

has been reported to delay onset of water saturation deficit and wilting of carnation petals (Borochoy et al., 1976). Application of CO₂ with ethylene has been shown to prevent the decline in water uptake of carnations (Borochoy et al., 1976).

Water potential and solute potential changes during the dark were measured in the control and ABA-treated plants. Water potential decreased during the dark in the control and ABA treatments, but reduction of water potential was faster in the control (Fig. 2, top). Solute potential of control plants decreased during the dark, but that of ABA-treated plants remained high (Fig. 2, bottom). Although solute accumulated during the dark, accumulation was not enough to maintain constant turgor potential in the ABA-treated plants (Fig. 2, bottom). The lack of photosynthesis and slow uptake of water due to slow transpiration may have prevented sufficient osmotic adjustment in the dark. As a result of slow solute accumulation and drop in water potential, pressure potential dropped during the dark in both control and ABA-treated plants (Fig. 2, middle).

The data obtained in this experiment suggest that pre-treatment with ABA and STS significantly decreased the transpiration rate of chrysanthemum during storage. Cost would limit the practical use of ABA. Although stomata are assumed to close in the dark, reduction of transpiration rate by pre-treatments indicates incomplete closure of stomata in the dark. Complete closure of stomata or prevention of stomatal opening by pre-treatment may have caused the reduction of transpiration rate of treated plants. Pre-treatment with ethylene increased water loss during the subsequent dark period, which can induce water stress conditions. Therefore, eliminating the build-up of ethylene or preventing its action, with compounds such as STS, likely would lessen water stress during dark shipping or storage.

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Phony Disease Influences Peach Leaf Characteristics

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Abstract. Midshoot peach [*Prunus persica* (L.) Batsch.] leaves were collected in 1984 and 1985 from phony-diseased [presumably infected with *Xylella fastidiosa* (Wells et al.)] and healthy trees of several cultivars at intervals during the summer. Leaves were evaluated for specific chlorophyll content, specific leaf weight, and color (lightness, hue, and saturation). The darker green of diseased trees reported previously could not be attributed to the quantitative changes in the leaf characteristics measured in this study. Midshoot leaves from diseased trees were more yellow and less green than midshoot leaves from healthy trees.

Phony disease of peach occurs in orchards in the Coastal Plain from North Carolina to Texas (Hutchins, 1933). The disease is caused by a xylem-limited bacterium (*Xylella fastidiosa* strain phony disease of peach) (Wells et al., 1987). These bacteria are usually more abundant in peach roots than in stems or leaves (Davis et al., 1981; French et al., 1977; Wells et al., 1980). Roots of trees with obviously reduced shoot growth usually contain an abundance of this bacterium (Evert et al., 1981). Several species of xylem-feeding leafhoppers spread the bacterium from tree to tree (Davis et al., 1981; Turner and Pollard, 1959).

Symptoms of phony disease include small fruit and low yield (Hutchins, 1933), apparently because fruit fail to swell normally as they mature (Evert, 1985). The reduction in fruit size and yield, as well as other symptoms, develop 18 months or more after the initial infection (Hutchins, 1933; Turner and Pollard, 1959). Tree color is also affected by

phony disease, with several reports describing diseased trees as darker green than healthy trees (Wells and Raju, 1984; Hutchins, 1933; Turner and Pollard, 1959; Bertrand, 1982). Hutchins (1933) gives a detailed description of the symptoms of phony disease, of which the most obvious symptom is reduced terminal shoot growth. The reduced shoot growth of diseased trees is routinely used for field identification during the summer beginning in July (Bertrand, 1982; Hutchins, 1933).

The current method of field identification of diseased trees has several problems. Field identification of diseased trees is subjective and, therefore, observer-dependent. Infected trees may be a reservoir of infection during the 18-month or longer incubation period before disease symptoms develop.

A rapid, quantitative method for field identification of diseased trees would eliminate observer bias and might permit the identification of infected trees sooner than is currently possible. Leaf color can be measured rapidly and quantitatively with a tristimulus color meter. We selected leaf color for study because of the reports that phony disease affects leaf color.

We examined the effects of phony disease of peach on specific leaf dry-weight (SLW), specific chlorophyll-content (SCC), and leaf color attributes (hue-angle, saturation, and lightness). SLW and SCC were examined because changes in SLW and SCC might be related to color changes.

