# ACCLIMATIZATION OF SELECTED FOLIAGE PLANTS
# FOR CONTAINERIZED SHIPPING

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# INTRODUCTION

Foliage plant production has become an increasingly important part of Hawaii's nursery industry. The value of potted foliage alone has risen from a wholesale value of $171,000 in 1972 to over 2.4 million dollars in 1977. Out-of-state shipments in 1977 amounted to 1.4 million dollars, or well over half the total production of potted foliage plants (32).

At present the majority of the nursery products exported are by commercial air freight. Even though this is a fast, convenient method of shipping, rising costs may soon make air shipment of plant material unprofitable. It is estimated (46) that the shipping cost for an ocean container of plants is $350 more than an air freight container but that the capacity is eight times greater. This would be equivalent to $\$0.50/ft^3$ for a standard (8 X 24 feet) refrigerated Matson container and $\$1.78/ft^3$ for a LD3 air freight container.

A study by Akamine and Goo (1) shows that foliage plants can be sent by commercial surface shipping and maintained in good condition under controlled conditions. However, other studies indicate that even with controlled temperature, supplementary lighting, and increased humidity some foliage plant species may be unable to withstand the rigors of a 7-to 14-day transit period. For example, Conover (17) reports that grower observations and preliminary experiments on acclimatization indicate that plants will lose leaves after 7 days in a shipping box and will be severely injured after 10 days. Both Boodley (10) and Leider (39) feel that loss of quality during transportation is a major problem and even 7 days is too long under these conditions. Staby (48) reports that Brassaia (Schefflera) arboricola and Ficus benjamina will not tolerate storage without light or moist media for more than 7 days.

Early work by Conover and Poole (18) has shown that leaf abscission under low light and humidity can be reduced by shading of plants for several months before placement indoors. Similar acclimatization techniques may be useful during or after production of foliage plants to better prepare them for containerized shipping. Thus, it may be feasible to deliver a quality plant at one-fourth the cost of air freight by utilizing acclimatized plants and containerized surface shipping.

This study using selected tropical foliage plants was initiated to determine the optimum cultural conditions for producing plants adapted to containerized shipping. Three experiments were conducted with variations in light intensity, fertilization rates and practices and watering schedules.

# REVIEW OF LITERATURE

Acclimatization has been defined as the adaptation of a species from one environment to another (10). Vlahos and Boodley (51) elaborate by defining acclimatization as, "the process required to cause physiological changes within a plant system that will enable the plant to withstand a radical change in environment without exhibiting severe damage or even death." This process has been successfully used by researchers (14, 16, 19, 20, 24, 33, 47, 51) and commercial growers (27, 39) to condition plants to withstand the rigorous conditions of interior environments.

Leaf drop, chlorosis and necrosis of leaves, wilting and overall loss of quality are problems which have been reduced by acclimatization. Light, water and nutrient status are the factors found to be most important in adaptation to interior environments and should also be applicable to adaptation to shipping conditions.

Plants have been classified into sun and shade species depending on their ability to adapt to a selected light intensity (4). The relative differences between these plants primarily concerns their photosynthetic modifications and capabilities which are important in the acclimation process.

Leaf thickness has been shown to decrease with a decrease in light intensity during growth (3, 6, 28, 30, 37, 52). This increase in thickness in sun leaves is a result of increase in the depth of the mesophyll layer with an increase in the number of palisade cells. Thus shade leaves contain less tissue per unit of leaf area than sun leaves (6, 37). Mean leaf size of plants grown in weak light is approximately twice that of plants grown in high light intensities (4, 6, 54).

Shade grown leaves are usually found to be darker green in color in contrast to the pale-yellowish green color of leaves grown at higher light intensities (30, 52). Investigation on a variety of plants attribute this darker pigmentation in shade leaves to a higher chlorophyll content (2, 3, 5, 19, 30, 37), larger chloroplast size (3, 8, 30, 52) and a greater number of chloroplasts (5, 8, 30). Studies by Anderson *et al* (2) on several extreme shade leaves of *Alocasia macrorrhiza*, *Cordyline rubra*, and *Lomandra longifolia*, showed a larger number of chloroplasts in the mesophyll cells adjacent to the upper leaf surface compared with the sun leaves of *Atriplex patula*. Cells in the lower part of the mesophyll contain few chloroplasts. Chlorophyll content is usually found to be higher in shaded leaves both on a unit area basis and on a weight basis but is found to be lower on a per unit leaf area basis due to variations in leaf structures (8), i. e. the thicker leaves of some shade plants.

Chloroplasts of shade leaves have larger grana stacks with grana irregularly arranged in a chloroplast (3, 6, 30).

Ballantine and Forde (3) found that the well developed grana of soybean chloroplasts in low light intensity leaves contain greater amounts of starch than high intensity leaf grana. The extensive grana formation in shade leaf chloroplasts has been related to the higher total chlorophyll content and to a lower chlorophyll a to chlorophyll b ratio (2). Björkman and Holmgren (6, 7) also found lower chlorophyll a/chlorophyll b ratios in clones of Solidago vergaurea L. from shaded habitats.

Chloroplasts of sun plants have a higher capacity for electron transport than shade species. Increased rates of electron transport by sun species seem to be related to increased amounts of some of the electron carriers (8). Little difference has been found in size of the photosynthetic unit between sun and shade chloroplasts.

Stomatal frequency per unit leaf area was shown to increase with increasing light intensity on Atriplex leaves (5). Other workers (8, 30) report no significant difference in stomatal size and frequency between sun and shade plants. Mesophyll resistance to $CO_2$ movement is greater in plants grown in low light (4, 8). The decreased mesophyll resistance of high light leaves is due to the increase in the mesophyll cell surface area per unit of leaf surface. Photosynthesis in sun plants shows a greater linear dependence on $CO_2$ because of the lower mesophyll resistance. Photosynthesis in shade species is limited by an interaction of various factors (8).

Both the total protein content and the protein/chlorophyll ratio is higher in sun plants (4, 5, 29). Correlated with the higher protein level is the high RuDP carboxylase activity in these plants (4, 5, 8, 29). Other enzymes may also be at lower levels in shade plants. Björkman (4) suggests that the low respiratory rates in shade plants is related to the low activity of respiratory enzymes. Loach (37) and others (4, 5) also report that the lowest rates of respiration are correlated with the deepest levels of shade under which plants are grown.

