

Influence of Light Intensity and Drought Stress on *Ficus benjamina* L.¹

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Abstract. Water stress reduced dry matter accumulation in *Ficus benjamina* plants, especially those grown in the sun. Accumulation of carbohydrates and reduction of chlorophyll was associated with water stress in sun plants, but there were no stress related changes of carbohydrate or chlorophyll levels in plants grown under 47% shade. Electron micrographs of chloroplasts showed starch deposits and disruption of thylakoid structures with water stress in sun plants, while disruption due to water stress was less severe in shade-grown plants. Net photosynthesis (Pn) was lower for unstressed shaded plants, but interposure of water stress resulted in similar Pn levels for both light regimes. Photosynthesis was restored to non-stressed levels after irrigation in both sun and shade light treatments. Lowest light compensation points (LCP) occurred in shade plants with no influence due to water stress, but water stress caused high LCP in sun plants.

Light intensity and water regime affect acclimatization of foliage plants such as *Ficus benjamina*. Reduced light intensities during production improves quality (8) and results in lower LCP (10, 13) in foliage plants. Research relating light intensity to apparent photosynthesis has shown plants grown in full sun generally exhibit higher light saturation and CO₂ compensation points (3, 4).

Soil moisture levels affect plant water relations and growth. Increased drought stress has been shown to cause stomatal closure (17), reduced photosynthetic rate (16) and leaf ultrastructural changes (9). Root/shoot ratio of azalea plants was affected by soil moisture (6) and Johnson et al. (15) found reduced growth of *F. benjamina* associated with water stress.

This experiment was carried out to study combined effects of light intensity and water stress on growth parameters, chloroplast structure, photosynthesis and LCP of *F. benjamina*.

Material and Methods

Rooted cuttings of *F. benjamina* were planted August, 1979 in 25 cm plastic pots filled with 1 Canadian peat:1 sand (v/v) amended with dolomite, single superphosphate and STEM (Soluble Trace Element Mix manufactured by W. R. Grace & Co., Cambridge, Mass.) at 4.2, 3.0 and 0.25 kg/m³, respectively. Plants were fertilized with 12 g/25 cm diameter container every 3 months from surface applied Osmocote (18.0N-6.2P-15.6K). Factorialized treatments included 2 light levels in a plastic greenhouse: sun (0% light exclusion or 1080 $\mu\text{Em}^{-2}\text{s}^{-1}$) and shade (47% light exclusion black polypropylene or 58 $\mu\text{Em}^{-2}\text{s}^{-1}$) and 2 irrigation regimes. Irrigation regimes were designated as non-stressed (10% weight loss of container capacity) and stressed (20% weight loss of container capacity). Container capacity weights were established after 16-18 hr drainage following each irrigation. A randomized block design was used with treatments replicated 5 times and 2 plants as the experimental unit.

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Measurements of Pn were made at 1000 hr on newly expanded leaves before and 16-18 hr after irrigation by withdrawing 2 ml gas samples from a 1.936 cm³ cuvette similar to one described by Sullivan et al. (20). CO₂ concentrations were measured with an infrared gas analyzer using a procedure outlined by Clegg et al. (7).

Measurements of LCP were made using a procedure described by Johnson et al. (13) at conclusion of greenhouse research. Stem caliper, shoot and root dry weights were determined at experiment termination. Leaf tissue was analyzed for chlorophyll and carbohydrates. Chlorophyll was analyzed using Arnon's procedure (1) and estimation of total nonstructural carbohydrate was determined by treating leaf tissue extract suspensions with invertase, amyloglucosidase and takadiastase. Aliquots of extract were analyzed for reducing sugars according to Somogyi's adaption of the Nelson copper reduction test (19).

Leaf sections from newly expanded leaves were fixed with 5% glutaraldehyde in 0.1M cacodylate buffer (pH = 7.2) for 6 hr at 4°C at experiment termination. Fixed tissue was washed in 3 changes of buffer over a 1 hr period then post-fixed with 2% osmium tetroxide at 25°C. Specimens were dehydrated in a graded ethanol series followed by propylene oxide and embedded in modified Spurr's resin (18). Thin sections were cut with a diamond knife using a Porter Blum MT-2 ultratome, stained with uranyl acetate and lead citrate and examined with an Hitachi HU 11-E transmission electron microscope.

