

20. Piring, A. A., R. J. Downs, and H. A. Borthwick. 1961. Effects of photoperiod and kind of supplemental light on the growth of three species of citrus and *Poncirus trifoliata*. *Proc. Amer. Soc. Hort. Sci.* 77:202-210.
21. Reuther, W. 1973. Climate and citrus behavior, p. 280-337. In: W. Reuther (ed.). Vol. III. The Citrus Ind., Univ. of Calif., Berkeley.
22. Rieger, M. 1986. Light intensity, trunk temperatures and sprouting of wrapped and unwrapped young 'Hamlin' orange trees following a freeze. *Proc. Fla. State Hort. Soc.* 99:26-28.
23. Sauer, M. R. 1951. Growth of orange shoots. *Aust. J. Agr. Res.* 2:105-117.
24. Turrell, F. M. 1973. The science and technology of frost protection, p. 338-446. In: W. Reuther (ed.). Vol. III. The Citrus Ind., Univ. of Calif., Berkeley.
25. Webber, J. H. 1948. Plant characteristics and climatology, p. 41-70. In: H. J. Webber and L. D. Batchelor (eds.). Vol. I. The Citrus Ind., Univ. of Calif., Berkeley.
26. Young, R. and A. Peynado. 1965. Changes in cold hardiness and certain physiological factors of red blush grapefruit seedlings as affected by exposure to artificial hardening temperatures. *Proc. Amer. Soc. Hort. Sci.* 86:244-252.

Proc. Fla. State Hort. Soc. 101:53-58. 1988.

WATER TABLE BEHAVIOR UNDER MULTI-ROW CITRUS BEDS

T. A. OBREZA
A. Duda & Sons, Inc.
P. O. Box 788
LaBelle, FL 33935

Additional index words. seepage irrigation, upward flux.

Abstract. In order for citrus to be grown successfully in the Florida flatwoods, trees need to be planted on raised beds for drainage purposes. In 1985, a study was initiated to observe water table behavior and root zone soil moisture status under crowned 3- and 4-row citrus beds with respect to tree position on the bed. During dry periods, much higher soil water tensions occurred in the top 10 inches of soil near the top of the bed as opposed to the edge. Raising the water table for irrigation purposes affected the soil water tension 4 inches deep more strongly at the bed edge. The water table under the middle of the beds rose higher in response to rainfall than at the edge. Stunted growth of trees on the bed shoulder occurred with excessively high water tables. This emphasizes that proper water table management is an important factor when seepage-irrigating multi-row citrus beds.

Large commercial citrus acreage is relatively new in the southwest Florida flatwoods agricultural area. Most of the initial large-scale planting occurred during the mid-1960s, and growth continued at a slow but steady pace during the 1970s. Expansion has occurred at a rapid rate during the 1980s and will continue to do so as growers take advantage of the current citrus economy, the land availability, and the less severe winters in the region.

In order for citrus to be grown successfully in this generally wet area, trees need to be planted on raised beds for drainage purposes (1, 5). It was originally thought that citrus could not be grown in the area at all due to the wetness. Thus, most of the original plantings were designed with emphasis on drainage as opposed to irrigation, and numerous deep ditches at regular spacings were common in the early groves. A typical grove unit consisted of 8 to 15 rows of trees separated by deep dragline ditches, creating "blocks" of trees between ditches. Trees within blocks were planted on single-row beds, where the shallow water furrow on each side of the row provided for surface water removal through swale ditches cut perpendicular to the tree rows. Trees were generally overhead-irrigated with large volume guns, in most cases inadequately. Ridge grove-type sprinkler systems were also tried, but success

was poor due to low quantity and quality of well water (H. English, personal communication).

In the 1970s, grove design evolved such that dragline ditches were used primarily around the perimeter of large blocks of grove to move water to and from smaller V-ditches between beds, and the multi-row bed concept with seepage irrigation was introduced. Growers were able to use observation wells to determine that water table control was much easier and more precise with relatively shallow V-ditch water furrows between beds than with the old dragline ditch. One reason for this was that the walls of the deep ditch could seal off over time, preventing seepage of water from the ditch into and out of the block. Some growers converted old vegetable fields to citrus groves by turning the existing 70-ft spaced field ditches into V-ditch water furrows and building a 3-row citrus bed in between.

