by heavy rains before the plants could utilize them. Unfertilized, fresh volcanic, black cinders have a pH of 6.0 to 7.0. When used as a medium with slow-released fertilizers, the pH drops to 4.0. The acid pH, coupled with no Ca in the cinder, may account for the color breakdown of spathe in Hawaii.

Microautoradiography with ^{45}Ca showed that Ca was concentrated primarily in the cell wall of both spathe and leaf. There was no indication of crystallization of Ca, which would render it unavailable to the plants. Instead, it appears that color breakdown symptoms may be caused by cell membrane leakage causing the "water soaked" appearance of incipient injury.

The results show that Ca deficiency in anthurium can cause color breakdown disorder of the spathe. The lower Ca content in the lobe compared to the tip explains the localization of the color breakdown disorder to the lobe of spathes.

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Relationships between Water Translocation and Zinc Accumulation in Citrus Trees with and without Blight[1]

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Abstract. **Orange trees (*Citrus sinensis* (L.) Osb.) with early-stage (sectored) and moderate blight were evaluated for zinc accumulation and water translocation characteristics. Zinc accumulated at above-normal levels in the outer 2 cm of trunk wood, but water uptake was at below-normal levels in the inner 2 to 6 cm of trunk wood of moderately blighted trees. Water-flux density of roots was not correlated with zinc accumulation. In trees with early stages of blight, zinc accumulated at above-normal levels in the healthy-appearing sides of the trunks, as well as in the blighted sides, but the water uptake in the healthy-appearing sides was similar to that in the trunks of healthy trees. Evidence suggested that the blight effect on abnormal zinc metabolism developed prior to the dysfunction of water translocation.**

Citrus blight is a wilt disease found in several citrus-growing areas of the world (1, 3, 13, 20). The disease can be characterized by restricted water movement in roots, trunks, and large limbs (3, 4, 5, 17, 18, 20), xylem-vessel obstructions in roots and trunks (1, 2, 6, 8, 9, 12, 13), and above-normal zinc accumulation in the wood of roots, trunks, and large limbs (10, 15, 16, 20). Zinc accumulates at above-normal levels in the outer wood next to the cambium (10), whereas xylem-vessel obstructions occur in larger numbers in inner wood (8, 9). The restriction in water movement through roots, trunks, and limbs occurs in the inner, older xylem tissues (4, 17).

Since the cause of blight is unknown, characterization of zinc accumulation and water transport dysfunctions induced by the disease should provide new insight into its etiology. The purpose of this paper is to report new information on the relationships between the water-translocation dysfunction and the above-normal zinc accumulation that are associated with blight.

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Materials and Methods

Plant materials. Citrus used in these studies were 10-, 14- and 16-year-old 'Valencia' orange trees, *Citrus sinensis,* on rough lemon rootstock, *C. limon* (L.) Burm. f., and 14-year-old 'Hamlin' orange trees, *C. sinensis,* on Carrizo citrange, *C. sinensis* × *Poncirus trifoliata* (L.) Raf. These trees were located in 3 groves in central Florida. Trees selected included apparently healthy ones, those exhibiting an early stage of blight where the trees were sectored, and those exhibiting a moderate stage (16). On sectored trees, only one fourth to one third of the canopy exhibited the earliest typical visible blight symptoms. The sectored portion of the trees was confined to 1 or 2 adjacent major scaffold limbs. Moderately blighted trees had typical symptoms throughout the canopy. All sectored trees selected had exhibited blight symptoms less than 1 year as determined from our annual surveys of these groves.

Water uptake, dye distribution, and water-flux density measurements. In a study to compare water uptake by healthy and early-stage (sectored) blight trees, trunk water uptake was measured by the infusion method of Cohen (3). To measure water uptake at different depths in moderately blighted tree trunks, modified infusion methods were used. Uptake by xylem up to 2 cm in depth was accomplished through a specially designed surface-seal infusion device attached to the trunk (19). Uptake at depths of 2 to 4 cm and 4 to 6 cm was accomplished through metal injectors inserted into holes 12 × 20 mm and 12 × 40 mm, respectively, with each hole extended inward by a smaller 6- × 20-mm hole. In all instances, water uptake was measured over a 24-hr period by attaching calibrated water reservoirs to the metal injectors or modified infusion devices.

For a study of dye-distribution patterns, crystal violet (0.01% in water) was infused for 4 days into 6- × 20- and 100-mm holes through modified infusion devices (19). After dye infusion, trunk sections were cut at various locations above the injection site to observe dye distribution.

The water-flux density of roots 8 to 37 mm in diameter was determined by a vacuum method (5). Root pieces, 15 cm long, were connected between a vacuum source and a calibrated water reservoir, and the time required to pull 5 ml of water, at three-fourths atmosphere, through the root was recorded. Results are reported in flux density units as milliliters of waterflow per square centimeter of xylem cross-sectional area per minute ($ml/cm^2 \cdot min.$).

