Chlorophyll Photobleaching: An Occasionally Severe Disorder of *Ficus benjamina* in Southern California

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Abstract

In late June, 2023, we observed severe and extensive chlorophyll photobleaching (CPB) on the landscape tree *Ficus benjamina* in coastal Southern California from San Diego to Santa Barbara. We surveyed 258 trees along three 16.1- to 19.9-km transects from near the ocean to inland in Los Angeles and Orange Counties. We recorded the location, severity of CPB, height and width of trees, and whether they had been pruned in the previous nine months. Analyses of these data showed that trees closer to the ocean, recently pruned, and/or taller showed significantly more CPB. We suggest that a combination of environmental factors or stresses, many related to the unprecedented long, cool, and wet winter, and cultivation practices, such as pruning, likely triggered CPB. To prevent and/or mitigate future occurrences of CPB, we suggest providing optimal cultivation (water, fertilizer, mulch) and avoid pruning from July through February.

Introduction

Ficus benjamina (weeping fig or weeping banyan, shiny-leaf fig) ranges from India and southern China through Southeast Asia, Malaysia, and Indonesia to Australia and the Solomon Islands, where it occurs in primary or secondary tropical forest up to 1,300 m elevation. It is primarily a hemi-epiphyte or perhaps sometimes terrestrial tree reaching up to 35 m tall (Berg and Corner 2005) and as wide or commonly even wider in its native habitat or other tropical locations. As a

Figure 1. In wet, tropical locales, as here in Honomū, Hawai'i, *Ficus benjamina* can become an imposing, spreading tree with an umbrella-shaped canopy.

Figure 2. In wet, tropical locales, as here in Fiji, *Ficus benjamina* is typically festooned with aerial roots and root columns or trunks for added support.

Figure 3. In California, *Ficus benjamina* has a vase-shaped or rounded canopy with upright or spreading branches and lacks the aerial roots and support columns of those in tropical locales.

Figure 4. *Ficus benjamina* typically forms a rounded canopy with upright branches in California.

hemi-epiphyte, its seeds are deposited on a host species, they germinate, and the seedlings grow within the canopy of the host tree, sending down its own roots to the ground and eventually completely overtaking the host and killing or "strangling" it. The hemi-epiphyte then becomes a free-standing specimen. This phenomenon is common to many species of *Ficus* in wet, tropical areas but is seldom, if ever seen in arid, subtropical locations like California.

A variable species, *Ficus benjamina* is noted for its fine-textured canopy of shiny or lustrous, elliptic to oblong to subovate, flat to undulate, mostly glabrous, relatively small leaf blades 2–14 × 1.5–6(–8) cm with long-acuminate tips and rounded to obtuse bases. Blades emerge light green and mature to green or dark green and have 6–12(–16) pairs of lateral veins. Stipules are 0.5–1.5(–2) cm long and glabrous. Petioles are 0.5–1.5(–2) cm long and held on glabrous, tan to whitish, slender twigs 1–2(–3) mm in diameter, which are somewhat zig-zag distally and eventually with prominent lenticels and a sometimes flaky periderm. Figs are axillary, mostly paired, sometimes solitary, sessile, 0.5–1(–1.5) cm in diameter, subglobose to ellipsoid to obovoid or to subpyriform, yellow to orange to dark red, and mostly glabrous (Berg and Corner 2005).

In tropical locations, isolated, free-standing trees of *Ficus benjamina* are exceedingly handsome, forming a wide-spreading, umbrella-shape canopy with weeping or drooping branch tips and typically festooned with aerial roots and root columns or trunks for added support (**Figs. 1–2**). In contrast in California, old landscape trees typically attain about 8 to 12 m in height and spread, forming a vase-shaped or rounded canopy with upright or spreading branches with spreading to pendulous branch tips and lack the aerial root support columns (**Figs. 3–4**). They are still handsome trees, though, due to their lustrous leaves, fine texture, and small orange to reddish figs.

Because of its tropical origin, *Ficus benjamina* was mostly treated as an indoor decorative plant in Southern California until about the 1950s, a situation and use to which it is well adapted. By the 1950s through the 1970s, though, some specimens that grew too large indoors were planted outdoors in the landscape and grew fairly well, and a few nurseries began to offer it as an outdoor tree as well. Thus, by the latter part of the 20th century, *F. benjamina* had become an established outdoor tree, especially along the coast and adjacent plains and hills that correspond to Sunset Zones 22, 23, and 24, the most frost- and freeze-free environments in California (Williamson 1988). Because it is not as cold-hardy or -tolerant as other common outdoor landscape *Ficus*, such as *F. macrophylla*, *F. microcarpa*, and *F. rubiginosa*, it is more uncommon farther inland where yearly winter cold or occasional freezes severely damage or kill it.