The overall effect of light intensity on a given plant is more conveniently measured by light saturation and compensation points. The photosynthetic system is light saturated when there is no further increase in the rate of photosynthesis with an increase in light intensity. At the compensation point the carbon dioxide produced in respiration is equal to the carbon dioxide fixed in photosynthesis (31, 40, 42, 49). Earlier work by Rabinowitch (45) indicated that compared to shade leaves, sun leaves have a higher compensation point and become light saturated at a higher light intensity.

Bohning and Burnside (9) examined the average light saturation and compensation points for a variety of sun and shade species. They found the sun plants to be light saturated at 2000-3000 ft-c compared to 300-1000 ft-c for shade plants. Light compensation points were at 100-150 ft-c in sun plants and 50 ft-c in shade plants. Another study by

Burnside and Bohning (12) indicate that shade grown plants were light saturated at intensities 1000 ft-c lower than those grown in full sun. Light intensities above the saturation point of these shade plants may result in photodynamic injury (38). The compensation points of the shade plants are also lowered up to 100 ft-c over the sun plants.

The preceding characteristics relate to plants grown under selected light intensities during leaf expansion and development. Boardman (8) states that leaves can adapt to different light intensities even after leaf expansion has ceased. Anatomical changes probably do not occur but photosynthetic rates of fully expanded leaves of maize and Amaranthus appear to change upon transfer from low to high light levels. Results indicate this adaptation may be due to synthesis or breakdown of the carboxylation enzyme.

Björkman et al (5) conclude that adaptation to low light, which is of primary importance in acclimatization, is a question of economics. The shade plant invests a greater proportion of its synthetic capacity in the synthesis and maintenance of the light harvesting machinery. Thus, plants grown in shade are more photosynthetically efficient at low light levels while those grown at high light intensities have a greater photochemical capacity.

Even before these characteristics were applied to the acclimatization process, it was recognized that foliage plants differ in their response to certain environmental factors. Mott (41) classified foliage plants on the basis of their light, temperature and moisture requirements.

Conklin (15) recognized that heavy shading and reduced watering of plants after placement indoors results in a loss of quality for these same plants. This work led to a system of "preacclimatizing" plants for interior locations. Conover and Poole (18) found that leaf drop of Ficus benjamina is reduced by 50% by placing plants in 80% shade for 5 weeks before moving indoors. They report that foliage plants used in homes or offices are in environments much different from those under which they were grown (43) and that the detrimental effects may be reduced by conditioning foliage, establishing large root systems and fertilizing less frequently.

Conover and Poole (16, 21, 24) indicate that acclimatization should be more specifically defined. Light acclimatization would involve adaptation to lower light intensities to reduce leaf drop and improve foliage quality. Soil medium acclimatization would involve the reassessment of moisture and nutritional requirements of plants placed in less than optimum growing conditions. In production acclimatization, plants would be produced completely under one or more levels of shade rather than an abrupt conditioning period from full sun. The advantage in this method would be the total formation of shade leaves rather than a mixture of sun and shade leaves. Sun leaves are likely to abscise when plants are placed in dense shade as research has yet to show that sun leaves can be converted to shade leaves (47).

Subsequent research has been devoted to elucidation of these aspects of acclimatization.

An intensive study by Vlahos and Boodley (51) with Brassaia actinophylla and Ficus nitida indicates that B. actinophylla should be acclimatized for 8 weeks and watered every 10 days. Likewise F. nitida should be placed under 50% shade for 10 weeks and watered at 5-day intervals. Similar work has been done by Conover and Poole (20) on Brassaia actinophylla and Ficus benjamina. Leaf drop was reduced 100% and grade and density improved by conditioning full sun-grown plants for at least 5 weeks under 40 or 80% shade.

A single light conditioning period cannot be applied to all species, however. Björkman (6) found that the low photosynthetic efficiency of a high-light-intensity grown Solidago leaf increases to the level of a shade leaf after only 1 week. Photosynthetic efficiency of sun leaves of other species does not change when exposed to low light intensities.

Recent research deals with determining light compensation points (LCP) in order to estimate the minimum light levels needed to maintain a plant. Collard et al (14) reports that LCP decreased with increasing shade and increased with increasing fertilizer rates in Ficus benjamina. Forteno and McWilliams (26) report a 60 to 87% reduction in light compensation points during a 4-and 15-week acclimatization period, respectively.

Moisture levels of the medium are also critical in production or maintenance of acclimatized plants. Water uptake is influenced by size of root systems, root:shoot ratio, oxygen level in the medium, water holding capacity of the medium, humidity, air movement and temperature. Wetherell (53) states that an imbalance in the rate of water loss and the resupply by the root system creates problems just as complex as changes in light intensity. A water deficit reduces photosynthesis by reducing stomatal size. This is a serious setback for plants in reduced light intensities which must maintain maximum photosynthetic efficiency. Improper establishment of root systems before shipping is thought to be an important factor in the survival of plants (34).

Nutritional levels have been found to be directly related to acclimatization. Nitrogen content of Solidago virgaurea increases with light intensity and leaf thickness according to Björkman and Holmgren (6). Salsedo (47) finds that the requirement for fertilizer decreases by a factor of 10 after being placed indoors. If fertilization rates are not reduced, soluble salt levels increase and burned foliage, chlorosis, and foliage drop may occur. Nutritional and moisture levels may be manipulated to increase the root to shoot ratio. During acclimatization, root system size is improved by reducing fertilizer application and lengthening the watering intervals (47). Individual species have specific requirements that must be determined.

Conover and Poole (19, 23) reported on the effects of nutrition and/or watering on acclimatization of foliage plants. Dracaena marginata performed best indoors if grown at 40% or 80% shade rather than full sun and at fertilization levels equivalent to 1800 lb N-$P_2O_5$-$K_2O$/A/yr. The last fertilizer application was 6 weeks before being moved indoors and the plants were watered twice a week (19). A subsequent experiment on Ficus benjamina showed that high quality plants acclimatized to interior conditions were produced under 40% or 80% shade with 8 or 12g of Osmocote fertilizer per 20 cm container. As shade increased from zero to 80% there was an increase in N and K and a decrease in Ca and Mg in leaf tissue (23).

Results of a similar experiment by Conover and Poole (22) on Aphelandra squarrosa 'Dania' indicate plants produced under the lowest fertilizer level used (0.9KgN, 0.4KgP, 0.8KgK at 1X rate/$100M^2$/mo) or watered daily at any fertilizer level had the best quality after 8 weeks indoors. They conclude that fertilizer levels can be adjusted to provide reduced soluble salts at the end of the production cycle or that plants can be leached heavily before being placed in interior environments.