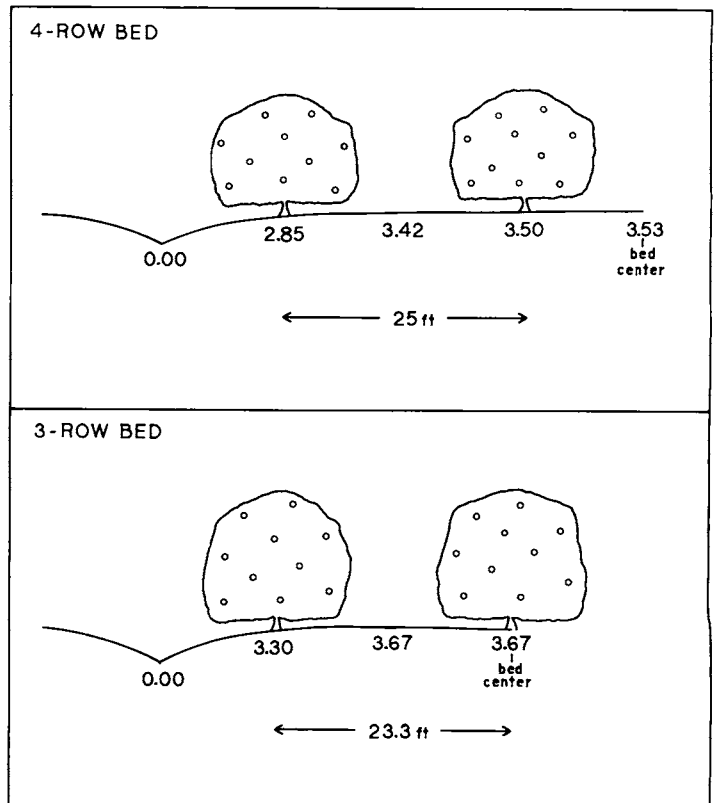


Fig. 1. Diagram of multi-row citrus beds. Numbers indicate the vertical distance in ft above the bottom of the V-ditch.

Four-row beds were also common on previously uncropped soil with high hydraulic conductivity which allowed for rapid lateral seepage. Land utilization was greater with the V-ditch system, as more trees could be planted on a gross acre of land with fewer dragline ditches.

Within the last 15 yr at the A. Duda & Sons, Inc. citrus groves at LaBelle, 2-, 3-, and 4-row beds have been constructed and planted with trees. The 3- and 4-row beds are crowned in the middle and slope slightly towards the water furrow on each side. Consequently, trees planted in the center rows on a bed are higher in elevation relative to a flat surface than trees planted in rows next to the water furrow. During subirrigation, there is potentially a greater vertical distance between the rising water table and the root zone of trees planted near the bed middle vs. trees at the water furrow, which could lead to a difference in root zone water regime. This differential could have a long-term effect on tree vigor and growth with respect to row position.

The objectives of this study were: 1) to observe water table behavior and root zone soil moisture status under 3- and 4- row citrus beds, 2) to relate water table depth to soil water tension in the root zone, and 3) to use measured soil

physical properties to estimate upward water flux as a function of water table depth.

Materials and Methods

In 1985, 2 groves were selected for close scrutiny of the variation in root zone soil water tension and water table level over a period of 2 yr. One was a 134-acre grove of 'Valencia' orange trees on Carrizo citrange rootstock, 11 yr old, planted on 4-row beds. The other was a 63-acre 'Hamlin' orange grove on Carrizo citrange rootstock, 10 yr old, planted on 3-row beds. The dimensions of each bed are shown in Fig. 1. Each grove was a rectangular unit with deep lateral irrigation/drainage ditches around the perimeter. The soil series in each grove was Immokalee sand with a coarse-textured surface horizon above a spodic horizon which was located about 48 inches below the surface of the beds. The groves were seepage-irrigated by raising the water level in the V-ditches between beds.

Tensiometers were installed at depths of 4, 10, and 16 inches below the soil surface on an interior bed within each grove. Three sets of 4- and 10-inch tensiometers were placed between trees within water-furrow rows and within