Figure 5. *Ficus benjamina* in Seal Beach, California showing its canopy of variously chlorophyll photobleached leaves (30 June 2023).

Figure 6. Close inspection of the canopy of *Ficus benjamina* shows various stages of chlorophyll photobleached leaves (30 June 2023).

In late June of 2023, we noticed a spectacular and strange phenomenon with landscape *Ficus benjamina* trees in coastal Southern California from San Diego to Santa Barbara, which garnered much attention among landscape professionals and the general public. From a distance, tree canopies appeared white or flocked, nearly like holiday Christmas trees (**Fig. 5**). Closer inspection showed leaves lacked chlorophyll and varied from a mosaic pattern of green and white to all white, as if they had been bleached (**Figs. 6–7**). The term for this phenomenon is chlorophyll photobleaching (CPB), and is primarily due to excessive light although other, mostly environmental factors, typically play a significant role in its development.

Symptoms of CPB on *Ficus benjamina* typically occur over the entire canopy of the tree, including the top and sides. Leaves exhibit a variety of stages of chlorophyll loss, ranging from less than 20 percent of the blade with a mosaic pattern of green and white to 100 percent of the blade being white (**Figs. 8–11**). Bleached leaves often fall away. In severe cases, petioles are white and twigs to which they are attached are pinkish red (**Fig. 12**). Sometimes all leaves, as many as seven or eight, on the distal end of a twig are all white (**Fig. 13**) while in other instances on short twigs of epicormic growth, the most proximal leaf is all white and each successive leaf progressively contains more chlorophyll until the most distal leaf is entirely green (**Fig. 14**). We have observed that affected leaves emerge green and normal and then became bleached. Bleached leaves do not regain chlorophyll, and recovery of the tree is dependent on bleached leaves falling away and/or new, normal green growth emerging from behind the bleached growth and overtaking and hiding it. Variegated selections of *F. benjamina* show different color patterns than that of CPB,and typically have leaves with green centers and white margins (**Figs. 15–16**) The long-term impacts on the tree of severe CPB are undocumented.

Curiously, CPB might not be limited simply to *Ficus benjamina*; other tree species exhibited similar or the same symptoms during the late spring and summer of 2023, including *Bauhinia galpinii*, *Cercis canadensis* 'Silver Cloud', *Cinnamomum camphora*, *Erythrina* × *sykesii*, *Ligustrum lucidum*, and *Pyrus calleryana* var. *calleryana* (*P. kawakamii*). However, the *C. camphora* mostly exhibited interveinal chlorosis with little or no mosaic green and white and the symptoms on *P. calleryana* might be due to or enhanced by fire blight disease.

Coming on the heels of a nearly unprecedented and prolonged, cool, and wet winter, suspicion was immediately cast upon the weather and related environmental factors. We also noticed that damage appeared to be more common on trees closer to the coast and more severe on trees pruned within the last nine months, especially on trees subject to severe and overzealous pruning techniques like coat-racking or hat-racking (**Fig. 17**).

Thus, we designed and conducted a multipronged study to determine the cause of this malady and develop the best management practices to correct it and prevent its recurrence in the future.

Figure 7. Leaves of *Ficus benjamina* show various stages of chlorophyll photobleaching (30 June 2023).

Figure 8. Leaves of *Ficus benjamina* show various stages of chlorophyll photobleaching (30 June 2023).

Figure 9. Leaves of *Ficus benjamina* with chlorophyll photobleaching show a distinct mosaic pattern of chlorophyll loss (25 July 2023).

Figure 10. *Ficus benjamina* adaxial leaf blade surface with chlorophyll photobleaching shows mosaic pattern (7 July 2023).

Figure 11. *Ficus benjamina* abaxial leaf blade surface with chlorophyll photobleaching shows mosaic pattern (7 July 2023).

Figure 12. In severe cases of chlorophyll photobleaching on *Ficus benjamina*, petioles are white and twigs to which they are attached are pinkish red (20 June 2023).

Figure 13. Sometimes with chlorophyll photobleaching of *Ficus benjamina*, all leaves on the distal end of a twig are all white (30 June 2023).

Figure 14. With chlorophyll photobleaching of *Ficus benjamina*, sometimes on epicormic growth the most proximal leaf is all white and each successive leaf progressively contains more chlorophyll until the most distal leaf is entirely green (12 August 2023).