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Table 1. Specific leaf weight and specific chlorophyll content (SCC) by cultivar for healthy and diseased peach trees in 1985.^z

Cultivar	Specific leaf wt (g·m ⁻²)		SCC (mg·m ⁻²)	
	Healthy	Diseased	Healthy	Diseased
Junegold	48.0	49.4 ^{NS}	143	140 ^{NS}
Maygold	41.8	48.0*	130	145*
Harvester	44.0	45.0 ^{NS}	138	143 ^{NS}
Loring	43.7	49.7**	144	162**
Dixiland	43.8	54.6**	139	167**

^zMeans of 15 observations, except 10 observations for healthy 'Maygold'.

^{NS},*,**Nonsignificant or significant at $P = 0.05$ or 0.01 , respectively.

Table 2. Specific chlorophyll content (SCC) and leaf hue-angle by date for healthy and diseased peach trees in 1985.^z

Date	SCC (mg·m ⁻²)		Hue-angle (°)	
	Healthy	Diseased	Healthy	Diseased
14 May	142	166**	131.1	130.7 ^{NS}
12 June	146	169**	131.3	129.6*
9 July	138	148 ^{NS}	127.3	123.7**
6 Aug.	140	140 ^{NS}	124.9	121.5**
4 Sept.	128	133 ^{NS}	123.9	121.5**

^zMeans of 12 healthy trees and 15 diseased trees, 15 for all others.

^{NS},*,**Nonsignificant or significant at $P = 0.05$ or 0.01 , respectively.

1984. Healthy and diseased trees of 'Springcrest', 'Rio Grande', 'Flordagold', and 'Suwanee' peaches in commercial bearing orchards were identified 19 and 25 June and 9 and 16 July in Brooks County, Ga. Trees were considered diseased only when the new shoot growth was <20% of shoot growth of healthy trees of the same cultivar in the same orchard on the same date and when they had no symptoms of other diseases (Evert et al., 1981; Hutchins, 1933). Two healthy and two diseased trees per cultivar were identified on each date, and 50 fully expanded leaves were collected per tree from the middle third of shoots on the outside of the canopy at 1.5 to 2 m high.

Color values (L, a, and b) were measured near the center of each of 10 leaves per sample with a Gardner XL-20 tri-stimulus colorimeter. The colorimeter was standardized with a 1-cm-diameter aperture and a reference plate; L = 92.94, a = -1.05, and b = 0.44. Hue angle = $\tan^{-1}(b/a)$ and saturation = $(a^2 + b^2)^{1/2}$ were calculated and used with lightness (L) to evaluate leaf color.

Chlorophyll content of the same 10 leaves was determined from four disks per leaf cut with a 12-mm cork borer from regions free of major veins. The 40 disks were blended in 100 ml of acetone for 5 min. The mixture was covered and placed in the dark for 15 min. The liquid was filtered and the optical density of the filtrate was measured at 642.5 and 660 nm. The total specific chlorophyll concentration (SCC) (chlorophyll a + b) was calculated from the measured optical density and from chlorophyll extinction coefficients and was expressed as mg chlorophyll/m² of leaf (Smittle and Bradley, 1966).

Specific leaf dry weight (SLW) was calculated from the fresh weight of leaf disks (FW), the total area of the disks (A), the fresh weight of the remaining 40 leaves (W_r), and the dry weight of the remaining 40 leaves (W_d) by: $SLW = FW \cdot A^{-1} \cdot W_d \cdot W_r^{-1}$.

The dependent variables lightness, hue angle, saturation, SCC, and SLW were analyzed in a three-factor completely randomized design. The three independent factors were the four cultivars, the four dates, and the two disease ratings.

All five leaf characteristics—SLW, SCC, hue-angle, saturation, and lightness—had cultivar × date interactions ($P = 5\%$; data not shown). These interactions were expected because leaf characteristics vary among cultivars, respond to orchard management, and change as trees grow.

Phony disease did not affect saturation, lightness, or SCC (data not shown). Phony disease did affect hue-angle and SLW. Hue-angle, a measure of the dominant wavelength of light reflected by a sample, is the quantitative measure of color that corresponds most closely to the visually perceived color (Hunter, 1975). The mean hue-angle of all leaves was 127°, which would appear to the normal eye as green with some yellow. For comparison, the yellow colorimeter standard we used has a hue-angle of 91°; and the dark green standard has a hue-angle of 167°. The mean hue-angle for diseased trees was smaller than for healthy trees (more yellow and less green), but the difference was significant for only two of the 16 cultivar-date combinations. Diseased 'Flordagold' trees on 16 July had a hue-angle of 118° vs. 123° for healthy trees ($P = 0.01\%$), and diseased 'Rio Grande' trees on 9 July had a hue-angle of 126° vs. 129° for healthy trees ($P = 5\%$).

SLW was higher ($P < 5\%$) for diseased trees (36.8 g·m⁻²) than for healthy trees (35.1 g·m⁻²) ($P < 5\%$); the difference was independent of date and cultivar.