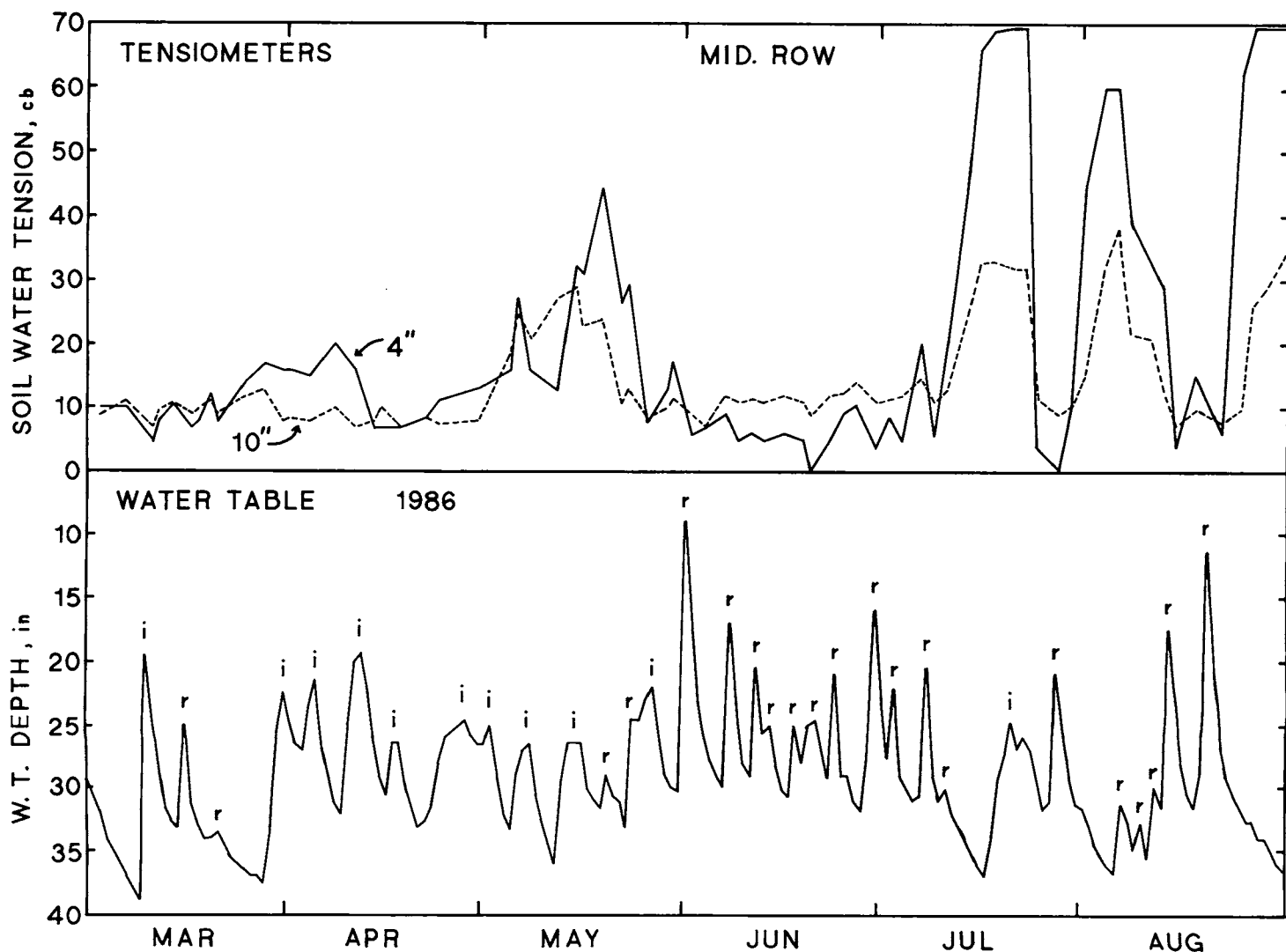


Fig. 2. Soil water tension and water table (W. T.) level fluctuation during spring and summer 1986 for a middle row of a 4-row bed (i = irrigation, r = rain).

adjacent middle rows. Sixteen-inch tensiometers were placed within middle rows only. Two Stevens Type F water table stage recorders were installed at each site, one on a water-furrow row, the other immediately adjacent to it on the middle row. The 5-inch diameter recorder float raised or lowered within a 6-inch vertical slotted PVC pipe which had been installed in the soil to a depth of 48 inches. The tensiometers were read 3 times per week while the stage recorders monitored water table levels continuously.

The field data were supplemented by soil water release characteristic data obtained in the laboratory. Undisturbed pairs of soil cores (1.7 inch diameter x 1.2 inch length) were removed from the field from the midpoint of the soil depths 0 to 12, 12 to 24, and 24 to 36 inches. These were placed in Tempe pressure cells, and the relationship between soil water tension and water content was measured during a drying cycle (2). Saturated hydraulic conductivity was also measured using the cores (3).

The soil water characteristic curve was used as input data to a component of the DRAINMOD computer model which estimated the unsaturated hydraulic conductivity function using the method of Millington and Quirk (4). From these data and further use of DRAINMOD, the up-

ward flux-water table depth relationship was estimated for Immokalee sand.

Results and Discussion

In the typical, well-established 3- and 4-row beds studied, the rows at or near the center were higher in elevation with respect to the bottom of the water furrow than the rows on the bed shoulder (Fig. 1). The elevation difference between the middle and water-furrow rows was 0.37 ft (4.4 inches) and 0.65 ft (7.8 inches) for the 3- and 4-row beds, respectively.