Analyses of trunk and root wood zinc. Samples of trunk wood from healthy and sectored trees (composites of 1.2-cm-diameter holes drilled 2.5 cm deep, 10 cm above the bud union) and healthy and moderately blighted trees (composites of 1.2-cm-diameter holes, drilled 0 to 2, 2 to 4, and 4 to 6 cm deep, 10 cm above the bud union) were collected, oven dried, and ground to 20 mesh. Wood of roots 8 to 18 mm in diameter were dried, ground to 20 mesh, and used in their entirety for analysis. For those 20 mm in diameter and larger, the outer 8 mm was removed, dried, and ground to 20 mesh. Zinc concentration was determined by standard digestion procedures and quantified by atomic absorption spectroscopy (15).

Results

Zinc concentration in the outer 2 cm of trunk wood of moderately blighted trees was significantly greater than in the 2- to 4-, or the 4- to 6-cm depths (Table 1). The primary difference in the zinc concentrations between blighted and healthy trees was the greater accumulation in the outer 2 cm of blighted trunk wood. Water uptake was greater in the outer 2 cm of wood in both healthy and blighted tree trunks than in the 2- to 4-cm and 4- to 6-cm depths. In blighted trees, a significant reduction in water uptake was apparent in the older wood of the 2- to 6- cm depth. The outer 2 cm of the 14-year-old trees, where water movement was effective in both blighted and healthy trees, represented approximately 18% of the total trunk area.

Dye-distribution patterns in the trunks of 10-year-old healthy and moderately blighted 'Valencia' orange trees can be seen in Fig. 1. Dye was infused to a depth of 10 cm in both trees. In the healthy tree, the dye moved upward in the outer 8 cm of trunk xylem. In the blighted tree, the dye moved upward only in the outer 1 cm of xylem, which represented only about 18% of the trunk area. Zinc concentrations in xylem tissues of the healthy tree were 3, 2, and 4 ppm at depths of 0-2, 2-4, and 4-6 cm, and in the blighted tree, concentrations were 17, 5 and 3 ppm for the same corresponding depths.

Table 1. Water uptake and zinc concentration at different xylem depths in trunks of healthy and moderately blighted 'Valencia' orange trees.

Xylem depth (cm)	No. trees	Healthy trees: Water uptake (ml/24 hr)	Healthy trees: Zinc (ppm)	Moderately blighted trees: Water uptake (ml/24 hr)	Moderately blighted trees: Zinc (ppm)
0-2	4	394 a[z]	2 a	362 a	10 b
2-4	4	112 bc	2 a	26 c	5 a
4-6	4	158 b	2 a	18 c	5 a

[z]Means separated within columns by Duncan's multiple range test, 5% level.

The zinc concentration in individual roots removed from healthy and moderately blighted 'Valencia' orange trees varied from 2 to 16 ppm and 1 to 31 ppm, respectively (Table 2). Although root diameters varied from 8 to 37 mm, there was no relationship between root diameter and zinc concentration. Water-flux density varied greatly in roots from both healthy and blighted trees, but the mean water-flux density was slightly lower in blighted roots. The lower mean water-flux density value for blighted roots was due to reduced waterflow through roots 8 to 20 mm in diameter (healthy, 29.8; blighted, 13.3). Roots 20 to 37 mm in diameter from healthy and blighted trees had similar water-flux density values (healthy, 9.7; blighted, 13.9). The correlation coefficient (r) for water-flux density and zinc concentration for individual roots was –0.17, which was not statistically significant.

In early-stage blight (sectored) trees of 14- and 16-year-old 'Valencia' and 14-year-old 'Hamlin' orange trees, water uptake in the trunks (outer 6 cm) of healthy trees and in the healthy-appearing sides of the sectored trees was similar and ranged from 630 to 1,000 ml (Table 3). However, water uptake in the blighted sides of the sectored trees was much less than in healthy trees and ranged from 62 to 181 ml. Zinc concentrations ranged from 3 to 4 ppm in the trunks of healthy trees and from 10 to 18 ppm in the trunks of blighted trees. There was no significant difference between the zinc concentration in the trunk wood of the healthy-appearing and the blighted sides of sectored trees even though water uptake on the healthy-appearing side was similar to that in the trunk of healthy trees.

Discussion

In healthy 14-year-old trees, trunk xylem vessels as deep as 6 cm functioned actively in water translocation, although to a lesser degree than in the outer 2 cm. Of particular interest was the greater reduction of water translocation through the inner xylem vessels in blighted trees than in healthy trees. In both 10- and 14-year-old moderately blighted 'Valencia' trees, water translocation was primarily in the outer 18% of xylem. The lesser water translocation in inner xylem vessels of blighted trees than in healthy trees might be related to greater numbers of xylem-vessel obstructions in the inner, older wood of blighted trees (8, 9). Although we did not critically evaluate the numbers of xylem obstructions in blighted tree trunks, cursory examination indicated more obstructions in the inner xylem vessels of blighted trees than in healthy trees.