Joiner et al (35) found that Diffenbachia amoena plants are best adapted to interior conditions when produced with a fertilizer rate of 2240 kg/ha/yr of N and under 60% shade. Watering once or twice per week has no effect. Leaves of

Ficus benjamina were found to have increasing chlorophyll content as shade and fertilizer levels increase.

The preceding research has dealt exclusively with the conditioning of plants for interior environmental conditions. Few researchers have done specific studies related to shipping or storage of foliage plants. Conover (34) found that chlorophyll levels, reflecting the receptiveness of the plant cells to light, are highest in Ficus benjamina plants grown in 60% shade compared to 30% after 12 days of simulated shipping conditions. The recent report of Akamine and Goo (1) demonstrates the feasibility of surface shipment of ornamentals. They indicate the need for further studies on the effects and requirements of light, temperature, water, air circulation and loading methods.

# MATERIALS AND METHODS

Three experiments were initiated independently to determine the effects of long term container shipping conditions on selected foliage plants grown under different cultural regimens. A temperature-controlled storage chamber in the Pope Laboratory facility of the University of Hawaii was used to simulate an actual shipping situation. Temperature was maintained at 18°C and relative humidity was stable at 90% during this phase of the experiment. Supplemental lighting was not used during the simulated shipping period.

Measurements to determine plant response were made before treatment, before entry into the storage chamber, after a simulated shipping period of 10 to 14 days and at the end of a 21-day post-storage holding period under 54% shade. Plant height, measured from the pot rim to apex of the tallest growth, was used to indicate growth response. Significant increase in height did not occur during the storage period of Experiment I and therefore these measures were not repeated after removal from storage for Experiments II and III.

A visual subjective plant quality rating based equally on leaf color, density and overall plant appearance was used in each experiment using a scale of 1 = poor to 5 = excellent quality. Qualitative observations were made before and after the simulated shipment periods.

In an effort to detect gross physiological changes, total chlorophyll was measured in Experiments I and II and nitrogen (N) as percent dry weight in Experiments II and III. The second or third most recently matured leaves from terminals were used for chlorophyll analysis as suggested by Joiner and Waters (36).

Chlorophyll analysis was initiated immediately after the plant material was sampled. Ten 5 mm diameter discs comprised each of two replicate samples. After maceration with a mortar and pestle, the fresh leaf tissue was extracted for 24 hours in 50 ml of 100% acetone. Total chlorophyll (chlorophyll a + b) was determined for each replicate sample using the method of Bruinsma (11).

An observed loss of chlorophyll after storage will be described as etiolation. Bleaching will describe photodeterioration of chlorophyll upon exposure to higher light levels. Any other noticeable loss of chlorophyll will be termed chlorosis.

Leaf samples for N analysis were forced-air dried at 75°C for 72 hours and digested using the method described by Van Lierop (50). Colorimetric assay was determined using the method of Cataldo, Schrader and Youngs (13).

A leaf drop count was made after the termination of the shipping period for Experiments II and III. The leaf count was facilitated by the use of a 91.4 cm tapered paper sleeve in Experiment II and a 61 cm sleeve in Experiment III. The sleeves are normally used to protect plants during shipping and thus more realistically duplicated shipping conditions.

Light intensities and shade levels were determined from average mid-day readings in an enclosed plastic saran house. Readings were made at plant level using a Weston Sunlight Illuminator light meter, Model 756. A 54% and 73% shade level was recorded under plastic saran sections and a 94% level under white corrugated fiberglass. All pre- and post-shipment phases of the experiments were carried out at the Mid-Pac facility of the Department of Horticulture, University of Hawaii.

Mean separation and comparison for this and subsequent experiments was by the Bayes least significant difference (BLSD) test (25).

Experiment I. This study was initiated on July 19, 1977, to determine the influence of reduced light on acclimatization prior to container shipment of sun- and shade-grown plants. Established plants of *Ficus benjamina* L. 'Exotica' and *Polyscias guilfoylei* (Bull) L. H. Bailey 'Victoriae' were subjected to the pre-shipment treatments shown in Table 1. Sun-grown *Ficus* plants averaged 159 cm; shade-grown *Ficus* averaged 100 cm; and *Polyscias* plants averaged 55 cm high. Six replicate plants for each treatment were used.

All plants were grown in a one part woodshavings to one part soil media, by volume, in 15.2 cm plastic pots, one plant per pot. Fertilizer was applied at the rate of 2016

TABLE 1.--Pre-shipment acclimatization treatments for *Ficus benjamina* 'Exotica' and *Polyscias guilfoylei* 'Victoriae'

| Shade Level Treatments | Time Period |
|---|---|
| Sun-grown[z] *Ficus* and *Polyscias* | |
| Full sun | 8 weeks |
| 54% shade[x] | 8 weeks |
| 94% shade | 8 weeks |
| Full sun/54% shade | 4 weeks/4 weeks |
| Full sun/94% shade | 4 weeks/4 weeks |
| 54% shade/94% shade | 4 weeks/4 weeks |
| Shade-grown[y] *Ficus* | |
| 54% shade | 8 weeks |
| 54% shade/94% shade | 4 weeks/4 weeks |
| 94% shade | 8 weeks |

[z]Established under full sun prior to treatment.

[x]54% shade = 71.04 klx (6600 ft-c); 94% shade = 8.83 klx (825 ft-c).

[y]Established under 54% shade prior to treatment.

kg/ha/yr (1800 lb/A/yr) of N, $P_2O_5$ and $K_2O$ on a weekly basis for 4 weeks prior to commencement of the experiment. No fertilizer was applied during the treatment period. Water was applied to wet the medium thoroughly every 3 days during the first 4 weeks of the treatment period and every 7 days during the second 4-week period.

After the conclusion of an 8-week acclimatization period, the plants were thoroughly watered and grouped closely together in the dark storage chamber for a 10-day simulated shipping test. After removal from storage, normal watering and fertilization were restored during the holding phase.

Data obtained for this experiment was subjected to an analysis of variance utilizing a split-plot design. A representative example of an analysis of variance table for all variables and species in this experiment is shown in Appendix Table 22.

Experiment II. The objective of this experiment was to determine the optimum fertilization level at different shade levels and to evaluate the effect of these fertilization-shade combinations on the quality of plants in a container shipment environment.

Well-rooted 15 cm terminal cuttings of *Brassaia actinophylla* Endl., *Leea coccinea* Planch and *Schefflera arboricola* Hayata were potted in a one part peat to one part black cinder medium (vol/vol) in 15.2 cm diameter plastic pots on November 11, 1977. The medium was amended with superphosphate at 2.0 $kg/m^3$ (2 $oz/ft^3$) and calcium carbonate at the rate of 4.8 $kg/m^3$ (8 $lbs/yd^3$) to attain a pH of approximately 6.5.

