WATER STRESS AND STOMATAL DIFFUSION RESISTANCE IN CITRUS AFFECTED WITH BLIGHT AND YOUNG TREE DECLINE[1]

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Abstract. **Root and leaf water potentials, stomatal diffusion resistances, trunk radius changes, water uptake from injections, and hydraulic conductivities of twig and small root segments of diseased trees were compared with those of healthy trees in one grove with blight, and in another grove with YTD. In the study of blighted trees, root water potentials followed a similar daily cycle for both blighted and healthy trees, with an early afternoon low of about —9 bars. The leaf water potential, however, decreased to about —11 bars in healthy trees and to about —25 bars in blight trees. Stomatal diffusion resistances of both healthy and diseased trees were similar in the morning and increased slowly, but diverged and became much greater for the afflicted trees in the afternoon. Water uptake rates from trunk injection were about 10 times greater for healthy trees. Healthy and afflicted trees had similar root conductivities and twig conductivities. Both water potential and trunk injection data imply poor hydraulic conductivity in the xylem of diseased trees. These and other data suggest that flow restriction is severest in the trunks and large branches of the trees.**

Blight has been present in Florida citrus since the 1880's (11). Young tree decline and sand hill decline have been described more recently (2). These diseases are probably all manifestations of the same disorder (6, 10). Blight appears to be a xylem malfunction (5).

Kaufmann (9) compared xylem sap pressure potential of citrus branch tips measured with the pressure chamber method (13) with leaf water potential measured with a thermocouple psychrometer. He found a linear relationship, although the pressure chamber method overestimated leaf water potential at high water potential and underestimated it at low water potential. The methods agreed best at potential of about —8 to —12 bars.

Bell *et al.* (3) measured leaf-water potentials (sap pressure) of healthy trees and declining trees ('Valencia' scions on rough lemon rootstocks) using the Schlander-type (13) pressure chamber. Leaf water potentials averaged about —15 bars in trees afflicted with blight or YTD and about —7 or —8 bars in healthy trees.

Gee *et al.* (8) showed that root water potentials of pepper could be accurately estimated with the pressure chamber, provided that the roots were not damaged. They, and also Boyer (4), pointed out that the pressure potential of the xylem sap measured with a pressure chamber should be higher than the actual xylem water potential by the amount of the osmotic potential of the xylem sap. However, this osmotic potential is usually very small, so the pressure chamber measurements approximate xylem water potential quite well. In this paper, we will consider the xylem water potential and leaf-water potential to be equal.

This report compares leaf and root water potentials, stomatal diffusion resistances, trunk water injection rates, and dendrometer measurements (trunk radius changes) of afflicted trees with those of healthy trees. The objectives were to compare the apparent restriction in water flow in the xylem of the blight- and YTD-afflicted trees with the water stress and stomatal diffusion resistances of healthy trees over diurnal cycles, and to determine the location of the water flow restriction.

Methods and Materials

Two groves were selected for the study. The trees studied in April 1974, were 24-year-old 'Valencia' oranges on rough lemon rootstocks (*Citrus sinensis* (L.) Osb. on *Citrus jambhiri* Lush.) at an Agricultural Research Center planting at Ft. Pierce, Florida. Two trees suffering from blight (trees no. 2 and 4, conditions 1.5 and 2.0, respec-

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tively)[2] were compared with two healthy trees (trees no. 1 and 3, conditions 0.0 and 0.1, respectively). These trees were in the same grove studied by Bell *et al.* (3). The grove was irrigated on March 28, and measurements of water potential, stomatal diffusion resistance of fully exposed leaves, and trunk radius were begun on April 3. The soil was Wabasso sand, with a 6-inch organic pan within 30 inches from the surface, underlain by fine-textured material with a low hydraulic conductivity.

The second set of four trees, also 'Valencia' scions on rough lemon rootstocks, studied in May 1974, was in an 11-year-old commercial grove (ALD-COMP grove) about 20 miles west-southwest of Ft. Pierce. The YTD trees (trees no. 2 and 4, both condition 1.0), were compared with two healthy trees (trees no. 1 and 3, both condition 0.0). Measurements were begun on May 14 (except for soil water content and trunk injections, which were begun on May 9). The soil was Felda fine sand.

The leaf and root water potentials were measured with a pressure chamber similar to that described by Scholander *et al.* (13). We used a procedure similar to that described by Bell *et al.* (3).

