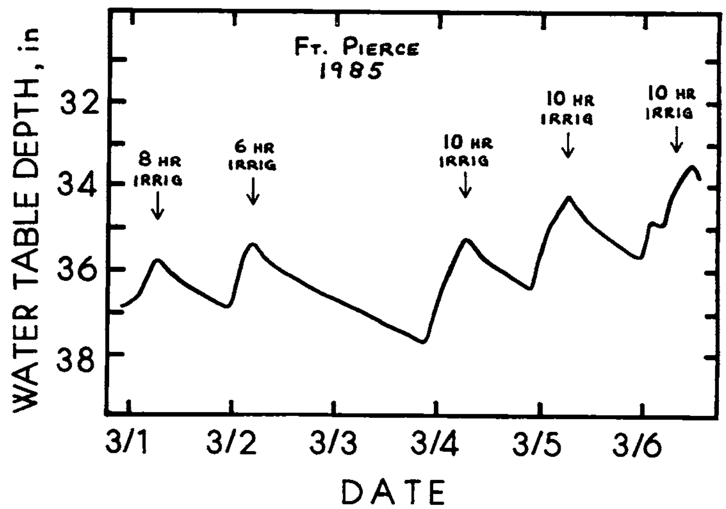

Fig. 6. Shallow water table level vs. time for 1-6 Mar 1985.

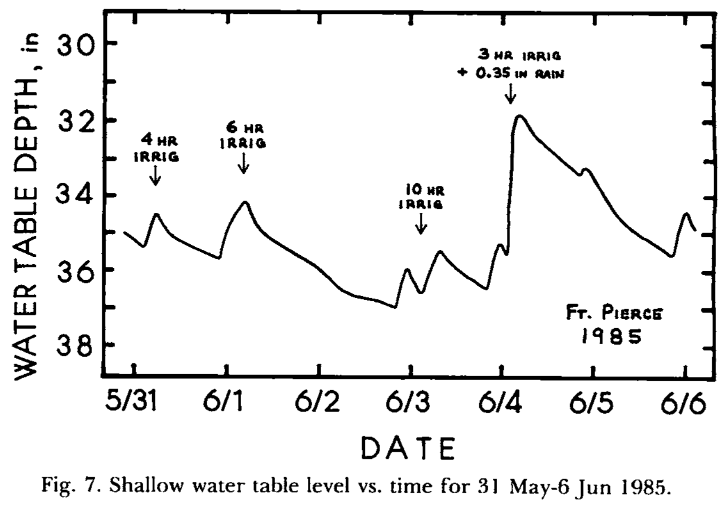

Fig. 7. Shallow water table level vs. time for 31 May-6 Jun 1985.

obtained from an access tube placed on the dripper line midway between two emitters indicated no soil moisture increase at 0-12 inches and a very slight increase at 12-24 inches during and after an irrigation event of approximately 3 hr. The diameter of the wetting pattern under each emitter averaged about 18 inches at the 0-12 inch depth and about 24 inches at the 12-24 inch depth.

Individual, uninterrupted irrigation events can be seen in Figs. 6 and 7 as single peaks of the water level record. After it was realized that much of the irrigation water was percolating through rather than remaining in the root zone, daily irrigations were split into two approximately equal applications separated 3 to 4 hr apart. These can be seen as double peaks in Figs. 5 and 7. This was an attempt to decrease the volume of water moving out of the root zone, but the data show that the effect was minimal.

The amount of shallow water table rise was well correlated with length of irrigation. Linear regression analysis of the relationship yielded the following equation: Water table rise, inches = 0.24 (Irrigation length, hr) – 0.10. There were 20 data points used in the calculation, and the correlation coefficient was r = 0.89.

The data in Figs 5, 6, and 7 illustrate that irrigation lengths of 4 to 6 hr per day maintained the shallow water table at an approximately constant level during periods of little or no rainfall. The average water table level was gradually raised when the irrigation length was increased to 9 to 10 hr per day (Figs 5 and 6). This indicates that the location of the free water surface beneath the citrus trees was being controlled by the low-volume irrigation system during dry periods, although it was not designed for this purpose. If the water table was close enough to the root zone, the possibility existed that irrigation water was being made available to the trees from below through upward capillary movement as well as from above through downward percolation. It is apparent that the potential effect of the low-volume irrigation system on the soil water regime was more widespread than originally thought.