A 3 X 4 factorial experiment was started on November 21, 1977, using three shade levels and four fertilization levels. Each plant species was subjected to 12 treatments with five replications for each treatment. The treatments were continued until February 24, 1978.

The plants were grown at shade levels of 54% and 73% under saran and 94% under fiberglass. These shade levels were equivalent to 71.04 (6600 ft-c), 40.90 (3800 ft-c) and 8.83 (820 ft-c) klx, respectively, based on mid-day light meter readings. At each of these shade levels, fertilization rates of 672 (600 lb/A/yr), 1344 (1200 lb/A/yr), 2016 (1800 lb/A/yr) and 2688 kg/ha/yr (2400 lb/A/yr) of N, $P_2O_5$ and $K_2O$ were established by biweekly applications of a soluble 20-20-20 fertilizer. Five replicate plants of each species were used at each fertilization rate and shade level. Appropriate measurements were made at the previously designated periods.

The container (shipping) period commenced on March 16, 1978, and was extended to 14 days to maximize the effects of a long storage period under adverse conditions. Furthermore, plants were grouped closely together on a tiered shelf to maximize use of available space. Final data was taken on April 27, 1978.

All variables (except %N) were analyzed with the analysis of variance for a split-split plot design. The analysis of variance table for height of Leea coccinea (Appendix Table 23) is used as representative of the analysis of all variables and species.

Experiment III. Based on the preliminary results from Experiment I, this experiment was designed to determine a sequence for producing acclimatized plants for containerized shipping. The effect of length of acclimatization period, watering schedule and time of fertilization were primary considerations.

Rooted 6-inch terminal cuttings of Ficus benjamina 'Exotica' and Schefflera arboricola were placed in 15.2 cm plastic pots on October 29, 1977. A one part black cinder to one part peat by volume medium was used which was amended with treble superphosphate at 2.0 $kg/m^3$ (2 $oz/ft^3$) and $CaCO_3$ at 4.8 $kg/m^3$ (8 $lbs/yd^3$). The plants were grown under 54% shade and fertilization was applied biweekly at the rate of 2016 kg/ha/yr (1800 lb/A/yr) as recommended by Conover, Poole and Henley (24).

After an establishment period of 12 weeks, the plants were incorporated into a 3 X 2 X 3 factorial experiment on January 27, 1978, replicated five times. Each species was held at 94% shade for 8, 10 or 12 weeks. Water was applied to thoroughly wet the medium either once or twice a week. Fertilization was withheld, applied for the first one-half of the acclimatization period or applied throughout the time of treatment at the rate of 1344 kg/ha/yr of N, $P_2O_5$ and $K_2O$. A soluble fertilizer was incorporated into the watering schedule on a weekly basis for the prescribed period.

After the appropriate acclimatization period, the plants were thoroughly watered and placed in the tapered paper sleeves. They were immediately transferred to the dark storage chamber for a 14-day period. The plants were grouped closely together on a tiered shelf as in Experiment II. After the 14-day dark period the plants were removed and placed under 54% shade for a holding period of 21 days. Fertilization was resumed on a weekly basis at the rate of 2016 kg/ha/yr. Application of water was restored to a three times per week schedule. Final data was taken on May 26, 1978.

Variables and species were analyzed as split-split-split plot design. The analysis of variance table for height of <u>Schefflera arboricola</u> (Appendix Table 24) serves as an example for analysis of all other variables and species.

# RESULTS AND DISCUSSION

Each of the following experiments were initiated to assess the effects of different cultural factors and subsequent long term shipping conditions on various foliage plants. Experiment I shows the results of light acclimatization on sun- and shade-grown plants prior to shipment. The effect of fertilization-shade combinations on plant quality during container shipment is shown in Experiment II. Experiment III incorporated acclimatization period, water and fertilization schedule into an optimum production sequence.

Experiment I. Shade treatment did not affect growth of sun-grown *Ficus benjamina* as measured by height increments (Table 2). Quality and chlorophyll also appeared to be unaffected by the shade treatments used in this experiment. This may indicate that the treatment period (8 weeks) was not sufficiently long for a measurable adaptation to lower light intensities.

Effects of the shipping phase indicate the largest height increase occurred during the treatment phase of the experiment. No significant height increase was made during storage, or during the holding period. Lack of significant growth during storage can be attributed to the absence of photosynthesis. Carbohydrate reserves could account for the

TABLE 2.--Effect of shade treatment and shipping condition on sun-grown *Ficus benjamina* 'Exotica'

| Treatment | Mean increase in height (cm) | Quality[z] | Total chlorophyll ($mg/cm^2$) |
|---|---|---|---|
| Shade | | | |
| FS-8wks[y] | 1.0a[x] | 2.3a | .14a |
| 54%SH-8wks | 0.5a | 2.2a | .16a |
| 94%SH-8wks | 1.2a | 2.3a | .17a |
| FS-4wks/54%SH-4wks | 0.9a | 2.2a | .16a |
| FS-4wks/94%SH-4wks | 1.4a | 2.3a | .15a |
| 54%SH-4wks/94%SH-4wks | 0.4a | 2.3a | .17a |
| Shipping | | | |
| Begin treatment | -- | 2.5a | .14a |
| Into storage | 2.4a | 2.3b | .19a |
| After 10 days storage | 0.3b | 2.1c | .14a |
| End of hold | 0.9b | 2.2cb | .16a |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]FS = full sun, SH = shade level.

[x]Means in the same column followed by the same letter do not differ significantly at the .05 level by Bayes least significant difference (BLSD).

small increase in height that did take place. Slow growth following storage could be due to depletion of these stored carbohydrates and the reorientation and synthesis of chloroplasts. A decrease in quality during storage was followed by a small increase during the holding period.

Conover and Poole (20) found that quality ratings and leaf density of _Ficus benjamina_ were greater after 10 weeks in an interior environment with only 5 weeks of a 40% or 80% shade acclimatization level compared to full sun plants. Again, the lack of significant results with _Ficus_ in this experiment suggests acclimatization or storage period may not have been long enough to detect measurable differences.

Increasing shade levels from full sun to 94% shade increased quality and chlorophyll in leaf tissue of sun-grown _Polyscias guilfoylei_ 'Victoriae' (Table 3). This agrees with the results of other workers (14, 19, 23) who found that quality and chlorophyll increased with increasing shade levels.