Figure 15. Variegated selections of *Ficus benjamina* typically have leaves with green centers and white margins.

Figure 16. Variegated selections of *Ficus benjamina* typically have leaves with green centers and white margins.

Figure 17. Chlorophyll photobleaching on *Ficus benjamina* is more severe on trees pruned within the last nine months, especially on trees subject to severe and overzealous pruning techniques like coat-racking or hat-racking (20 June 2023).

Materials and Methods

Three Transects

Because observations led us to suspect that CPB tended to be more severe closer to the coast and on recently pruned trees, in July, 2023, we selected three major thoroughfares or streets (transects) that ran nearly due south from the coast to north, about 16 to 20 km inland (**Table 1**). The three transects were selected because they ran mostly through residential areas where we suspected trees might be more common. The transects are parallel to each other and spaced about 4 to 5.5 km apart. Transect 1, the farthest west, was entirely within Los Angeles County. Transect 2, the next one to the east, began in Orange County but ended in Los Angeles County. Transect 3, the farthest east, was entirely within Orange County (**Fig. 18**). We ended the transect when we observed no tree damage after several km.

Along each transect, starting from the south near the coast, we recorded the address of each visible *Ficus benjamina* tree and consensus rated CPB damage on a scale of 1 to 5 (1 = 0 to 20% of canopy photobleached, 2 = >20 to 40% of canopy photobleached, 3 = >40 to 60% of canopy photobleached, 4 = >60 to 80% of canopy photobleached, and 5 = >80 to 100% of canopy photobleached. For each tree we consensus estimated height and width in meters and whether it had been pruned in the previous nine months. Although the transects ran mostly south to north, they intersected the coast at about a 45° angle; thus, we determined distance from the ocean for each tree using Google Earth Pro and measured from each address on the shortest-line vector to the coast.

We performed statistical analyses with an analysis of variance using the R base package (R Core Team, 2021) and the CAR package (Fox and Weisberg 2019). Analysis of tree damage used a linear model that included the fixed effects of pruning and transect, and the effects of distance from the ocean and tree height as covariates. We compared two pruning treatments (pruned and unpruned) on occurrence and severity of CPB along with the differences in damage severity across transects. Least squares means and mean differences between effect levels were estimated, and we then estimated regression coefficients for effects of tree height and distance from the ocean.

Transects 2 and 3 had many more trees than Transect 1, which was mostly due to the fact that they had substantially more addresses with multiple trees than did Transect 1. For example, Transect 1 had only one address containing more than two trees while Transect 2 had 12 addresses with more than two trees with a maximum of 18 trees in one address and Transect 3 had 13 addresses with more than two trees with one of these having 18 trees and another having 20 trees. This disparity resulted in an unbalanced data set.

Table 1. Characteristics of transects (arranged west to east) used in *Ficus benjamina* chlorophyll photobleaching study, July, 2023.

	Transect 1	**Transect 2**	**Transect 3**
Thoroughfare Names	**Bellflower Blvd.**	**Seal Beach Blvd./ Los Alamitos Blvd./ Norwalk Blvd.**	**Goldenwest Ave./ Knott Ave.**
Length (km)	16.1	18.0	19.9
Cities	Long Beach, Lakewood, Bellflower, Downey	Seal Beach, Los Alamitos, Long Beach, Hawaiian Gardens, Lakewood, Cerritos, Artesia, Norwalk	Huntington Beach, Westminster, Garden Grove, Stanton, Cypress, Anaheim, Buena Park
Starting Location	33.768053, -118.121000, 1 m elev.	33.737011, -118.125191, 8 m elev.	33.673128, -118.012057, 18 m elev.
Ending location	33.912413, -118.125191, 36 m elev.	33.893912, -118.073074, 30 m elev.	33.851140, -118.011089, 20 m elev.
Distance to next transect to east (km)	4.0	5.5	---
Quantity of Trees	37	87	133
Mean Trees/ km	2.3	4.8	6.7
Mean Trees per Address	1.6	2.7	4.0

To determine if this unbalanced data set was significantly skewing our analyses, we randomly selected only one tree from any address that had multiple trees in each of the three transects to create a revised, smaller data set. We analyzed this smaller data set similarly to how we did the original, larger data set.