1985. 'Junegold', 'Maygold', 'Harvester', 'Loring', and 'Dixiland' trees in an 8-year-old commercial peach orchard in Tift County, Ga., were rated in May 1985 as healthy or diseased based on shoot growth.

The disease rating was confirmed by microscopic examination of root extracts for phony peach bacteria (PPB) (French et al., 1977). Healthy trees had normal shoot growth and zero PPB per microscope field; diseased trees had <20% of the shoot growth of healthy trees and >20 PPB per microscope field. Trees not meeting both requirements (shoot growth and PPB counts) were excluded. Three diseased and three healthy trees were selected from each of the five cultivars. Data were discarded from one apparently healthy tree whose roots contained <20 PPB per microscope field when sampled Mar. 1986, after the experiment was completed. Samples of 50 leaves per tree were collected every 4 weeks from 14 May to 4 Sept. 1985. The leaf samples were collected and handled as in 1984.

The design was a split-plot experiment with both fixed and random effects. Main plots were individual trees with a factorial arrangement of cultivar and phony disease; split-plots were the five months. Cultivar and date were treated as random samples from all possible cultivars and dates, and phony disease was treated as a fixed effect (Steel and Torrie, 1980). Cultivar, date, phony disease, and their interactions were tested for significance using the error terms appropriate for a mixed model (Steel and Torrie, 1980).

Main effects of cultivar and date were significant for each dependent variable ($P \leq 0.1\%$) when tested for significance by the cultivar × date interaction. However, the cultivar × date interaction was significant ($P = 0.01\%$) for each dependent variable other than SCC (data not shown).

Phony disease affected color saturation and lightness, but the effect varied with cultivar and date and lacked consistency (data not shown).

SLW was 44.3 g·m⁻² for healthy trees and 49.4 g·m⁻² for diseased trees ($P < 5\%$), and SCC was 139 mg·m⁻² for healthy trees and 151 mg·m⁻² for diseased trees ($P < 10\%$). The main effect responses of SLW and SCC to phony disease were tested for significance using the phony × cultivar interaction. However, the effect of phony disease on SCC and SLW varied with cultivar. SLW and SCC were higher in diseased than in healthy 'Maygold', 'Dixiland', and 'Loring', but not in 'Junegold' or 'Harvester' (Table 1). The increased SCC in leaves of diseased trees did not consistently translate into increased saturation or decreased lightness (data not shown), and chlorophyll content of diseased and healthy trees was equivalent when chlorophyll content was expressed per unit of dry weight rather than per unit of area (data not shown).

The effect of phony disease on SLW was independent of month (data not shown), but the effect on SCC varied with month (Table 2). SCC was higher in diseased trees than in healthy trees in May and June and equivalent in later months. Identification of diseased trees in the field by color or growth is difficult in May and June (Hutchins, 1933).

Hue-angle was 128° and 125° for healthy and diseased trees, respectively ($P < 5\%$).

The difference between the hue-angle of healthy and diseased trees was tested for significance using the phony \times date interaction. The effect of phony disease on hue-angle was independent of cultivar (data not shown), but the effect varied with date. Hue-angle was smaller for diseased trees than for healthy trees at all dates from June on (Table 2). SCC and hue-angle tended to decline in healthy and diseased trees after June; however, diseased trees had increased SCC and decreased hue-angle relative to healthy trees (Table 2).

We had expected the quantitative measurements of leaf color to confirm previous reports that diseased trees have darker green leaves than healthy trees (Hutchins, 1933; Turner and Pollard, 1959; Wells and Raju, 1984). Instead, we found the opposite. This unexpected response probably occurred because the eye tends to perceive the color of an entire tree, not individual leaves.

The overall perceived color of diseased trees may be a darker green than the color of healthy trees for most of the growing season because healthy trees produce new leaves in spring and summer while diseased trees produce new leaves only in spring. The presence of new, light-green leaves on the outside of the canopy of healthy trees makes the perceived color of healthy trees appear a lighter green than that of diseased trees. Also, the relatively sparse foliage of a healthy tree transmits more light through the canopy than

does the relatively dense canopy of a diseased tree, which has shortened internodes.

Hue-angle has the best potential, of the measurements studied, for identifying diseased trees. Hue-angle measurements of individual leaves could provide a rapid and quantitative method to replace the current subjective method of field identification. Neither hue-angle measurements in this study nor visual appearance of the tree in other studies could identify diseased trees when new leaves are present on all trees. Finally, hue-angle measurements showed that leaves of diseased trees were more yellow and less green than leaves of healthy trees, which was contrary to what we expected.

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