Quality and chlorophyll content decreased with time over the shipping sequence. As with _Ficus_, a slight increase in quality was found during the holding period after storage but was below the original reading. The decrease in chlorophyll during shipping could be due to a very slow response of the variegated _Polyscias_ to decreased light intensities or lack of increased production of chlorophyll at the higher shade levels.

TABLE 3.--Effect of shade treatment and shipping condition on sun-grown *Polyscias guilfoylei* 'Victoriae'

| Treatment | Mean increase in height (cm) | Quality[z] | Total chlorophyll ($mg/cm^2$) |
|---|---|---|---|
| Shade | | | |
| FS-8wks[y] | 0.9a[x] | 2.0c | 0.14f |
| 54%SH-8wks | 0.9a | 2.1bc | 0.18b |
| 94%SH-8wks | 0.4a | 2.6a | 0.19a |
| FS-4wks/54%SH-4wks | 1.1a | 2.0c | 0.16d |
| FS-4wks/94%SH-4wks | 0.5a | 2.3b | 0.15e |
| 54%SH-4wks/94%SH-4wks | 0.4a | 2.3b | 0.17c |
| Shipping | | | |
| Begin treatment | -- | 2.7a | 0.19a |
| Into Storage | 1.4a | 2.4b | 0.17b |
| After 10 days storage | 0.1a | 1.9d | 0.17b |
| End of hold | 1.4a | 2.2c | 0.12c |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]FS = full sun, SH = shade level.

[x]Means in the same column followed by the same letter do not differ significantly at the .05 level by BLSD.

Quality of shade-grown Ficus benjamina 'Exotica' was highest after 8 weeks of either 54% or 94% shade (Table 4). Shade treatments had little influence on height or total chlorophyll levels.

No significant increases in height were observed during shipping but, as with the other two species, the largest height increment was during the treatment period. Quality agreed with the previous results indicating a decrease in quality during shipping followed by a slight increase. Chlorophyll increased during treatment indicating a more rapid adaptation to higher shade levels by these shade-grown plants. Stress conditions during storage in darkness and re-orientation to a higher light intensity may explain the subsequent decreases in chlorophyll.

Comparison of the results (Tables 2, 4) of sun-grown and shade-grown Ficus benjamina 'Exotica' indicate that production under prolonged shading gives a higher quality plant with higher chlorophyll levels presumably better adapted for a reduced light intensity environment. Optimum acclimatization treatment for shade-grown Ficus (54% or 94% shade for 8 weeks) showed a greater increment of height and higher quality value than any of the sun-grown Ficus treatments. New growth was initiated rapidly after removal from storage on the shade-grown Ficus and sun-grown Polyscias but was delayed for several weeks on the sun-grown Ficus.

The simulated shipping treatments did not have any visible detrimental effects on any of the species in this

TABLE 4.--Effect of shade treatment and shipping condition on shade-grown *Ficus benjamina* 'Exotica'

| Treatment | Mean increase in height (cm) | Quality[z] | Total chlorophyll ($mg/cm^2$) |
|---|---|---|---|
| Shade | | | |
| 54%SH-8wks[y] | 0.8a[x] | 2.8a | 0.17a |
| 54%SH-4wks/94%SH-4wks | 2.0a | 2.4b | 0.18a |
| 94%SH-8wks | 0.6a | 2.7a | 0.18a |
| Shipping | | | |
| Begin treatment | -- | 3.0a | 0.19b |
| Into storage | 2.4a | 2.5bc | 0.20a |
| After 10 days storage | 0.5a | 2.4c | 0.18c |
| End of hold | 1.7a | 2.6b | 0.14d |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]SH = shade level.

[x]Means in the same column followed by the same letter do not differ significantly at the .05 level by BLSD.

trial. Leaf drop was minimal but simulated shipping period could have been too short for leaf abscission to occur. Soil moisture remained at a high level during shipping because of the high relative humidity (90%) in the chamber.

The results of this experiment indicate that Ficus and Polyscias plants can be shipped by container without undue problems. Best quality Ficus plants with minimal delay in increase in height were produced under shade as compared to sun-grown plants; however, no such comparison could be made for Polyscias since only sun-grown plants were used.

Experiment II. Best growth of Schefflera arboricola, as measured by height and number of nodes, was obtained at the 54% and 73% shade levels (Table 5). A significant reduction in growth was apparent at the 94% level. Highest quality was found at the intermediate 73% shade level with poorest quality at 94% level. However, leaf drop increased with decreasing shade levels. No difference in % nitrogen in leaf tissue was found at any of the three shade levels. Obviously, the 94% shade intensity was not conducive for best growth of Schefflera arboricola but provided the best light level to reduce leaf abscission. This may indicate a 73% shade production period followed by a period of exposure to 94% shade level would be optimum for acclimatization of Schefflera before shipping.

Height tended to increase with increasing fertilizer level but was significantly less at the lowest level.

TABLE 5.--Effect of shade, fertilizer and shipping condition on *Schefflera arboricola*

| Treatment | Height (cm) | No. of nodes | Quality[z] | %N | Avg. leaflet drop |
|---|---|---|---|---|---|
| Shade (%) | | | | | |
| 54 | 29.1a[y] | 13.0a | 2.5b | 1.69 | 15.0a |
| 73 | 30.0a | 12.7a | 2.9a | 1.46 | 8.7b |
| 94 | 13.5b | 7.3b | 2.3c | 1.79 | 0.0c |
| Fertilizer (kg/ha/yr) | | | | | |
| 672 | 20.0b | 9.6a | 2.2c | 1.62 | 2.9c |
| 1344 | 25.4a | 11.0a | 2.5b | 1.52 | 7.9b |
| 2016 | 25.2a | 11.6a | 2.8a | 1.76 | 9.9a |
| 2688 | 26.2a | 11.9a | 2.8a | 1.83 | 8.1b |
| Shipping | | | | | |
| Begin treatment | 8.98c | 5.3c | -- | 1.42 | -- |
| Into storage | 29.3b | 11.4b | 3.0a | -- | -- |
| After 14 days storage | -- | -- | 2.3c | 1.92 | -- |
| End of hold | 34.4a | 16.3a | 2.4b | 1.72 | -- |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]Means in the same column followed by the same letter do not differ significantly at the .05 level by BLSD.

Highest quality ratings were found at the two highest fertilizer levels but this also resulted in the greatest leaf drop during storage. Leaf drop was much lower at the lowest fertilizer level. There was a trend of increasing % nitrogen with increasing fertilizer level even though there were no significant differences. These results indicate the optimum fertilization rate should be used during production followed by a reduced period of fertilization before shipping which has been suggested by several workers (22, 34, 51).