Soil and Leaf and Root Tissue Analyses

Also, we gathered soil and leaf and root tissue samples from one severely affected tree on Transect 2 in Seal Beach for laboratory analyses. Soil samples were analyzed for salinity, pH, nitrogen, phosphorous, potassium, magnesium, sulfur, calcium, manganese, iron, boron, copper, and zinc. Leaf tissue was analyzed for nitrogen, phosphorous, potassium, magnesium, sulfur, calcium, manganese, iron, boron, copper, and zinc.

Figure 18. Google Earth image showing the three transects used in this study of chlorophyll photobleaching on *Ficus benjamina*, Los Angeles and Orange Counties, July, 2023.

Pest and Disease Detection

Leaves, buds, twigs, and roots were carefully and microscopically examined for evidence of pests and diseases and cultured where appropriate. Because evidence of past whitefly activity was present, leaves were also screened for viruses in the closterovirus, begomovirus, and emaravirus (*Ficus* mosaic emaravirus) groups using qPCR detection methodology. Waypoint Analytical (Anaheim, CA) analyzed soil and leaf tissues and checked for pests and diseases, including viruses. The California Department of Food and Agriculture, Plant Pest Diagnostics Center, also checked for viruses.

Climatological Data

We obtained monthly climatological data from November, 2022 through July, 2023, and 30-year means for four sites representative of the coastal and inland termini of Transects 1 and 3 from the National Weather Service (NWS 2023) in Los Angeles. Because weather stations were not always available exactly at these termini, the NWS (Ryan Kittell, pers. comm.) suggested that representative sites would be Long Beach and downtown Los Angeles (the latter substituting for Downey) for Transect 1, and Costa Mesa and Fullerton (substituting for Huntington Beach and Buena Park, respectively) for Transect 3.

Results

Transect Data

We collected data and rated a total of 258 specimens of *Ficus benjamina* along the three transects (**Table 1**). Transect 1 had 38 trees, Transect 2 had 87 trees, and Transect 2 had 133 trees. Mean trees per km were 2.3 for Transect 1, 4.8 for Transect 2, and 6.7 for Transect 3.

The smaller data set used to check for data abnormalities had many fewer trees, with 23 in Transect 1, 32 in Transect 2, and 33 in Transect 3. A comparison of transect analyses between the larger, original data set and the smaller, revised data set showed no significant differences; thus, we retained only the larger, original data set for our analyses, which are now reported.

Mean CPB rating across all 258 trees was 2.0; however, the mean rating per transect varied considerably. Transect 1 had an estimated mean rating of 1.54, Transect 2 had an estimated mean rating of 2.15, and Transect 3 had a, estimated mean rating of 2.06. Ratings were significant ($P<.05$) between Transects 1 and 2 and Transects 1 and 3 but not between Transects 2 and 3 (**Table 2**).

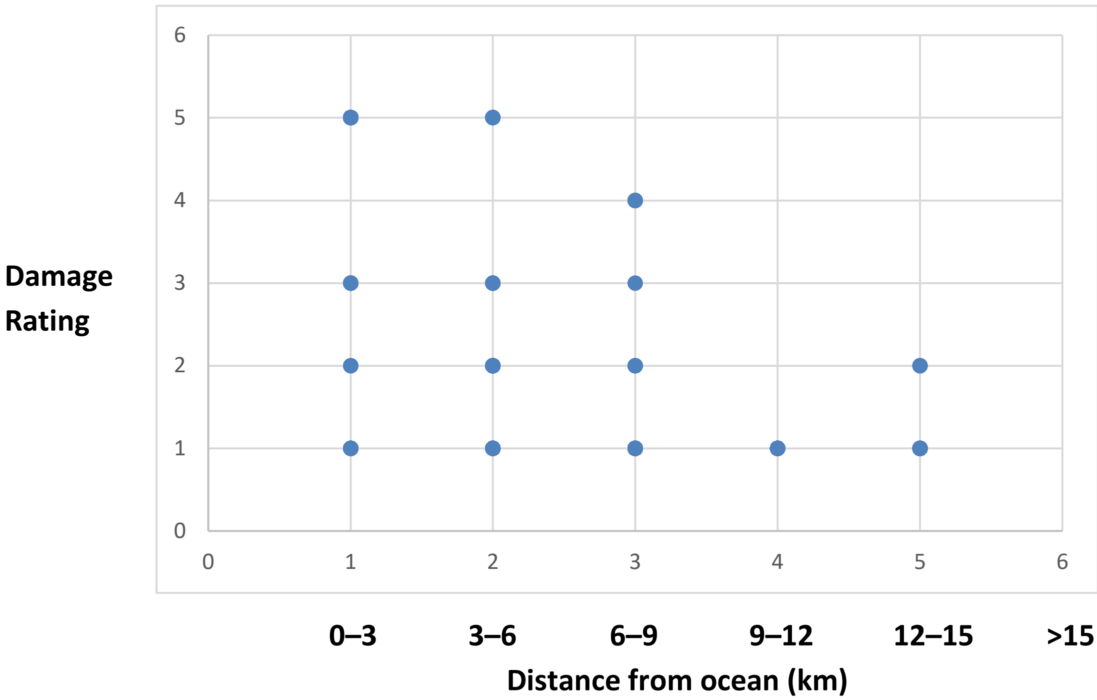
Table 2. Comparison of least squares mean of *Ficus benjamina* chlorophyll photobleaching ratings of three transects, Los Angeles and Orange Counties, July, 2023.