The finding of above-normal levels of zinc in the outer 2 cm of the trunk wood of moderately blighted trees was consistent with the findings of Smith (10). Additionally, zinc concentrations were high in the trunk wood of both healthy-appearing and blighted sides of early-stage (sectored) trees. No relationship was found between zinc levels and reduced water translocation capability (water-flux density) in roots. It was quite common to find roots, from moderately blighted trees, that had above-normal zinc concentrations and normal water-flux density values.

Our findings provided new insight into the physiology of citrus blight. From our data it was clear that above-normal levels of zinc accumulated in tissues other than those in which water-translocation dysfunction occurred. In fact, it was apparent that the effect of blight on zinc accumulation occurred prior to the reduction of water-translocation capability as evidenced by the above-normal accumulation of zinc in the trunk of the apparently healthy side of sectored trees where the water-translocation capability was still similar to that in healthy trees. We suspect that an even earlier stage of blight development exists in which visible blight symptoms are not apparent,

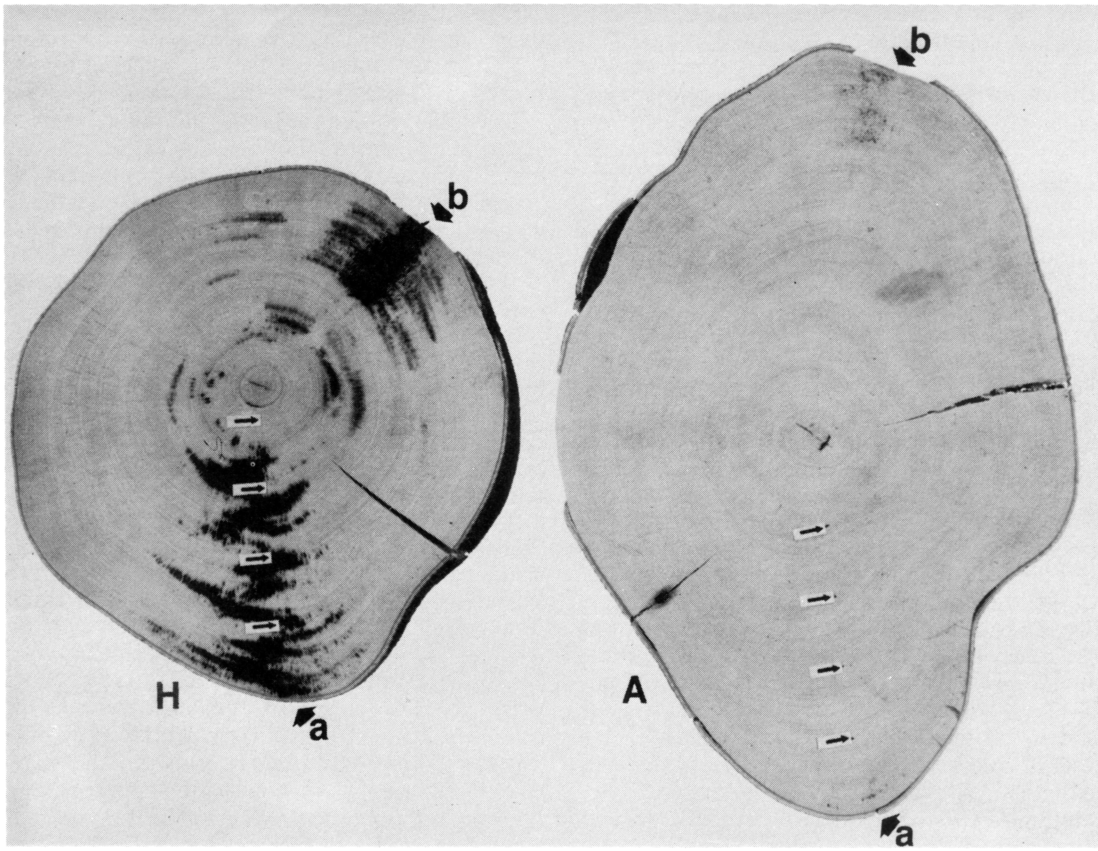

Fig. 1. Dye distribution patterns in trunk sections (15 cm above the injection site) of (H) healthy and (A) blighted 10-year-old 'Valencia' orange trees. Small arrows indicate successive 2-cm wood depths. Large arrows indicate injection sites into a) 100 mm- and b) 20 mm-hole depths.

and water-translocation dysfunction has not occurred, but in which an abnormal zinc metabolism has resulted in zinc accumulation in roots, trunks, and large limbs. Smith (10) and Wutscher (16) reported that the minor elements, manganese, copper, and iron, do not accumulate abnormally, like zinc, in the wood of blighted trees. It has also been reported that zinc accumulates in the materials composing the xylem-vessel obstructions and in border pits (10), but this accumulation has not been confirmed. Phenolic compounds (15, 18, 20) and lipids (6, 7, 9) also accumulate with zinc in wood of moderately blighted trees but the relationship, if any, is not clear. Further clarification of the nature of above-normal zinc accumulation should provide important leads to the cause of blight.