Height and node number increased with time with the greatest increase in both occurring during the 12 week production period. A significant reduction in quality after 3 weeks of simulated shipping was followed by a small increase but the original level was not attained. A non-significant decrease in % nitrogen occurred after removal from storage, possibly due to the fairly rapid resumption of photosynthesis utilizing available nitrogen for production of photosynthates. This could cause a decrease in nitrogen even though a resumption of a weekly fertilizer program was initiated after removal from storage. Nitrogen levels in leaf tissue fluctuated from 1.35 to 2.02 in the various treatments but were not significantly different.

Shade and fertilizer interactions are shown in Tables 6, 7, 8 and 9. There was a significant interaction between shade levels and fertilizer on height of <u>Schefflera</u> (Table 7). Increasing shade decreased height at each fertilizer

TABLE 6.--Effect of shade and fertilizer levels on height, number of nodes, quality, % nitrogen and average leaf drop of *Schefflera arboricola*

| Treatment | | | | | | |
|---|---|---|---|---|---|---|
| % Shade | Fertilizer level | Height (cm) | No. of nodes | Quality[z] | %N | Avg. leaflet drop |
| 54 | 672[y] | 25.8d[x] | 11.7a | 2.1e | 1.49 | 6.2cd |
| 54 | 1344 | 28.1cd | 12.0a | 2.4bcde | 1.59 | 17.0ab |
| 54 | 2016 | 29.3bc | 13.6a | 2.7abcd | 1.77 | 21.0a |
| 54 | 2688 | 33.1a | 14.5a | 2.9ab | 1.91 | 15.8b |
| 73 | 672 | 21.1e | 9.5a | 2.4cde | 1.35 | 2.6de |
| 73 | 1344 | 33.6a | 13.3a | 2.8abc | 1.39 | 6.6c |
| 73 | 2016 | 33.2a | 14.5a | 3.3a | 1.72 | 8.6c |
| 73 | 2688 | 32.1ab | 13.7a | 3.2a | 1.83 | 8.4c |
| 94 | 672 | 13.1f | 7.5a | 2.2de | 2.02 | 0.0e |
| 94 | 1344 | 14.4f | 7.6a | 2.3cde | 1.65 | 0.0e |
| 94 | 2016 | 13.2f | 6.8a | 2.5bcde | 1.76 | 0.0e |
| 94 | 2688 | 13.4f | 7.5a | 2.2de | 1.74 | 0.0e |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]kg/ha/yr of N, $P_2O_5$ and $K_2O$.

[x]Means in the same column followed by the same letter do not differ significantly at the .05 level by BLSD.

TABLE 7.--Interaction of shade and fertilizer on height (cm) of *Schefflera arboricola*

| % Shade | Fertilizer level (kg/ha/yr) | | | |
|---|---|---|---|---|
| | 672 | 1344 | 2016 | 2688 |
| 54 | 25.8d[z] | 28.1cd | 29.3bc | 33.1a |
| 73 | 21.1e | 33.6a | 33.2a | 32.1ab |
| 94 | 13.1f | 14.4f | 13.2f | 13.4f |

[z]Means followed by the same letter do not differ significantly at the .05 level by BLSD.

TABLE 8.--Interaction of shade and fertilizer on quality[z] of *Schefflera arboricola*

| % Shade | Fertilizer level (kg/ha/yr) | | | |
|---|---|---|---|---|
| | 672 | 1344 | 2016 | 2688 |
| 54 | 2.1e[y] | 2.4bcde | 2.7abcd | 2.9ab |
| 73 | 2.4bcde | 2.8abc | 3.3a | 3.2a |
| 94 | 2.2de | 2.3cde | 2.5bcde | 2.2de |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]Means followed by the same letter do not differ significantly at the .05 level by BLSD.

TABLE 9.--Interaction of shade and fertilizer on leaf drop of *Schefflera arboricola*

| % Shade | Fertilizer level (kg/ha/yr) | | | |
|---|---|---|---|---|
| | 672 | 1344 | 2016 | 2688 |
| 54 | 6.2cd[z] | 17.0ab | 21.0a | 15.8b |
| 73 | 2.6de | 6.6c | 8.6c | 8.4c |
| 94 | 0.0e | 0.0e | 0.0e | 0.0e |

[z]Means followed by the same letter do not differ significantly at the .05 level by BLSD.

level. Fertilizer level affected height only at the lowest and highest rates under 54% shade and only at the lowest rate at the 73% shade level. Low fertilization effects were evident only at shade levels which permitted growth, 54% and 73%, and increased growth occurred only at these higher light levels.

There was also a significant interaction between shade and fertilizer on quality (Table 8). A significantly lower quality was found at the lowest fertilizer level for the 54% shade level. Similarly, the lowest rate of fertilizer at the 73% shade level was lower in quality than the two upper rates. At 2016 kg/ha/yr, the 73% shade level was significantly higher than the 94% level. In addition, at the 2688 kg/ha/yr level the two lower shade levels had higher quality values than the 94% level.

Except at the lowest fertilizer level, shade and fertilizer interacted on leaf drop resulting in a significant decrease in leaf drop with increasing shade levels while leaf drop increased with increased fertilizer (Table 9). The lowest and highest fertilizer rates at 54% shade and the lowest rate at 73% shade showed significantly lower leaf drop values.

Observation of plants after storage showed elongation of terminal growth of some plants. In addition, the elongated terminals of those plants grown at 672 and 1344 kg/ha/yr at 73% and 94% shade levels were temporarily chlorotic. This chlorosis could be attributed to the lack of available nitrogen during elongation while in storage or simply etiolation of the new growth. Some overall chlorosis was noted on individual plants. Severe bleaching occurred on a few random plants during the post-storage period.

Examination of all factors suggests that a production regimen of 73% shade with fertilization at 1344 or 2016 kg/ha/yr followed by a 94% shade conditioning period would result in the best acclimatized Schefflera arboricola plant for tolerance of surface shipping conditions.

The effect of shade and fertilizer on the shipping quality of Leea coccinea is given in Table 10. Values for height and node number indicate best growth occurred under 73% shade. Quality ratings were highest at the lower shade levels. Even though adequate height was attained at the 94% shade level, lower node number indicates some stretching of internodes occurring which may have reduced quality. However, lowest leaf drop occurred at the 94% shade level. These results coincide with those for Schefflera indicating the optimal shade levels to be 73% during production followed by 94% during acclimatization.

Slightly taller plants were produced at the two lower nutritional levels while higher quality plants were produced at the upper levels. Nitrogen content was not affected by fertilizer rates or influenced by simulated shipping tests. Less leaf drop occurred with the lowest fertilizer rates but the difference was not statistically significant.