Effect of ET. Fig. 8 shows an example of water table drawdown over a 7-day period with no rainfall or irrigation events. The drawdown curve is wavy as opposed to smooth, indicating a fluctuating rate of decline over time. This fluctuation is also apparent in Figs. 2, 3, and 4. The inflection points of the curve occur at approximately 8 AM and 8 PM of each day. A greater rate of drawdown occurred between the daytime hours (8 AM – 8 PM) than between the nighttime hours (8 PM – 8 AM). There was no apparent reason for the rate of downward drainage off of the restrictive layer to vary between daytime and nighttime hours on a given day; thus, another process was causing the increased drawdown rate during the daytime. It was postulated that this process was upward capillary flux from the free water surface into the citrus tree root zone in response to soil water loss due to ET demand. The capillary fringe above the shallow water table entered into the root zone during the time period shown in Fig. 8 and supplied available soil moisture for tree use. As the level of the water table declined, the upflux potential decreased due to an increase in distance from the root zone. Evidence for this was the decreased waviness of the drawdown curve in Fig. 8 as the water table moved farther down in the soil profile. By the end of the time period shown in Fig. 8, the drawdown curve had smoothed-out considerably.

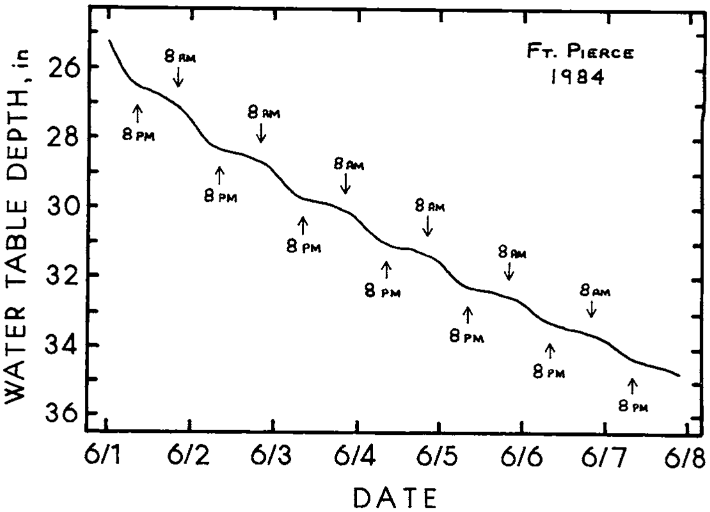

Fig. 8. Shallow water table level vs. time for 1-8 Jun 1984.

For a given 24-hour period, the nightly drawdown rate was assumed to be the constant water loss rate due to drainage. This value was subtracted from the daytime drawdown rate to yield a net daytime water table drawdown rate (in inches of water table/hr) attributed to ET demand. This value was then multiplied by 12 hr (an arbitrarily selected figure) to yield the net daytime water table drawdown amount (in inches of water table). Results of these calculations for three time periods of water level measurement not affected by rainfall or irrigation are shown in Tables 1, 2, and 3.

In order to make the drawdown amounts more meaningful, they were converted from inches of water table (a depth unit) to inches of water (a volume unit). This was done using the drained volume-water table depth relationship for Pineda sand shown in Fig. 9. This relationship was calculated from soil water characteristic curve data as outlined by Skaggs (6). The average daily citrus water uses measured at Ft. Pierce in the early 1970's for Jun, Aug, and Mar were 0.15, 0.15, and 0.12 inches/day, respectively (5). Comparison of these values to the net daytime water volume losses in Tables 1, 2, and 3 shows that their magnitudes are similar, especially when the position of the shallow water table was higher in the soil profile. The amount of drawdown that occurred varied depending on daily potential ET and amount of water stored in the root zone, but it appeared that a water table at a depth of about 32 inches or higher contributed significantly to the ET demand of the citrus trees in the observed grove.