Since both bedding systems behaved similarly in terms of water table movement and root zone soil moisture with respect to row position (middle row vs. water-furrow row), detailed data from only the 4-row bed is presented and discussed. Water table levels and tensiometer readings from this bed from Mar. 1986 to Feb. 1987 are presented in Figs. 2-5.

Periods of dry weather are evidenced by low water table levels and soil water tensions greater than 20 to 30 cb. Acute dry periods occurred in May and July 1986, and a more chronic dry period occurred from Sept. through

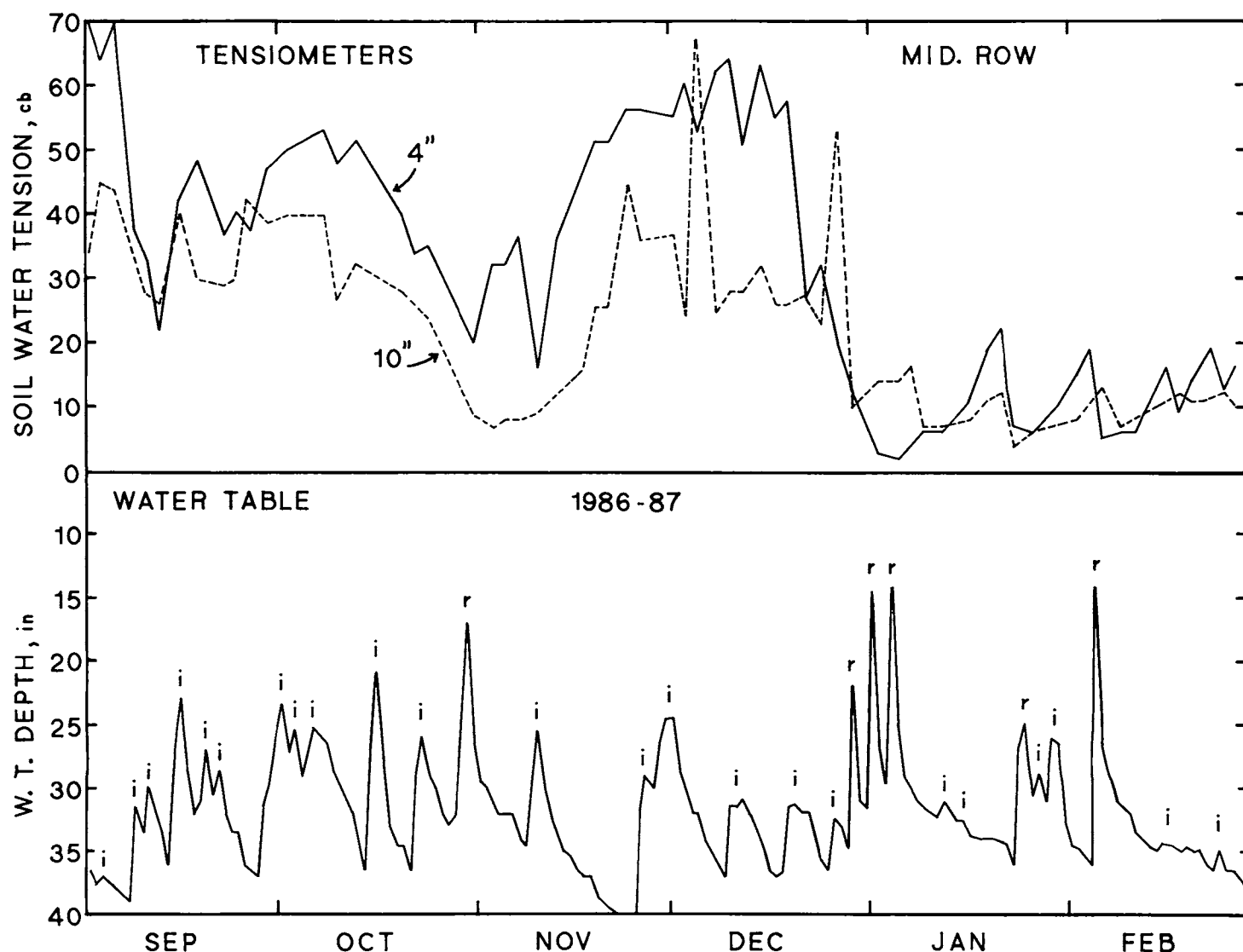


Fig. 3. Soil water tension and water table level fluctuation during fall and winter 1986-87 for a middle row of a 4-row bed (i = irrigation, r = rain).