TABLE 10.--Effect of shade, fertilizer and shipping condition on *Leea coccinea*

| Treatment | Height (cm) | No. of nodes | Quality[z] | %N | Avg. leaflet drop |
|---|---|---|---|---|---|
| Shade (%) | | | | | |
| 54 | 18.2b[y] | 4.6b | 3.0a | 1.90 | 7.0a |
| 73 | 22.6a | 4.7a | 3.0a | 1.78 | 7.2a |
| 94 | 19.5a | 4.0c | 2.4b | 2.12 | 2.6b |
| Fertilizer (kg/ha/yr) | | | | | |
| 672 | 22.2a | 4.1b | 2.5d | 1.60 | 3.6a |
| 1344 | 20.7ab | 4.5a | 2.7c | 2.07 | 6.1a |
| 2016 | 18.4c | 4.6a | 3.0b | 2.01 | 5.1a |
| 2688 | 19.0bc | 4.5a | 3.1a | 2.06 | 7.6a |
| Shipping | | | | | |
| Begin treatment | 10.6c | 1.8c | -- | 1.18 | -- |
| Into storage | 22.4b | 4.8b | 3.0a | -- | -- |
| After 14 days storage | -- | -- | 2.5c | 2.89 | -- |
| End of hold | 27.2a | 6.8a | 2.9b | 1.73 | -- |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]Means in the same column followed by the same letter do not differ significantly at the .05 level by BLSD.

*Leea* was less strongly influenced by simulated shipping. After a decrease during simulated shipping, good growth resumed and quality nearly reached the original rating by the end of the post-storage period.

Interactions of shade and fertilizer levels on height, number of nodes, quality and leaf drop of *Leea* are shown in Table 11, 12 and 13. Fertilizer level had no effect on height at the 54% and 94% shade levels (Table 12). At 672 and 1344 kg/ha/yr the 73% shade level resulted in plants of greater height but of lower quality.

At the 54% and 73% shade levels, increasing fertilizer levels increased quality with the highest value at 2688 kg/ha/yr (Table 13). Highest quality for the highest shade level was at 2016 kg/ha/yr.

Etiolation of new growth did not appear after storage but some overall chlorosis was seen on several plants, primarily at the lower fertilization levels indicating possible insufficient stored carbohydrate reserves to sustain the plants during storage. In addition, some necrosis and bleaching were visible on a few plants but were not representative of any treatment group.

These results suggest that quality plants can be produced under 73% shade. Increasing fertilization rates reduces height of *Leea* but increased quality at the 73% level. Further reduction in shade level prior to surface shipping may be beneficial to reduce leaf drop.

TABLE 11.--Effect of shade and fertilizer levels on height, number of nodes, quality, % nitrogen and average leaf drop of *Leea coccinea*

| Treatment | | Height (cm) | No. of nodes | Quality[z] | %N | Avg. leaflet drop |
|---|---|---|---|---|---|---|
| % Shade | Fertilizer level | | | | | |
| 54 | 672[y] | 18.9c[x] | 4.1a | 2.4d | 1.90 | 4.4a |
| 54 | 1344 | 20.5bc | 4.7a | 3.0b | 2.12 | 5.2a |
| 54 | 2016 | 16.0c | 4.8a | 3.4a | 2.00 | 4.2a |
| 54 | 2688 | 17.4c | 4.8a | 3.5a | 2.05 | 14.4a |
| 73 | 672 | 26.0a | 4.5a | 2.5cd | 1.46 | 5.6a |
| 73 | 1344 | 23.3ab | 4.9a | 3.0b | 1.80 | 10.4a |
| 73 | 2016 | 19.1c | 4.9a | 3.0b | 1.88 | 6.6a |
| 73 | 2688 | 21.8bc | 4.6a | 3.4a | 1.97 | 6.0a |
| 94 | 672 | 21.7bc | 3.7a | 2.5cd | 1.89 | 0.8a |
| 94 | 1344 | 18.2c | 3.9a | 2.1e | 2.29 | 2.8a |
| 94 | 2016 | 20.0bc | 4.3a | 2.6c | 2.16 | 4.4a |
| 94 | 2688 | 17.9c | 4.1a | 2.5cd | 2.16 | 2.4a |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]kg/ha/yr of N, $P_2O_5$ and $K_2O$.

[x]Means in the same column followed by the same letter do not differ significantly at the .05 level by BLSD.

TABLE 12.--Interaction of shade and fertilizer on height (cm) of *Leea coccinea*

| % Shade | Fertilizer level (kg/ha/yr) | | | |
|---|---|---|---|---|
| | 672 | 1344 | 2016 | 2688 |
| 54 | 18.9c[z] | 20.5bc | 16.0c | 17.4c |
| 73 | 26.0a | 23.3ab | 19.1c | 21.8bc |
| 94 | 21.7bc | 18.2c | 20.0bc | 17.9c |

[z]Means followed by the same letter do not differ significantly at the .05 level by BLSD.

TABLE 13.--Interaction of shade and fertilizer on quality[z] of *Leea coccinea*

| % Shade | Fertilizer level (kg/ha/yr) | | | |
|---|---|---|---|---|
| | 672 | 1344 | 2016 | 2688 |
| 54 | 2.4d[y] | 3.0b | 3.4a | 3.5a |
| 73 | 2.5cd | 3.0b | 3.0b | 3.4a |
| 94 | 2.5cd | 2.1e | 2.6c | 2.5cd |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]Means followed by the same letter do not differ significantly at the .05 level by BLSD.

Effect of shade on Brassaia actinophylla were similar to Leea (Table 14). The 73% shade level had the most positive effect on height, number of nodes and quality. Minimal leaf drop occurred at the 73% and 94% shade levels.

Fertilizer levels had no measurable effect on plant height and number of nodes. Better quality plants were obtained at the highest fertilizer level but there was a nonsignificant increase in leaf drop at this rate.

Simulated shipping effects were consistent with those of the former species showing a recovery in growth response and quality after shipping and no change in nitrogen content of leaf tissue.

Shade and fertilizer had no effect on height and node number of Brassaia actinophylla (Table 15). Quality increased with increasing fertilizer levels at 54% and 94% shade as shown in Table 16, but the highest quality at all fertilizer rates occurred under 73% shade. Likewise, leaf loss was lowest at the 73% shade level (Table 17) and at the 672 and 1344 kg/ha/yr fertilizer rates for all shade levels.