Additional data which support the upward flux concept are shown in a plot of soil water content vs. time (Fig. 10). The water content values for the 12-24 inch soil depth were obtained by averaging neutron probe measurements from four sites located in the root zone of a tree but not near the volume of soil wetted by percolating irrigation water. The lowest soil water content observed during the 5-month period of highest average ET was about 8% by volume, which was 3% higher than the defined field capacity value (0.10 bars soil suction). Thus, the 12-24 inch soil depth always held moisture which was available to the roots that existed in it. The source of this moisture during periods of dry weather was the capillary fringe of the shallow water table.

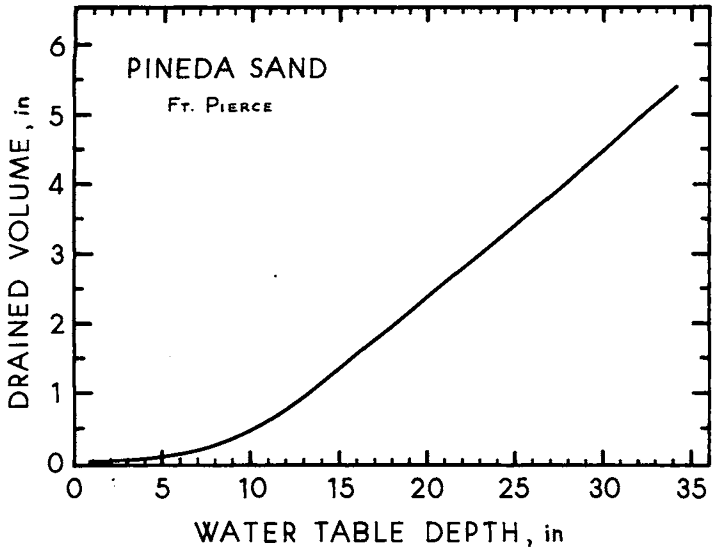

Fig. 9. Drained volume—water table depth relationship for Pineda sand, 0-34 inches.

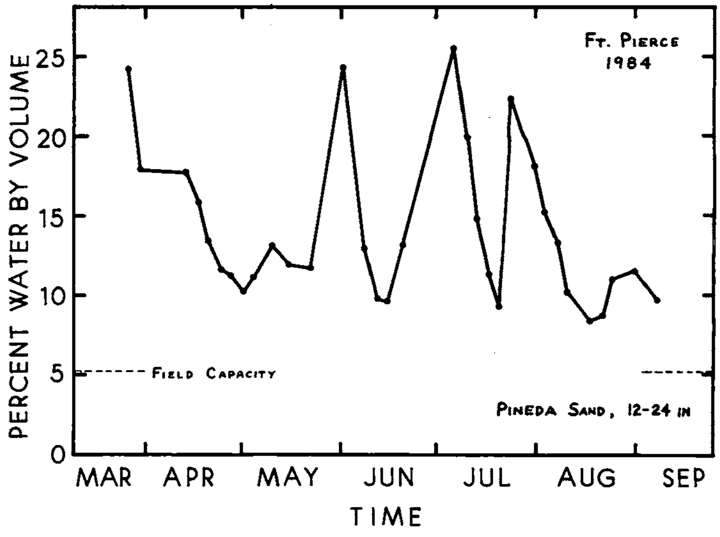

Fig. 10. Volumetric soil water content vs. time, Pineda sand, 12-24 inch depth.

Table 1. Net daytime water table (WT) drawdown (inches of WT) and water volume loss (inches of water) for 2-7 June 1984.

Date	Starting WT level	12-hour day loss (8AM-8PM)	12-hour night loss (8PM-8AM)	Net daytime WT drawdown	Net daytime water volume loss
	inches				
2 June	27.1	1.20	0.36	0.84	0.18
3 June	28.7	1.08	0.36	0.72	0.15
4 June	30.1	0.96	0.36	0.60	0.13
5 June	31.4	0.84	0.36	0.48	0.10
6 June	32.6	0.72	0.36	0.36	0.08
7 June	33.7	0.60	0.36	0.24	0.05

Table 2. Net daytime water table (WT) drawdown (inches of WT) and water volume loss (inches of water) for 5-9 Aug. 1984.