Table 1. Influence of light intensity and irrigation regime on growth of *Ficus benjamina* L.

Treatment		Stem caliper (cm)	Dry wt tops (g)	Dry wt roots (g)
Light	Irrigation ^z			
Sun	Non-stress	1.36 a ^y	84.0 a	154.6 a
Shade (47%)	Non-stress	1.09 b	68.6 b	76.6 b
Sun	Stress	0.96 c	39.2 d	77.8 b
Shade (47%)	Stress	0.98 c	49.4 c	68.6 b

^zNon-stress (10% weight loss of container capacity) and stressed (20% loss of container capacity).

^yMean separation with columns by Duncan's multiple range test, 1% level.

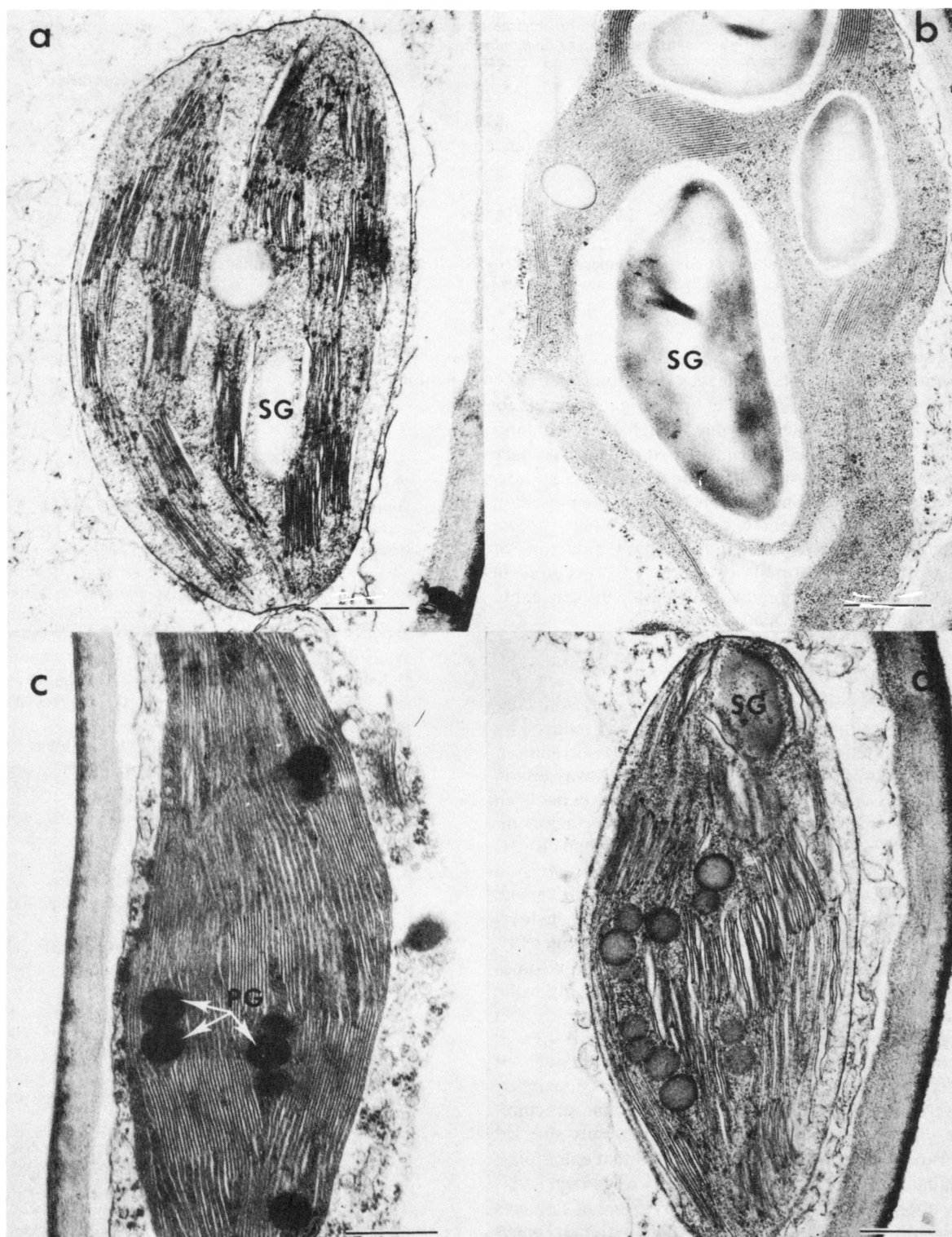


Fig. 1. Electron micrograph showing leaf chloroplast ultrastructure of *Ficus benjamina* L. leaves A) Sun unstressed, B) Sun stressed, C) Shade unstressed, D) Shade stressed, PG = polyglobuli, SG = Starch granules.