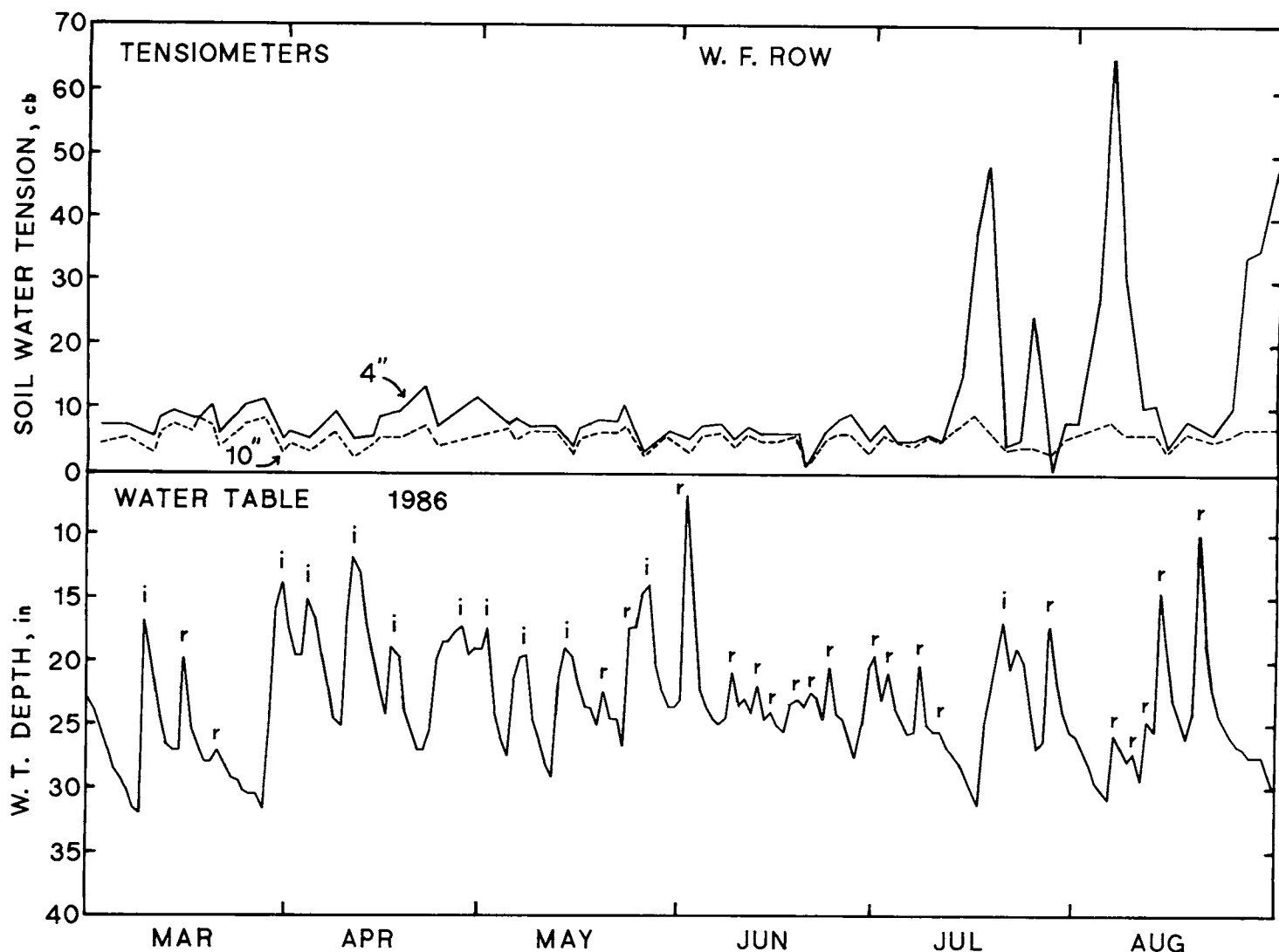


Fig. 4. Soil water tension and water table level fluctuation during spring and summer 1986 for a water-furrow row of a 4-row bed (i = irrigation, r = rain).

Dec. 1986. The severity of the dry period in terms of upper root zone soil moisture status was different with respect to row position on the bed. Much higher soil water tensions occurred at the center of the bed as opposed to the edge. This was due to the position of the water table relative to the curved surface of the bed.

During each dry period, the root zone at both 4- and 10-inches below the soil surface at the center of the bed experienced drying; drying at the edge of the bed was seen only at the 4-inch depth, while the 10-inch depth remained constantly moist (soil water tensions less than 10 cb), as did the 16-inch depth at the bed center (not shown).