Date	Starting WT level	12-hour day loss (8AM-8PM)	12-hour night loss (8PM-8AM)	Net daytime WT drawdown	Net daytime water volume loss
	inches				
5 Aug.	29.8	1.80	0.60	1.20	0.25
6 Aug.	32.2	1.08	0.36	0.72	0.15
7 Aug.	33.6	0.72	0.36	0.36	0.08
8 Aug.	34.7	0.84	0.36	0.48	0.10
9 Aug.	35.9	0.72	0.36	0.36	0.08

Table 3. Net daytime water table (WT) drawdown (inches of WT) and water volume loss (inches of water) for 22-28 Mar. 1985.

Date	Starting WT level	12-hour day loss (8AM-8PM)	12-hour night loss (8PM-8AM)	Net daytime WT drawdown	Net daytime water volume loss
	inches				
22 Mar.	22.0	1.56	0.84	0.72	0.15
23 Mar.	24.4	1.44	0.84	0.60	0.13
24 Mar.	26.7	1.20	0.72	0.48	0.10
25 Mar.	28.6	1.08	0.48	0.60	0.13
26 Mar.	30.2	0.72	0.48	0.24	0.05
27 Mar.	31.4	0.60	0.36	0.24	0.05
28 Mar.	32.3	0.48	0.36	0.12	0.03

Conclusions

Further research is necessary to quantify upward flux from shallow water tables under a variety of flatwoods conditions. If it can be shown on a widespread basis that upward flux contributes a significant amount of the water that satisfies citrus ET demand, then some irrigation scheduling methods currently in use in Florida will need to be adjusted to take this source of water into account.

Growers who have low-volume drip or microjet systems installed in their flatwoods groves may be unknowingly managing the level of the shallow water table with their irrigation water.

Before choosing a specific type of low-volume irrigation system for a grove, the grower needs to evaluate the physical properties of the soil, then fit the system to his specific set of conditions. The grower should weight the cost of installation and maintenance of a low-volume system against the results that he can expect from it in terms of efficiency of water application and potential yield increases.

The integrity of flatwoods grove drainage systems needs to be maintained. This involves the V-discing of water furrows and cleaning of swale and lateral ditches. An ideal situation may not be possible in many cases. Thus, the shallow water table may always have a direct influence on the vigor and productivity of some flatwoods citrus groves.

Literature Cited

1. Ahmad, C. N. 1975. Plant uptake of water from a water table. Colorado St. Univ. Water Management Tech. Rpt. No. 41.
2. Ford, H. W. 1964. The effect of rootstock, soil type and soil pH on citrus root growth in soils subject to flooding. Proc. Fla. State Hort. Soc. 77:41-45.
3. Ford, H. W. 1984. How to use a water table observation well in poorly drained citrus soils. Lake Alfred Citrus Res. Edu. Ctr. Res. Rpt. CS-84-2.
4. Ford, H. W., B. C. Beville, and V. W. Carlisle. 1985. A guide for plastic tile drainage in Florida citrus groves. Fla. Coop. Ext. Serv. Cir. 661.
5. Harrison, D. S. 1984. Citrus water use and evapotranspiration (ET)

requirements for Florida flatwoods soils. Univ. of Fla. Inst. Food Agr. Sci. Ag. Eng. Dept. Ext. Rpt. 84-1.
6. Skaggs, R. W. 1981. Methods for design and evaluation of drainage-water management systems for soils with high water tables. U. S. Dept. Agr. Soil Conserv. Serv.
7. Watts, F. C., and D. L. Stankey. 1980. Soil survey of St. Lucie county area, Florida. U.S. Dept. Agr. Soil Conserv. Serv.
8. Wells, L. G., and R. W. Skaggs. 1976. Upward water movement in field cores. Trans. Amer. Soc. Agr. Eng. 9(2):275-83.