We made pressure chamber measurements during April 3, 4, and 5 and May 14, 15, and 16 on the roots and leaves of the experimental trees. Only unbroken or undamaged roots (8) with diameters of about 1/10 inch were used. Most of the leaf measurements were made on fully exposed leaves. Before May 15, all measurements were made on terminal branches with three to six leaves (9). Thereafter we used single leaves (3), and we did not detect significant differences between patterns obtained with three to six leaf terminals and patterns obtained with single leaves.

Stomatal diffusion resistance measurements on fully exposed leaves were made on the same group of trees on the same dates, alternating with the pressure chamber readings. A Lambda[3] diffusion resistance meter, calibrated by the method of van Bavel, Nakayama, and Ehrler (15), was used.

Linear variable displacement transformers (LVDT) were used to measure diurnal cycles of trunk radius changes (14). The LVDT's were mounted with a lag-screw bracket at the base of the four trees, similar to the method used by Ryan *et al.* (12) on peach trees. Four transformers were connected to a Daytronic Model DS 201C exciter-demodulator through a serial stepping switch, and outputs were recorded on a strip-chart recorder. Transducer outputs from each tree were obtained at 10-minute intervals. The LVDT's were calibrated for the exciter-demodulator with a micrometer; both LVDT and micrometer were fixed by brackets to a common base plate.

Soil water content (percent of oven-dry weight) was measured gravimetrically on samples obtained at depths of 0-6 inches (0-15 cm), 6-12 inches (15-30 cm), and 12-18 inches (30-45 cm) on April 2, 4, 10, and 16, at the base of each of the four trees. Composite sample size was about 200 gm of (oven-dry) soil. Similar soil water content measurements were made in the YTD grove on May 9, 15, and 20.

Stem and root hydraulic conductivities were determined by measuring the rate of flow of water through 5.25-inch (13.3 cm) lengths of stems and roots under known hydrostatic heads. The hydrostatic head was provided by a column of water 107 inches (272 cm) long for stems and 37.5 inches (95 cm) long for roots. Stem and root lengths were about 0.3 inch (8 mm) in diameter. Root conductivity was not measured in the ALD-COMP commercial grove, which had the YTD trees.

Results and Discussion

Agricultural Research Center Planting (Blight)

Fig. 1 shows changes in water potential of leaves and roots throughout a daylight period. Data for April 3, 4, and 5, from 110 individual measurements, were grouped into the curves. Each day was clear but had variable cumulus cloud cover. Water potential decreased in the morning and reached a minimum at about 1400 hr (2:00 p.m.) EST. In the late afternoon, the water potential began to rise and recovered to about —6 bars by 2000 hr (8:00 p.m.) EST for both healthy and blight-afflicted trees. The water potential of roots of both healthy and afflicted trees followed the same daily pattern and reached a low of about —9 bars. Big differences in leaf water potential occurred, however. The leaf water potential decreased to about —11 bars in the healthy trees and to about —25 bars in the afflicted trees. These results show that water flow between the roots and the leaves was restricted in the afflicted trees. If we assumed an equal leaf area (transpiring surface) on each tree, the root-to-leaf water potential gradients would imply that the hydraulic conductivity in the af-

[2] Trees were rated visually on a scale ranging from 0 to 3.0 where 0 = healthy; 1 = moderate decline; 2 = advanced decline and 3 = very severe decline.

[3] Mention of proprietary products is for the convenience of the reader only, and does not constitute endorsement or preferential treatment by the U.S. Department of Agriculture.

flicted trees was about 1/8 that in the healthy trees. Since the leaf area was actually smaller in the diseased trees, the hydraulic conductivity must have been even lower.

Fig. 1 also shows average stomatal diffusion resistances over the same three days. Seventy-five individual measurements were grouped into appropriate time-of-day values to form the curves. The diffusion resistance was similar for both healthy and diseased trees up until about noon. In the early afternoon, the average resistances for the diseased trees are much larger than for the healthy trees. The grove had been irrigated with 2 inches (5 cm) of water on March 28, so the healthy trees showed no signs of water stress. The hydropassive closure of stomata in the diseased trees lagged behind the development of leaf water stress. The stomata had closed because of darkness by 2000 hr EST.

Fig. 2 shows daily cycles of trunk radius changes over later days in April (April 14-18).