Severe drying of the soil was seen during the July 1986 dry period. This was due to a combination of high evapotranspirative demand and the delaying of irrigation in anticipation of rainfall which did not occur. High soil moisture tensions at the bed center continued through the fall dry period, even though irrigations were timed 2 to 5 days apart. These same irrigations were sufficient to maintain a much higher root zone moisture status at the edge of the bed, where the soil water tension at 4 inches did not rise above 25 cb for most of the fall.

The water table responded very quickly to irrigation, rainfall, or drainage. Stage recorder data indicated that

there was only a 30 min time lag between water table rise under the edge row and concurrent rise under the middle row of the bed following initiation of an irrigation.

The tensiometer readings lowered in response to rainfall (i.e., infiltration) regardless of position on the bed. Lowering of readings during irrigation was dependent on bed position. Decline in the 4-inch tensiometer reading was greater in frequency and magnitude at the bed edge than at the center due to closer proximity to the rising water table.

The water table rise following rainfall was greater under middle rows than under water-furrow rows (Fig. 6). Infiltration of rain water was favored near the bed center due to the relative flatness at that point, while the slope at the bed shoulder favored more surface runoff into the water furrow and out into the larger drainage canals.

The effect of time of year (i.e., differing evapotranspiration demand) on soil water depletion is evident. Soil moisture remained relatively high throughout the bed during the winter and early spring even with infrequent irrigations; but, during the late spring and summer, a net soil water depletion occurred with a series of irrigations timed less than 7 days apart.