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AERIAL COLOR INFRARED PHOTOGRAPHY FOR PROPERTY APPRAISAL OF CITRUS GROVES

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Abstract. **Aerial color infrared (ACIR) photographs were taken (at the scale of 2.54 cm = 61 m) of all citrus groves in Charlotte County (3181 ha) in June 1983, May 1984, and June 1985 and analyzed with a 2 camera video system to obtain total number of healthy trees in each property parcel. In previous years, tree counts were made by ground surveys. Data of the type of rootstock, variety of scion, estimated and reported yield of grove (boxes/tree), and the total number of ha in property from the ground surveys were compared with data from ACIR transparencies. Questionable tree counts by ACIR were verified by special field surveys. Comparisons were made between ground surveys and ACIR photography to determine the length of time, accuracy, estimated costs, and potential benefits of each method of data collection. Results indicated that the advantages of ACIR were: 1) reduction in time of appraisal, 2) ability to compare images from 2 different years and produce a more accurate property appraisal, 3) reduction of arithmetic errors in recording tree counts, 4) only 1 appraiser was needed for 7 to 8 weeks for photointerpretation, releasing a position for other work, 5) visits to groves were minimized, an important factor in the potential spread of citrus canker, and 6) calculated costs of conducting ACIR survey were considerably less than for ground survey.**

Property Appraisers are charged by the Florida Constitution, and the Florida Statutes to assess agricultural property (6). The Florida Department of Revenue (DOR) is the agency responsible for providing aerial photographs to the County Property Appraisers for determining property assessment. Rules of the State of Florida, Department of Revenue, Division of Ad Valorem Tax were formulated in 1983 with the guidelines approved by the Governor and the Cabinet in 1982. They were filed with the Secretary of State, and became effective on 30 Dec 1982 (6). Expected changes in state rules for appraising citrus property induced the Property Appraiser in Charlotte County to conduct a detailed and accurate ground survey in 1981 of all citrus groves in the county showing the different varieties, rootstocks, and age of trees for each property. In Charlotte County, small citrus groves are predominant, with the larger groves being no more than 500 acres. Therefore, appraisers were able to keep mapping procedures to a minimum, and did not require complicated grove maps as those prepared for groves in other counties (3, 4). A set of forms was developed that was compatible with computer forms of a Nixdorf 600 minicomputer that stores all appraiser's data base.

Citrus grove appraisal values are also of interest to grove owners (1, 2, 7, 8). It has been suggested that owners and managers maintain grove maps to keep track of tree progress (1, 3, 4, 5) so that comparisons may be made after changes occur, such as the disastrous freeze of 1983 (7). However, tree counts of groves are not easy to obtain, and owners/managers who initiate grove mapping in the first few years of ownership generally do not continue the practice because its a time consuming effort (1, 2, 3).

The purpose of this report is to compare surveys of citrus groves by ground field observations with ACIR photography and twin video camera photointerpretation, and to evaluate benefits and disadvantages from each system.

Materials and Methods

Citrus Grove Sites. Commercial citrus groves (3,181 ha) selected from Charlotte County Property Tax Rolls were outlined on U.S. Geological Survey Quadrangle (Quad) Sheets for aerial photography. Property boundaries of each grove (recorded in 2.54 cm = 61 m scale maps) were labeled by Section, Township, and Range for matching with aerial photography. Property records included: rootstock and scion, date planted, and estimated or actual production records during the past 4 yr. Total acreage in the property boundary was determined by the formula:

$$\frac{\text{Total number of trees} \times \text{spacing factor (m}^2\text{)}}{\text{m}^2 \text{ per hectare}} = \text{Total Hectares}$$

Ground Inspection Surveys. A list was prepared of all commercial citrus groves and property recorded on tax rolls as having citrus groves. Aerial photographs of grove properties were used as maps to make ground inspections (surveys) in 1981. A 4-wheel drive vehicle was used to drive through groves, which were usually irrigated and had a considerable number of ditches and gullies. These obstacles made it difficult to drive throughout the groves. Tree counts were only made for productive trees from each property. Large groves with trees of the same variety and

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