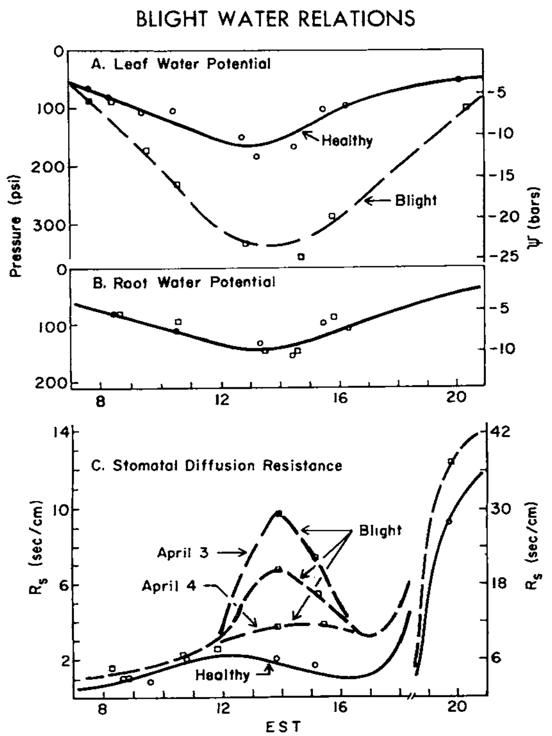

Fig. 1. Daytime cycle of water potential in leaves (A) and in roots (B), and daytime cycle of stomatal diffusion resistance (C) of healthy citrus (circles, ○) and of citrus afflicted with blight (squares, □). April 3-5, 1974, 24-year-old Valencia orange scions on rough lemon rootstocks. Blighted trees showed much higher stomatal diffsusion resistances in the afternoon of April 3 than in the afternoon of April 4.

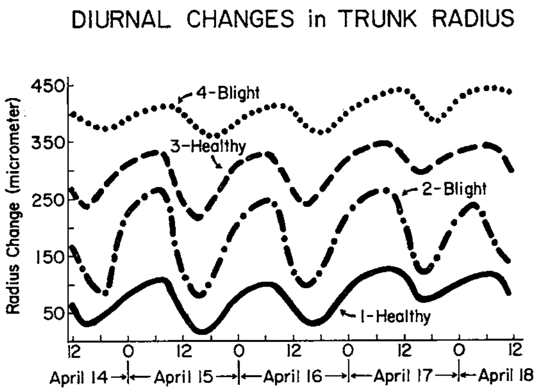

Fig. 2. Diurnal changes in trunk radius of healthy citrus and of citrus afflicted with blight, obtained with linear variable differential transformers. Scale is arbitrary; only changes have meaning. 1 micrometer = 0.03937 mil (thousanth of inch).

We chose dates later than April 3-5, because the dendrometer on tree 4 failed to operate properly during that earlier period. All trunk radius changes were plotted as relative changes. The trunk diameters were approximately 10 inches (25 cm). Tree 2, the blight tree with the most severe visible wilt symptoms, showed the largest diurnal change in radius. Trees 1 and 3, which were healthy trees, showed smaller diurnal changes. Tree 4, with blight, showed the smallest changes.

The trunk water injection technique delineates the difference in water uptake between healthy trees and trees affected with blight or YTD more effectively than any other technique (6). The average ratio of water uptake by the healthy trees to that by the diseased trees was nearly 10 to 1 on April 4 and 5, 1974 (Table 1).

Average conductivity (cm/hr) for stems for 3 trials in the Agricultural Research Center grove was 0.93 for healthy and 0.85 for diseased trees; for roots: 4.74 for healthy and 2.60 for diseased trees. Measured conductivities were variable and inconsistent. Differences between healthy and diseased trees were not significant.

Based on soil sampling, the healthy trees appeared to use about 30% more water than the diseased trees from April 4 to April 16.

ALD-COMP Planting (YTD)

The patterns of water potential changes throughout a daily cycle (Fig. 3) in the ALD-COMP YTD grove were similar but the magnitudes were different from those obtained in the Agricultural Research Center blight grove. First, the root water potentials dropped lower during the early afternoon to about —16 bars. Second, the leaf

Table 1. Cummulative water uptake from gravity-fed trunk injection into Valencia orange scions on rough lemon rootstocks grown on Wabasso soil at the Ft. Pierce Agricultural Research Center.

			April 4							April 5				
			Eastern Standard Time											
Tree no.	Condition	Time Started	1008	1108	1215	1307	1407	1507	1607	0710	0829	0944	1137	1433
		EST	uptake in milliliters											
1	healthy	0810	52	97	144	178	214	249	280	483	497	511	538	560
2	blight	0815	2	4	7	10	11	14	18	29	30	30	31	34
3	healthy	0820	14	25	47	63	82	105	124	240	250	274	274	285
4	blight	0825	8	16	23	27	32	36	40	56	56	61	61	66

water potential of the afflicted trees remained at about 5 bars lower than the root water potential and apparently did not drop to as low as —25 bars. These diurnal curves of leaf and root water potential were constructed from 104 individual readings.