Table 2. Water flux density and zinc concentration in roots from healthy and moderately blighted 'Valencia' orange trees.

Factor		Healthy roots	Moderately blighted roots
Number of roots		13	16
Root diameter (mm)	mean	23	24
	range	8-32	8-37
Water flux density (ml/cm^2·min)	mean	16.2	13.5
	range	4.2-50.0^z	0.0-42.0^z
Zinc concentration (ppm)	mean	6	8
	range	2-16^z	1-31^z

^{z}Correlation coefficient: water flux density vs. zinc content: r = –0.17, N.S.

The reason(s) for the water-translocation dysfunction in blighted trees remains in question. It has been suggested that xylem-vessel obstructions (1, 8) and small xylem-vessel diameters (8) contribute appreciably to reduced water translocation in moderately blighted trees. There seems to be no question that more obstructions are present in the xylem vessels of moderately blighted trees than in those of healthy trees and that some areas contain massive vessel plugging. Cohen (4) and Young (17) recently demonstrated areas of massive restricted water movement in trunks and large limbs. However, definitive experiments to conclusively prove that vessel plugs restrict water movement have not been conducted. A further suggestion has been made (11) that the restriction of vertical water movement by vessel plugging is not sufficient to cause blight symptoms, and that lateral water movement must also be

Table 3. Water uptake and zinc concentration in trunks of healthy and sectored 'Valencia' and 'Hamlin' orange trees.

Tree condition	No. trees	Water uptake (ml/24 hr)	Zinc concentration (ppm)
Healthy	11	947 a^z	3 a
Sectored	11		
Healthy side		787 a	15 b
Blighted side		108 b	12 b

^{z}Means separated within columns by Duncan's multiple range test, 5% level.

restricted. Evidence that lateral dye movement is greatly restricted in blighted tree trunks has been reported (17). An examination of xylem vessels from blighted trees by electron microscopy has demonstrated not only vessel obstructions, but also the presence of plugging materials in vessel pits, which are part of the lateral water movement system (12). Xylem-vessel obstructions, which originate from paravascular parenchyma cells (6) or primary walls or middle lamella (12), may result from a natural phenomenon related to senescence or a host response to a pathogen. Toxins or enzymes from a pathogen may be involved. Presently, no evidence exists to relate xylem-vessel obstructions or reduced vessel size with incipient water-translocation dysfunction.

Studies currently underway on the mechanisms of above-normal zinc accumulation and water-translocation dysfunction are of prime importance in determining a cause of blight. The use of trees with early stages of blight where trees are sectored offers a valuable tool for the accomplishment of this reasearch.

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Drainage Requirements for Sweet Potato at Harvest[1]

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Additional index words. pH, potassium, soil texture, flood damage, *Ipomoea batatas*

Abstract. **Poor drainage resulting in high soil moisture causes wet soil injury in the fleshy roots of sweet potato (*Ipomoea batatas* (L) Lam). Sweet potato lines with varying resistance to flood damage were grown in a sandy loam and a silt loam soil and subjected to water table drawdown rates of 5, 20, 35 and 100 cm/day for 7 days prior to harvest. Decay increased with time after harvest and decreasing drawdown rate. 'Julian' had the longest postharvest keeping quality for the various drainage rates applied and there was no difference in keeping quality between soils. 'Centennial' was intermediate, showing wet soil damage with lower drainage rates and the damage was higher on the silt loam than on the sandy loam soil. NC 257 showed high wet soil injury for all drainage rates with greater injury in the finer textured soil. Decay of the roots was greater in 1976 than in 1975 for all genetic sources. pH, titratable acidity and soluble K were well correlated with decay in 1975 but not in 1976.**

In humid areas, where rainfall often occurs during the harvest season, lack of adequate drainage delays maturity of grain crops and induces flood damage in tuber and root crops. Furthermore, inadequate drainage for root crops such as sweet potato and yam produces conditions suitable for decay, thus reducing root quality and the length of time they may be stored. The amount of injury caused by excessive soil water during the harvest period depends on the plant species, soil, temperature and stage of plant development.

Plants respond differently to depth of free water in soil. The effect of wet soils on crops and the response of crops to drainage

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