Transects	**Estimated Mean Difference Damage Rating and Standard Error**	**P Value of Difference**
T1-T2	-0.61 +/- 0.204	<0.01
T1-T3	-0.51 +/- 0.19	<0.03
T2-T3	0.09 +/- 0.1549	0.82

Transect 1 had no tree with a CPB rating higher than a 2. Transect 2 had 17 trees with a rating higher than a two, with five rated a 3, four rated a 4, and eight rated a 5. Transect 3 had 51 trees rated higher than a 2, with six rated a 3 and 45 rated a 5.

CPB ratings 2 or higher were mostly within nine km of the ocean; only three trees were rated higher than a 1 (all with a 2 rating) beyond nine km from the ocean. Ratings of 5 were nearly all

Figure 13. Scatter plot comparison of *Ficus benjamina* chlorophyll photobleaching ratings and distance (km) from the ocean, Los Angeles and Orange Counties, July 2023.



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within three km of the ocean, with 47 within three km, three within three to six km, and three within six to nine km. Only 12 trees were rated a 3 or 4, and all were within nine km of the ocean (**Fig. 13**).

Trees closer to the ocean, recently pruned, and/or taller showed the most CPB damage. Damage decreased by an estimated score of 0.24 for every km from the ocean ($P<.001$) and was absent over the last several km of each transect. Damaged increased by estimated score of 0.17 for every meter increase in tree height ($P<.0001$). Recent (past nine months) pruning significantly affected tree damage. Estimated mean damage rating for pruned trees was 2.39 while on unpruned trees it was 1.39 ($P<.0001$) (**Table 3**). Tree width had no effect on CPB.

Table 3. Comparison of least squares mean *Ficus benjamina* chlorophyll photobleaching ratings on pruned and unpruned trees, Los Angeles and Orange Counties, July, 2023.

Pruning	Estimated Mean Damage Rating and Standard Error	P Value of Difference
No	1.44 +/- 0.10	<.0001
Yes	2.39 +/- 0.10	

Toward the most northerly reaches of each transect, we noticed that symptoms seemed to be restricted to the tops of the canopies with none on the sides, which is more reminiscent of traditional cool or cold damage than CPB, which makes sense because these areas are farther from the moderating influence of the ocean and are subject to colder winter night temperatures.

Soil and Leaf Tissue Analyses

Soil analyses from the severely affected tree on Transect 2 showed that nearly all properties were in normal or optimal ranges although available nitrogen was low (2.5 ppm) and phosphorus (7 ppm), manganese (2 ppm), iron (8 ppm), and zinc (3 ppm) were low to very low.

Leaf tissue analyses showed that nearly all nutrient levels were in a sufficient range although calcium was low (1.1%), and phosphorus (0.30%) and magnesium (0.30%) were high.

Pests and Diseases

Microscopy showed no current pests on leaves, buds, twigs, or roots. A small quantity of old whitefly nymphal casings was observed on leaves.

No diseases were observed on or in roots, including vascular staining and cankers. Roots appeared "clean" with no *Phytophthora* detected. Viruses in the closterovirus, begomovirus, and emaravirus groups were not detected.

Climatological Data

From November, 2022 through June, 2023, mean monthly temperatures were surprisingly similar across the three transects (**Table 4**). They ranged from 15.5°C in Los Angeles to 15.9°C in Fullerton. All were below 30-year means for the sites, ranging from 0.5°C below in Long Beach to 1.3° C below in Los Angeles. Mean temperatures started to rise in April and by June were around 19°C and by July around 23°, and all were 1. 0° C to 2.8°C above 30-year means except Costa Mesa, which was 0.2°C below the 30-year mean.

Mean precipitation ranged from 448.3 mm in Costa Mesa to 711.5 mm in Los Angeles, and all were 181.9 mm to 368.0 mm above 30-year means for the period.