Stomatal diffusion resistance (Fig. 3) in the morning was about the same for the healthy and afflicted trees; it diverged at about noontime, with

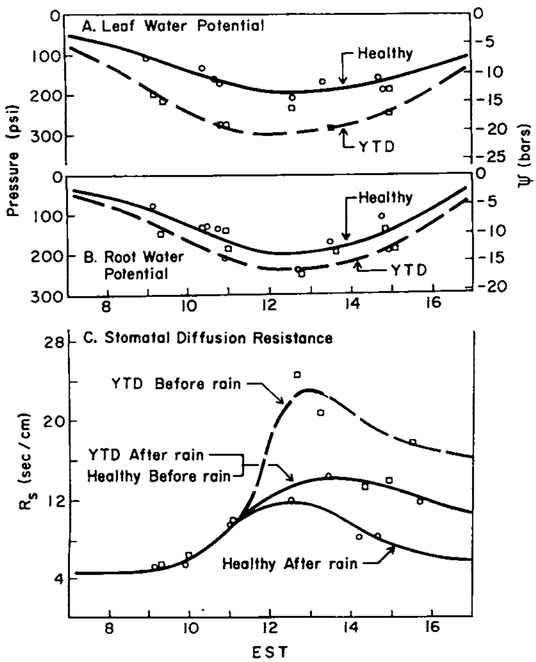

Fig. 3. Daytime cycle of water potential in leaves (A) and in roots (B), and daytime cycle of stomatal diffusion resistance (C) of healthy citrus (circles, ○) and of citrus afflicted with YTD (squares, □). May 14-16, 1974, 11-year-old Valencia orange scions on rough lemon rootstocks. Both healthy and YTD trees had lower stomatal diffusion resistances after the rain on the afternoon of May 15.

the diseased trees showing much larger values. (147 individual measurements were grouped into these curves.) However, even in the morning, the stomatal diffusion resistance was considerably higher for these trees than for the trees at the Agricultural Research Center (Fig. 1). We believe that both sets of trees in the ALD-COMP commercial grove were experiencing drouth stress because of the 11- to 13-day period since the last irrigation (flood irrigation on May 3) and the sandier soil. New root growth was not prominent in this grove.

The higher stomatal diffusion resistance in the morning in the 11-year-old ALD-COMP commercial grove (average about 7 sec/cm) was similar to that found by Elfving and Kaufmann (7) for 10- to 12-year-old 'Valencia' scions on 'Troyer' citrange rootstocks in southern California.

A 1.0 inch rain began at about 1300 EST on May 15. Except for that afternoon, the sky cover was about 60% cumulus clouds. The data collected on May 16 and on May 20 indicate that the stomata did not close as drastically in the afternoons after the May 15 rain. However, the morning values remained high compared to Agricultural Research Center planting.

Fig. 4 shows dendrometer data for the four trees of the 11-year-old ALD-COMP commercial grove for May 14- to 18. The trunk diameter for all trees increased rapidly after the early afternoon rain on May 15. This rapid recovery suggests that the major change in dendrometer recordings may be due to the bark shrinking and swelling as a result of evaporation from and wetting of its surface (1). The diurnal cycle of shrinking and swelling was only about 0.008 inches (0.2 mm).

Again, water uptake by healthy trees from gravity-fed trunk injection was about 10 times as great as in the diseased trees (Table 2), even though these trees with YTD had not declined as

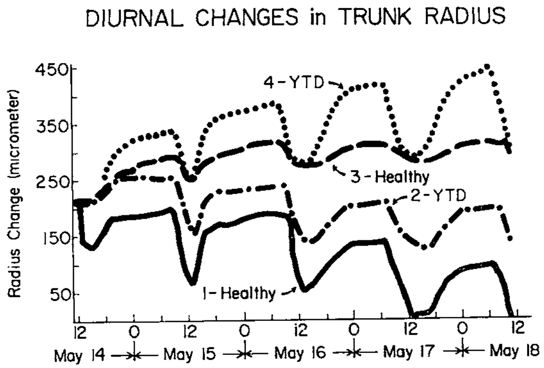

Fig. 4. Diurnal changes in trunk radius of healthy citrus and of citrus afflicted with YTD, obtained with linear variable differential transformers. Scale is arbitrary; only differences have meaning. 1 micrometer = 0.03937 mil (thousanth of inch).

extensively as the ones with blight at the Ft. Pierce Agricultural Research Center.