The average monthly water table levels under middle

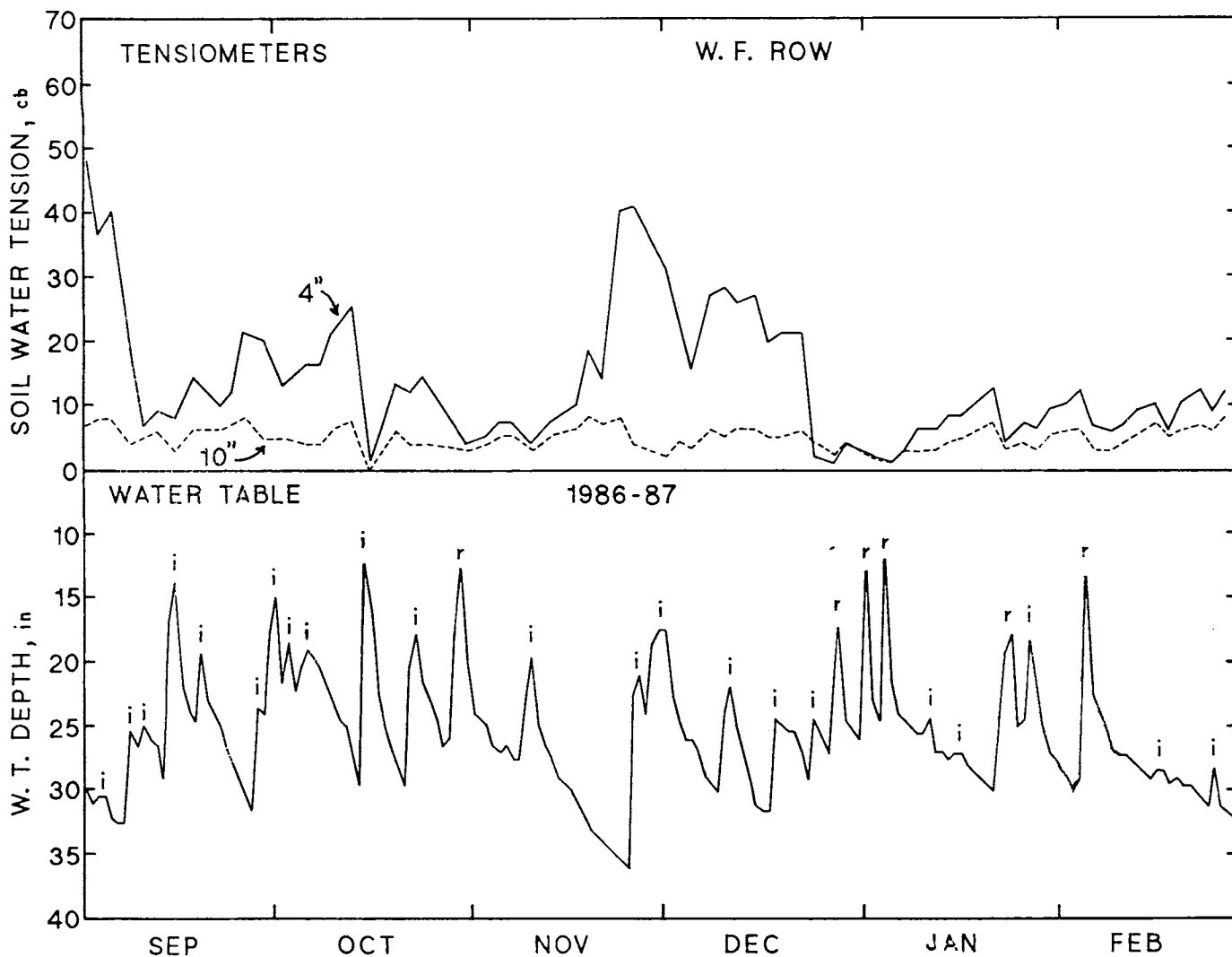


Fig. 5. Soil water tension and water table level fluctuation during fall and winter 1986-87 for a water-furrow row of a 4-row bed (i = irrigation, r = rain).

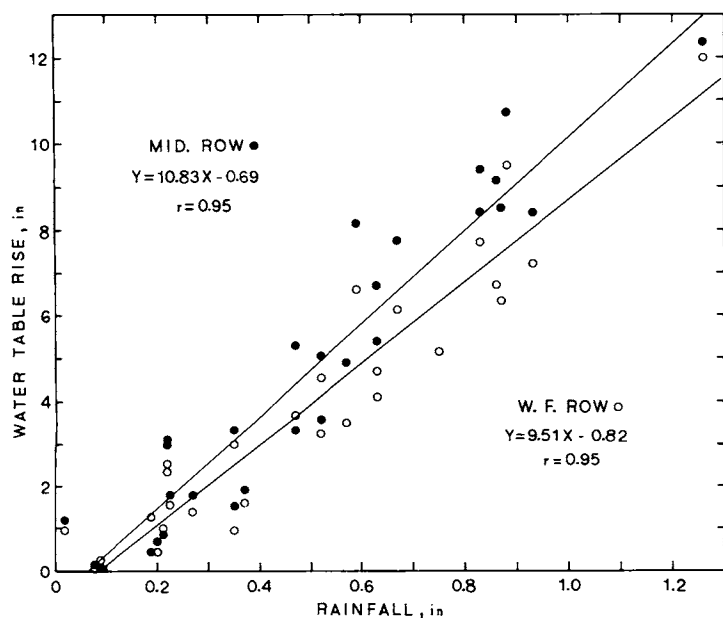


Fig. 6. Water table response to rainfall with respect to row position (4-row bed).

and water-furrow rows for the 3- and 4-row beds are shown in Table 1. Differences in water table depth between middle and water-furrow rows were generally greatest during months with frequent irrigation and little or no rainfall (Mar., Apr., May, Nov.) and were smallest during high-rainfall months (Jun., Aug.). This indicates that infiltrating rain water was more effective in raising the water table under the bed center than was seepage irrigation and suggests a possible explanation for the large difference in upper root zone soil moisture tension with respect to row position seen during the dry periods.

The significance of the monthly and annual differences in water table depth between middle and water-furrow rows (Table 1) becomes apparent when considering the estimated upward flux-water table depth relationship for Immokalee sand (Fig. 7). Although the estimation is a steady-state approximation of a transient process, it still provides a valid explanation for the differences in root zone water content seen with respect to row position on the bed. The relationship indicates that a water table positioned 20 inches or less below mid-root zone should provide an upward flux of greater than or equal to 0.06 inches hr^{-1} . However, if the water table is 27 inches or more below mid-root zone, the upward flux is reduced to

Table 1. Average monthly values of water table level under multi-row citrus beds.

Month	4-row bed			3-row bed		
	Mid row	W. F. row	Diff.	Mid. row	W. F. row	Diff.
	Inches below soil surface		Inches	Inches below soil surface		Inches
Mar. 1986	32.4	26.2	6.2	31.4	27.1	4.3
Apr.	26.9	20.0	6.9	29.3	24.8	4.5
May	28.9	22.2	6.7	29.5	24.4	5.1
Jun.	25.4	22.2	3.2	26.3	21.9	4.4
Jul.	29.2	23.9	5.3	29.5	24.1	5.4
Aug.	30.5	25.2	5.3	30.3	26.2	4.1
Sep.	32.8	26.0	6.8	31.4	27.2	4.2
Oct.	28.0	21.9	6.1	26.3	21.1	5.2
Nov.	33.6	27.6	6.0	33.6	27.9	5.7
Dec.	32.6	25.9	6.7	32.1	26.7	5.4
Jan. 1987	29.9	24.4	5.5	30.9	25.9	5.0
Feb.	33.6	28.0	5.6	33.9	29.3	4.6
Avg	30.4	24.5	5.9	30.3	25.5	4.8

0.01 inches hr^{-1} or less. Thus, a difference of 7 inches in water table depth can mean the difference between a high and low upflux value.