Monthly mean degree days reflect the amount of heating, needed to raise, or cooling, needed to lower, the mean temperature to 18.3°C (65°F). While they are mostly used for tracking energy use, they reflect overall temperatures and are another useful tool for measuring, in our case, lack of heat during the time period of our study. From November, 2022 through June, 2023, coastal monthly mean degree days ranged from 81.4°C in Long Beach to 82.8°C in Costa Mesa while inland they ranged from 65.6°C in Fullerton to 72.3°C in Los Angeles. They dropped to single digits

Table 4. Mean monthly climatological data from November 2022 through June 2023, and July 2023, at four sites representative of the termini of Transects 1 and 3, *Ficus benjamina* chlorophyll photobleaching study, Los Angeles and Orange Counties.

	Mean Temperature (Departure from Normal) (°C)	Precipitation (Departure from Normal (mm)	Mean Degree Days (Departure from Normal) (°C)	Mean Cloudy Days (Mean Sky Cover)	Mean Wind Speed (km/hour)
Long Beach					
Nov. 22 thru June 2023	15.7 (-0.5)	530.6 (242.3)	81.4 (1.3)	15.0 (0.39)	8.5
July 2023	23.9 (1.1)	0.0 (-1.27)	0.0 (0.0)	7.0 (0.19)	8.9
Los Angeles					
Nov. 22 thru June 2023	15.5 (-1.3)	711.5 (368.0)	72.3 (19.3)	14.5 (0.39)	2.7
July 2023	23.9 (1.0)	0.0 (-0.5)	0.0 (0.0)	6.0 (0.12)	2.3
Costa Mesa					
Nov. 22 thru June 2023	15.7 (-0.7)	448.3 (181.9)	82.8 (8.6)	20.5 (0.51)	8.2
July 2023	23.9 (-0.2)	0.0(-1.0)	0.0 (0.0)	16 (0.37)	9.7
Fullerton					
Nov. 22 thru June 2023	15.9 (-1.0)	529.3 (245.4)	65.6 (8.1)	15.6 (0.42)	6.3
July 2023	24.2 (2.8)	0.0 (-0.5)	0.0 (0.0)	5.0 (0.17)	6.0

in June and by July were 0°C, the latter meaning no additional heat was needed to raise the mean temperature to 18.3°C (65°F).

From November, 2022 through June, 2023, monthly mean cloudy and partly cloudy days ranged from 14.5 to 15.6 for all sites except of Costa Mesa, where it was 20.5. Similarly, from November, 2022 through June, 2023, mean monthly sky cover ranged from 0.39 to 0.42 except Costa Mesa, where it was 0.51. Surprisingly, perhaps because of the return of the marine layer (May Gray and June Gloom), May and June were cloudier than the eight-month period mean, with cloudy and partly cloudy days ranging from 26 to 29 in May and 17 to 25 in June while sky cover ranged from 0.66 to 0.77 in May and 0.52 to 0.62 in June. By July, 2023, values had dropped precipitously, with cloudy and partly cloudy days ranging from five to seven except again, in Costa Mesa, where it was 16 while sky cover was below 0.20, except again in Costa Mesa, where it was 0.37.

Monthly mean wind from November, 2022 through June, 2023, tended to be higher nearer the coast than inland, ranging from 2.7 kmh in Los Angeles to 8.5 kmh in Long Beach, and changed little by July of 2023.

Discussion

The reason for the disparity in quantity of trees of *Ficus benjamina* per transect is probably due to the fact that Transects 2 and 3 had many more addresses with multiple trees. Why this occurred is unclear but might be due to the ages of the neighborhoods traversed and the popularity of *F. benjamina* as a landscape subject at the time. Generally, neighborhoods along Transect 1 are the oldest (ca. 1930s to 1950s), when *F. benjamina* had yet to attain popularity as a landscape subject, and those along Transects 2 and 3 are younger (ca.1950s to 1970s), when *F. benjamina* was becoming more popular as a landscape subject. Also, trees tended to be slightly unevenly distributed along the transects. The unevenness in quantity and distribution, the latter especially in the southern and middle regions of Transects 2 and 3, is again probably the result of multiple addresses having multiple trees, sometimes up to 20 trees at one address.