Results

Growth of *F. benjamina* was strongly influenced by light and irrigation level (Table 1). Stem caliper of unstressed shade grown plants was less than that of unstressed sun grown plants, but when stress was imposed the caliper did not change in sun or shade plants. Sun grown unstressed plants accumulated more top dry matter than shaded unstressed plants, but the opposite was observed with water stressed treatments. Dry weight of roots was

greatest in unstressed sun plants.

Pre-irrigation Pn was highest for unstressed sun plants and stressed plants had the lowest Pn levels in both light regimes (Table 2). Photosynthetic restoration 16–18 hr after irrigation resulted in similar Pn for stressed and unstressed plants in each light regime. Chloroplasts were more prevalent with greater thylakoid structure in unstressed plants than in stressed plants (Fig. 1). Shade grown plants had a more highly organized thylakoid struc-

Table 2. Influence of light intensity and irrigation regime on light compensation point (LCP), chlorophyll, total soluble carbohydrates, and net photosynthesis in *Ficus benjamina* L.

Treatment		LCP ($\mu\text{Em}^{-2}\text{s}^{-1}$)	Carbohydrate (mg/g dry wt)	Chlorophyll (mg/cm ² leaf area)	Net photosynthesis (mg CO ₂ -dm ⁻² hr ⁻¹)	
Light	Irrigation ^z				Before irrigation	16 hr after irrigation
Sun	Non-stress	69.6 b ^y	121.7 b	0.165 b	10.0 a ^y	9.6 a
Shade (47%)	Non-stress	52.2 c	89.9 c	0.252 a	7.0 b	7.1 b
Sun	Stress	73.9 a	148.8 a	0.126 c	4.1 c	9.4 a
Shade (47%)	Stress	50.8 c	90.9 c	0.216 ab	4.7 c	7.3 b

^zNon-stress (10% weight loss of container capacity) and stressed (20% weight loss of container capacity).

^yMean separation with columns by Duncan's multiple range test, 1% level.

ture than did sun plants.

Carbohydrate level was higher in leaves from sun water stressed plants and lowest values resulted at both irrigation levels for shaded plants (Table 2). Electron micrographs showed large starch deposits in sun stressed and unstressed plants, but shade grown plants were nearly devoid of starch deposits (Fig. 1). Phosphoglobuli were observed in shade plants but were not present in sun plants. Chlorophyll content was highest in shade grown plants, although water stress resulted in slight reduction of chlorophyll levels. Most desirable or lowest LCP occurred in shade grown plants with water regime having little influence, but stress caused high LCP in unshaded plants.

Discussion

Imposition of water stress resulted in smaller plants with considerably reduced dry matter accumulation. Pn was reduced by water stress and, although there was restoration after irrigation, overall net production of photosynthate and growth was less in water stressed plants. Lower Pn potential of shade leaves has been observed in several plants (4) and relates to numerous factors including lower RUBP carboxylase (2) and cytochrome levels (3).

Disruption of the thylakoid structure observed in water stressed *F. benjamina* was also noted in cotton by DaSilva et al. (9) and was related to a subsequent increase in inorganic phosphate level and an alteration in photosynthetic and respiratory enzymes (9). They also observed a degeneration in ribosomes, peroxisomes and other cellular organelles. We did not concentrate on organelle changes other than chloroplast structure in the present study, but the poor organization observed in the chloroplast of stressed plants most likely accounted for reduced Pn levels. Recovery of Pn after watering is not surprising since stress levels apparently were not severe enough to result in loss of membrane structure. Furthermore, Pn levels would be observed in severely stressed plants since Boyer and Potter (5) have observed that chloroplast activity is maintained until turgor is lost. However, low Pn levels and recovery after watering may be related to closure of stomates under stress conditions while recovery is related to stomatal opening following watering (17).