Conductivity measurements of stem segments from two trials on May 14 and 15 did not show clear-cut differences. In fact, conductivities of stem segments from the diseased trees (0.65 cm/hr) were slightly greater than those from the healthy trees (0.54 cm/hr). Likewise, the soil water content data were not clear-cut, and implied more water use by the YTD trees than by the healthy trees, even for the period May 9-15, 1974. Use of water by the weeds abundant in this grove may have contributed to the difference. We measured stomatal diffusion resistances of several grove weeds and found them all to be about 1 sec/cm, even in midafternoon, whereas the minimum average values for the trees were about 5 sec/cm in the morning, and much higher in the afternoon (Fig. 3).

In conclusion, we found that leaf water potential of trees with blight or YTD was always lower during daytime hours than the water potential of healthy trees. The daily water potential minima usually were lowest about 1400 EST.

No significant differences in stomatal diffusion resistance of well-exposed leaves were observed until after 1100 EST. In the early afternoon, the stomatal diffusion resistance tended to increase in the diseased trees, although there was considerable variation among leaves. The stomatal resistance also rose significantly in the afternoon in healthy trees in the ALD-COMP commercial grove; this rise may have occurred because the soil water content was lower in this grove than in the Ft. Pierce Agricultural Research Center grove.

The trunk water injections showed the greatest differences between diseased and healthy trees. The healthy trees typically took up water about 10 times faster than did the diseased trees. In general, the trunk injection and the water potential data suggest that the main restriction to water flow is in the above-ground parts. Because hydraulic conductivity of small stems or twigs was not different for the diseased and healthy trees, restriction of water flow in the major trunks and branches is implicated. More work is needed to pinpoint the sites of water flow restriction.

Table 2. Cumulative water uptake from gravity-fed trunk injection at the ALD-COMP grove.

		May 9 to May 15 Started 1300 - 1320 EST				May 20 to May 24 Started 1400 - 1420 EST		
		May 9	May 10	May 14	May 15	May 21	May 22	May 24
Tree no.	Condition	1500 EST	1300 EST	0830 EST	0856 EST	0935 EST	0945 EST	1400 EST
		uptake in milliliters						
1	healthy	12	136	175	180	307	390	434
2	YTD	0	4	9	10	11	18	28
3	healthy	7	88	135	138	260	365	442
4	YTD	0	7	23	24	10	16	25

Even though only a few trees were chosen for this study, many samples of root and leaf water potential, and stomatal diffusion resistance were taken. These samples showed consistent diurnal differences in water relations between blight or YTD trees and healthy trees.

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YOUNG TREE DECLINE AND SAND HILL DECLINE; STATUS OF INDEXING INVESTIGATIONS

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Abstract. **One hundred nineteen trees (donors) from 15 groves were indexed on 12 Citrus spp. (indicators) to determine virus content of trees affected with young tree decline (YTD) and sand hill decline (SHD). Indexing procedures and selection of indicators were designed to ascertain presence of at least 18 known citrus virus and virus-like diseases. Data from 1972 and 1973 indexing revealed primarily 3 transmissible agents: exocortis, tristeza, and a previously unreported stem pitting factor in seedlings of Mme. Vinous and Pineapple sweet orange. Stem pitting in these sweet orange indicators as well as in Rusk citrange, grapefruit, and Citrus excelsa appears to be dormancy/temperature related. Dual infections of tristeza and the Mme. Vinous-Pineapple stem pitting factor were present in all grove locations and there was a good correlation with YTD and SHD when budwood for indexing was obtained from donor trees in the early stage of disease. Although very extensive transmission and propagation experiments are in progress, neither transmission nor propagation of YTD and SHD has yet been demonstrated.**

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Young tree decline (YTD) and sand hill decline (SHD) are new and serious diseases of citrus trees on rough lemon rootstocks *(Citrus jambhiri)* in Florida. The former refers to decline of young trees in new groves in the flatwood areas, and the latter refers to the disorder affecting trees on sandy soils of the central ridge area. Both YTD and SHD (hereafter referred to as YTD) are considered to be diseases of the stock because the rough lemon root system appears to be the primary stressed area (9). Loss of trees from YTD, now estimated at 50,000 to 75,000 acres, has been most prevalent among groves of sweet orange on rough lemon rootstock. Grapefruit *(C. paradisi)* on rough lemon has also been severely affected in some areas. Some groves have become commercially unproductive in 6 years (5).

Etiology of YTD currently is unknown. Mineral nutrition (1), nematodes (13), lead toxicity from