We initially hypothesized that the reason for the differences in mean CPB ratings across the three transects might be attributed, at least partially, to more properties having multiple trees in Transects 2 and 3 than in Transect 1. Multiple trees at the same address typically were homogenous in size and CPB rating, which unnaturally tended to amplify their impact on the data. However, Transect 1 had no CPB rating higher than a 2, Transect 2 had 17 rated higher than a 2, and Transect 3 had 47 rated higher than a 2. Furthermore, after we reduced the data set to limit multiple trees at an address, the differences seen with all the data among the transects remained. Therefore, although this disparity in CPB ratings is not well understood, we suggest it but might be due to the older neighborhoods along Transect 1 having older and larger companion trees that might have protected *Ficus benjamina* from environmental stresses, especially excessive light.

The physiological basis for CPB is complex. Prolonged exposure to excessive light causes photoinhibition, an oxygen-independent inhibition of photosynthesis, mainly affecting photosystem II (PSII) and leading to a decrease in photosynthetic activity (a decrease in CO_2 assimilation and reduction in accumulated biomass). Under high light intensities, and often in the presence of other predisposing factors such as environmental stresses, photoinhibition damage is often unavoidable but the plant can counteract it with several repair mechanisms. The rate of repair determines whether photoinhibition leads to significant damage; if repair rates are slower than photoinhibition rates, damage occurs, typically as smaller leaves. Photoinhibition can lead to CPB, the irreversible oxygen-dependent loss of photosynthetic pigments like chlorophyll and collapse of the photosynthetic apparatus (Andreeva et al. 2007, Dominy and Williams 1987, Lingvay et al. 2020).

Unlike chlorophyll photoinhibition, which is a chronic, daily event, CPB is a rare, uncommon, sudden, and catastrophic event. Leaves emerge green but then lose varying amounts of chlorophyll. Affected leaves do not recover. CPB can occur on any leaves, but older ones are usually more susceptible because of longer exposure to light, and they have abundant chlorophyll. Unaffected parts of the leaf can still function if a vascular connection to the phloem is intact and functioning.

CPB typically occurs when excessive light and photoinhibition produce reactive oxygen species (ROS), the highly reactive by-product chemicals of normal plant metabolism (Aro et al. 1993, Fischer et al. 2013, Triantaphylides et al. 2008, Vass 2011). ROS have a dual role; they are critical to cell functioning but can also damage cell contents and prevent them from performing their original functions, such as repairing and maintaining adequate chlorophyll for photosynthesis (Callahan et al. 1986, Dominy and Williams 1987). Environmental stress factors, such as excessive light intensities, low light intensity and cool temperatures followed by high light intensity and warm temperatures, low soil and air temperatures, inadequate soil nutrients, improper soil pH, drought, salinity, root pathogens, metal toxicity, and UV-B radiation, are known to affect production of ROS and lead to CPB (Dominy and Williams 1987, Takahashi and Murata 2008).

Thus, we propose that a “perfect storm” or timely confluence of several abiotic, environmental factors caused CPB in *Ficus benjamina*. Some CPB is observed nearly every spring and summer in *F. benjamina* but nothing like what occurred in 2023. The unprecedented and prolonged, cool, wet winter, which lasted from early November of 2022 through April 2023, provided many of the environmental stress factors that could lead to severe CPB. From November, 2022 through June, 2023, temperatures were 0.5 to 1.3°C below and rainfall about double the 30-year means. Also, mean sky cover was 0.12 to 0.19(–0.37) and mean cloudy and partly cloudy days numbered 14.5 to 15.6(–20.5). Nearly every night from November through April temperatures ranged from 4.5° to 10°C and daytime temperatures sometimes never exceeded 15.5°C.

While May and June were actually cloudier than the mean for November, 2022 through June, 2023 because of the seasonally typical low-cloud stratus peak (marine layer or "May gray/June gloom"), they were warmer and increased light in late June enhanced conditions for CPB. By July, temperatures had increased about 8°C from the previous eight month means, degree days had gone from a range of 65.6°C to 82.8°C down to 0.0°C, and the quantity of cloudy or partly cloudy days and sky cover reduced by about 50%, and CPB was in full swing.

Other factors that could have contributed to the occurrence and severity of CPB was the excessive, but well spaced rainfall, about 650 mm, that kept root zones wet, reduced soil oxygen, and encouraged soil-borne diseases, all factors that can inhibit root activity and lead to deficiencies of essential elements, several of which are critical to repair and maintain chlorophyll. Also, the excessive rainfall can simply leach essential nutrients from the soil and create deficiencies. Strangely, while some nutrients, such as nitrogen, phosphorus, manganese, iron, and zinc, were at low concentrations in the soil, they were at adequate levels in the plant tissues, a phenomenon we cannot easily explain.