Carbohydrates were lower in shade leaves probably because of lower Pn, but were not affected by water stress. However, carbohydrates were apparently accumulated in leaves of plants sun stressed at the expense of other plant parts as indicated by poor growth of tops and roots. Other scientists (11, 21) have shown that C¹⁴-labeled assimilates are retained in leaves in water stressed plants, indicating reduced translocation.

LCP of shaded plants was lower than sun plants indicating better acclimatization. Although shade leaves had lower Pn levels per unit leaf area, because of factors such as reduced dark respiration (10), efficient orientation (13), and modified internal struc-

ture (3), they are efficient in utilizing light at low levels of illumination.

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Seasonal Variation of Leaf Nutrient Composition in 'Tifblue' Rabbiteye Blueberry¹

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Abstract. 'Tifblue' rabbiteye blueberry (*Vaccinium ashei* Reade) leaves were sampled at 2-week intervals during the growing seasons of 1979 and 1980. Each sample was analyzed for 5 macronutrients and 5 micronutrients. Prediction equations for the estimation of nutrient element content on a growing season basis were calculated. Leaf elemental content patterns correlated closely between years with the exception of Fe. Leaf elemental N, P, and Zn were highest in the early season, tended to decrease until harvest, and leveled off as the growing season progressed. The levels of leaf C and Mg remained relatively constant through the season with lowest percentages present during harvest. Leaf contents of K, Mn, and to a lesser extent B and Na, were high during April and early May, low during harvest, and high again in October. Regression analyses for most elements were more linear from late June to early August. Therefore, optimum time for the collection of leaf samples of rabbiteye blueberries for mineral analyses appears to be a 4-week interval coinciding with the last 2 weeks of the harvest season through a 2-week period immediately following harvest.

The nutritional status of many small fruit crops can be diagnosed by leaf mineral analysis. Seasonal changes in the foliar elemental concentration of nutrients have been reported for highbush and lowbush blueberries (*Vaccinium corymbosum* L.) by several workers (1, 2, 3, 5, 6, 10, 11). Chuntanaparb and Cummings (6), in a study on seasonal trends of leaf-nutrient concentrations, reported that macronutrient content was lower in highbush blueberries than in other crops tested. Also, nutrient concentration differences between leaf portions (margin vs. blade) were generally much less in blueberry than in other species tested. Ballinger (2) stated that leaf macronutrient components of 'Wolcott' highbush blueberry followed relatively predictable seasonal patterns and the optimum time for leaf sampling of highbush blueberry appears to be the 2-3 week period immediately after harvest. Bailey et al. (1), working with 'Rubel' highbush blueberry, reported that seasonal curves of N, P, K, Mg, and Ca in the leaves were similar to those for late apples and 'Elberta' peaches with the exception of a late season K increase in blueberry leaves. They stated that leaf sampling just before fruit ripening was probably most desirable.

In most fruit crops, foliar contents of the macro- and micronu-

trients vary with the time of season. Since the rabbiteye blueberry industry is relatively young, little research on mineral nutrition has been reported. The objective of this study was to determine seasonal changes in leaf nutrient content of rabbiteye blueberries for use as a base in developing methods for diagnosing nutrient deficiencies and/or nutrient imbalances.

Materials and Methods

Leaf samples were collected at random from 3 representative 'Tifblue' rabbiteye blueberry plots, all located on Typic Ochreultic soils with pH ranges of 4.8 to 5.2. Plants at all locations had been established for 5-8 years at the initiation of this study. Fifty leaves per sample were taken at approximately 2-week intervals during the 1979 (April 2 - September 20) and 1980 (April 28 - November 28) growing seasons. Samples consisted of the 4, 5, or 6 positioned leaves from branch terminals. Dried, finely ground leaf samples were analyzed by the Plant Analysis Laboratory, University of Georgia, Athens. Elemental analyses were by emission spectroscopy and N by Kjeldhal. Prediction equations for the estimation of nutrient element content on a growing season basis were calculated. Data from both years were pooled and the highest significant regression equation (linear, quadratic, or cubic) was used to compare the concentration of each element (Y) vs. sampling time (X) recorded as Julian dates for each element analyzed.

Results and Discussion

Nitrogen. Percentage of leaf N was highest in the early sampl-

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