Average differences in water table level between middle and water-furrow rows were greater than 6 inches during dry months for the 4-row bed (Table 1). Large differences in tensiometer readings with respect to bed position during these months can be explained by differences in upward flux. When seepage irrigating, a decision must be made as to the placement of the water table: if it is placed such that the upper root zone of the middle rows is wetted, then the rows at the bed edge become too wet; if the placement is such that the water-furrow rows are sufficiently but not excessively wetted, then the middle rows may become too dry. At Duda's groves in LaBelle, a compromise is generally made. Although the 0 to 10 inch root zone of middle-row trees may not be significantly wetted with this practice, the trees may not suffer water stress due to a potentially deeper, more extensive root zone which could occur with the generally lower water table position below the soil surface. This has yet to be confirmed with root density sampling with depth.

Duda citrus harvest personnel have reported as much as 100 box acre^{-1} or higher fruit yields from middle tree rows as compared to adjacent water-furrow rows in areas where high water levels were held throughout the growing season (S. Raborn, personal communication). In addition, stunted growth of newly-planted trees in water-furrow rows has been observed in groves where excessively high water tables were maintained in an attempt to irrigate middle-row trees. Thus, proper water table management has

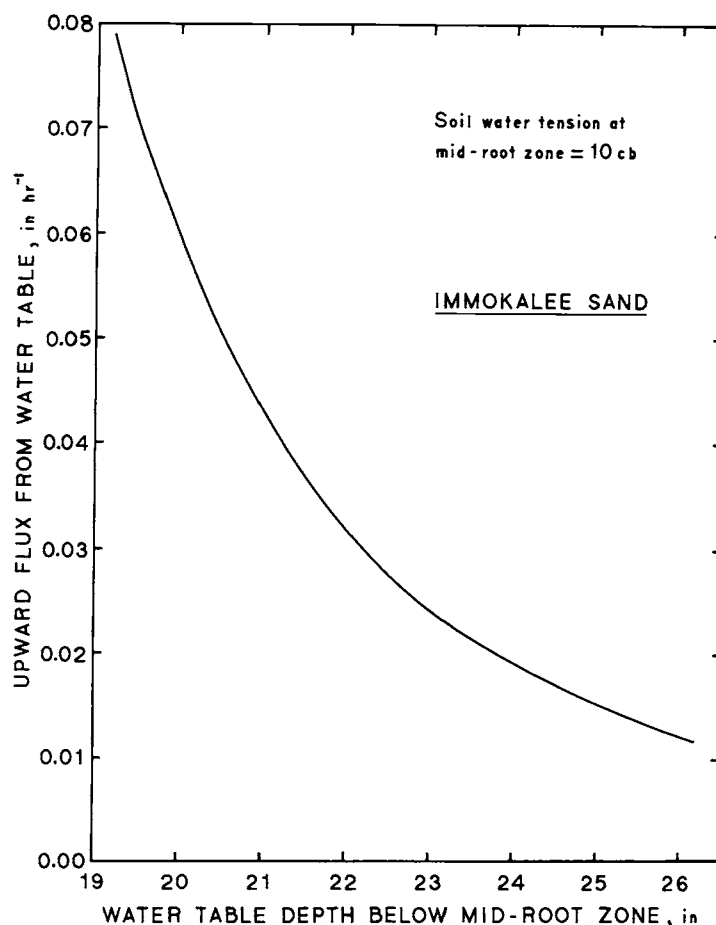


Fig. 7. Effect of water table depth on steady-state upward flux for bedded Immokalee sand.

been demonstrated to be an important factor when seepage-irrigating multi-row citrus beds.

Literature Cited

1. 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.
2. Klute, A. 1986. Water retention: laboratory methods. In: A. Klute (ed.). Methods of soil analysis, Part 1. Agronomy 9:635-662.
3. Klute, A. and C. Dirksen. 1986. Hydraulic conductivity and diffusivity: laboratory methods. In: A. Klute (ed.). Methods of soil analysis, Part 1. Agronomy 9:687-734.
4. Skaggs, R. W. 1980. Drainmod. Ref. Rpt. Methods for design and evaluation of drainage-water management systems for soils with high water tables. U. S. Dept. Agr. Soil Conser. Serv., South Technical Center, Ft. Worth, TX.
5. Smajstrla, A. G., D. S. Harrison, C. Tai, and D. Clapp. 1982. Water budget of crown flood irrigated citrus. Proc. Fla. State Hort. Soc. 95:11-14.