Pruned trees had more CPB damage. Pruning, especially overly zealous, late season (September through February) pruning, such as coat- or hat-racking, can open up canopies to higher light, and taller trees, simply by their habit, are also exposed to higher light, a well-established factor leading to CPB.

That occurrence and severity of CPB was greater nearer the ocean can probably be explained by the cloudier, cooler conditions closer to the coast, which can lead to CPB, especially as light and temperatures increase in the late spring and early summer.

Mean wind speeds during the study period tended to be higher near the coast than inland and perhaps could have affected occurrence and severity of CPB. However, Transect 1, which began in Long Beach, the windiest terminus, had no tree with a CPB rating higher than a 2.

In some instances, we suspected that CPB damage might have been more severe on the west and south sides of a tree, perhaps from wind or, more likely, increased light. Unfortunately, we did not rate which sides of a tree showed more CPB damage, if any, so we are unable to address this possible phenomenon.

Chlorophyll Photobleaching Management

Ficus benjamina is a tropical plant, which is really growing out of its environment in Southern California. Thus, nearly all strategies for avoiding CPB are centered on achieving and maintaining a plant of optimal health so it can withstand environmental stresses with little or no loss of quality. Providing proper cultivation, especially judicious irrigation to maintain appropriate soil health and moisture levels, proper fertilizer to maintain adequate nutritional levels, and mulch to improve soil tilth, structure, health, and nutritional status, are essential to achieving optimal health. Pest and disease management are also important to maintaining optimal plant health and avoiding stress.

When selecting *Ficus benjamina* for landscape planting, consider its appropriate placement and siting it in a favored microclimate or setting that provides optimal light and protection from wind, and then plant and maintain it properly. Also, ensure adequate space to accommodate future root and canopy growth; if not, periodic and sometimes severe root and canopy pruning will be necessary, which is stressful and can lead to or enhance PCB.

When pruning *Ficus benjamina*, follow recommended pruning principles and practices (ANSI 2023, Harris et al. 2004, Lilly et al. 2019) and prune at the beginning of the growing season in late winter to early spring just prior to seasonal growth flushes so that trees will have a long growing season to recover and develop an adequate canopy before winter; avoid pruning in the summer, fall, and winter. Also, late winter to early spring pruning tends to avoid bird nesting season and potentially excessive sap flow and drop from pruning cuts, both of which are more common in the summer. While we might want to control plant size and *Ficus* spp. are generally unusually amenable to severe pruning or even shearing, avoid such overzealous practices and follow more moderate, recommended pruning practices; remove no more than 25% of the canopy at a single pruning event (**Fig. 19**).

Fortunately, as we progress through late-summer into fall, damage on many of the affected trees appears to be self-correcting, with new healthy, normal, green leaves appearing at the ends of shoots with old, damaged, bleached leaves (**Figs. 19**–**21**).

Acknowledgements

Dhiraj Gautam and Joon Seo Lee, plant pathologists at the Los Angeles County Agricultural Commissioner office in South Gate, helped process *Ficus benjamina* samples and sent them to the California Department of Food and Agriculture in Sacramento, where Wei Belisle and Riad Baalbaki in the Plan Pest Diagnostic Center checked them for viruses. Also, Riad and Wei generously gave of their time to answer our queries about chlorophyll photobleaching, and Riad critically reviewed a portion of the manuscript. Waypoint Analytical in Anaheim also performed

Figure 19. Overzealous pruning, removing more than 25 percent of the canopy, makes *Ficus benjamina* more susceptible to chlorophyll photobleaching (2 July 2023).

Figure 20. Fortunately, *Ficus benjamina* with chlorophyll photobleaching seem to be recovering during the summer (12 August 2023). Compare with the same tree in Figure 19 taken five weeks earlier in July, 2023.

Figure 21. Evidence of chlorophyll photobleaching is nearly gone on this *Ficus benjamina* by 16 October 2023. Compare with same tree in Figures 19 and 20.

diagnostic work with the *Ficus benjamina* samples. Ryan Kittell, Meteorologist, National Weather Service, Los Angeles / Oxnard, assisted with weather data. We are grateful for and acknowledge all these valuable contributions.

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Publication Date: 16 October 2023.
PalmArbor: *http://ucanr.edu/sites/HodelPalmsTrees/PalmArbor/*
ISSN 2690-3245
Editor-In-Chief: Donald R. Hodel
Hodel Palms and Trees: *http://ucanr.edu/sites/HodelPalmsTrees/*