As with Leea and Schefflera, nitrogen content was not affected by shade and fertilizer treatments. The optimum range based on quality was within the 2.00 to 2.30 % nitrogen range which is slightly lower than the 2.5 to 3.5 % nitrogen determined by Poole et al (44).

Brassaia actinophylla was also adversely affected by the storage period. Twenty-four plants represented by all treatments exhibited etiolation of new growth. Overall

TABLE 14.--Effect of shade, fertilizer and shipping condition on *Brassaia actinophylla*

| Treatment | Height (cm) | No. of nodes | Quality[z] | %N | Avg. leaflet drop |
|---|---|---|---|---|---|
| Shade (%) | | | | | |
| 54 | 19.8b[y] | 5.7a | 2.6b | 2.09 | 4.8a |
| 73 | 22.9a | 6.0a | 3.2a | 1.82 | 0.6b |
| 94 | 14.9c | 4.8b | 2.6b | 1.78 | 0.6b |
| Fertilizer (kg/ha/yr) | | | | | |
| 672 | 21.0a | 5.0b | 2.5c | 1.45 | 0.9a |
| 1344 | 18.8a | 5.3b | 2.7b | 1.86 | 1.3a |
| 2016 | 18.7a | 5.5b | 2.8b | 2.24 | 1.8a |
| 2688 | 18.2a | 6.1a | 3.0a | 2.04 | 3.9a |
| Shipping | | | | | |
| Begin treatment | 8.3c | 2.8c | -- | 1.33 | -- |
| Into storage | 22.0b | 5.6b | 3.0a | -- | -- |
| After 14 days storage | -- | -- | 2.6c | 2.18 | -- |
| End of hold | 27.4a | 8.0a | 2.8b | 2.18 | -- |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]Means in the same column followed by the same letter do not differ significantly at the .05 level by BLSD.

TABLE 15.--Effect of shade and fertilizer levels on height, number of nodes, quality, % nitrogen and average leaf drop of *Brassaia actinophylla*

| Treatment | | | | | | |
|---|---|---|---|---|---|---|
| % Shade | Fertilizer level | Height (cm) | No. of nodes | Quality[z] | %N | Avg. leaflet drop |
| 54 | 672[y] | 23.5a[x] | 5.3a | 2.5de | 1.35 | 2.2b |
| 54 | 1344 | 19.6a | 5.5a | 2.6de | 2.24 | 8.8b |
| 54 | 2016 | 20.1a | 6.1a | 2.7cde | 2.65 | 4.4b |
| 54 | 2688 | 16.1a | 5.8a | 2.5de | 2.13 | 10.8a |
| 73 | 672 | 25.7a | 5.4a | 2.8bcd | 1.26 | 0.0b |
| 73 | 1344 | 21.6a | 5.8a | 3.0bc | 1.56 | 2.0b |
| 73 | 2016 | 21.4a | 5.9a | 3.2b | 2.32 | 0.2b |
| 73 | 2688 | 22.8a | 6,8a | 3.8a | 2.13 | 0.0b |
| 94 | 672 | 13.9a | 4.3a | 2.3e | 1.72 | 0.4b |
| 94 | 1344 | 15.2a | 4.7a | 2.6de | 1.78 | 0.2b |
| 94 | 2016 | 14.7a | 4.5a | 2.6de | 1.74 | 0.8b |
| 94 | 2688 | 15.8a | 5.7a | 2.8bcd | 1.86 | 0.8b |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]kg/ha/yr of N, $P_2O_5$ and $K_2O$.

[x]Means in the same column followed by the same letter do not differ significantly at the .05 level by BLSD.

TABLE 16.--Interaction of shade and fertilizer on quality$^z$ of *Brassaia actinophylla*

| % Shade | Fertilizer level (kg/ha/yr) 672 | 1344 | 2016 | 2688 |
|---|---|---|---|---|
| 54 | 2.5de$^y$ | 2.6de | 2.7cde | 2.5de |
| 73 | 2.8bcd | 3.0bc | 3.2b | 3.8a |
| 94 | 2.3e | 2.6de | 2.6de | 2.8bcd |

$^z$Based on a scale of 1 = poor to 5 = excellent quality.

$^y$Means followed by the same letter do not differ significantly at the .05 level by BLSD.

TABLE 17.--Interaction of shade and fertilizer on leaf drop of *Brassaia actinophylla*

| % Shade | Fertilizer level (kg/ha/yr) 672 | 1344 | 2016 | 2688 |
|---|---|---|---|---|
| 54 | 2.2b$^z$ | 1.8b | 4.4b | 10.8a |
| 73 | 0.0b | 2.0b | 0.2b | 0.0b |
| 94 | 0.4b | 0.2b | 0.8b | 0.8b |

$^z$Means followed by the same letter do not differ significantly at the .05 level by BLSD.

chlorosis was visible on 16 plants in all treatments following simulated shipping but especially at the lower fertilization rates indicating a depletion of available nitrogen. Some elongation of terminal growth did occur. Marginal and tip necrosis was found on ten plants and may have been a pathogenic (fungal or bacterial) response to the high humidity of the chamber. Bleaching occurred on six plants of the 94% shade level group and one of the 73% treatment. Soil moisture was retained at all treatment levels.

Based on these results, a production schedule of 73% shade at 2688 kg/ha/yr without a subsequent acclimatization period should be sufficient for container shipping of *Brassaia actinophylla*. The high fertilizer requirement for this species could be attributed to the rapid increase in size and leaf area.

The results presented in Experiment II are similar to those of Collard *et al* (14) and Conover and Poole (19). They found height and quality to increase with increasing shade levels up to 80% shade. Reduction in quality and growth at the 94% shade level suggests sub-optimal conditions for growth of these three plant species.

*Experiment III*. Length of time at 94% shade had no effect on plant height or % nitrogen of *Ficus benjamina* 'Exotica' (Table 18). Quality, however, was increased by the longer shading period. A slight drop in chlorophyll also occurred

TABLE 18.--Effect of length of acclimatizing shade period, watering frequency, fertilization schedule and shipping condition on *Ficus benjamina* 'Exotica'

| Treatment | Height (cm) | Quality[z] | Total chlorophyll ($mg/cm^2$) | %N | Avg. leaf drop |
|---|---|---|---|---|---|
| Shade period (94%) | | | | | |
| 8 weeks | 50.3a[y] | 2.6b | 0.13a | 2.26 | 2.1a |
| 10 weeks | 47.5a | 2.6b | 0.13a | 2.34 | 2.1a |
| 12 weeks | 44.5a | 2.9a | 0.12b | 2.41 | 1.0a |
| Watering frequency | | | | | |
| 1X/week | 46.4a | 2.8a | 0.12a | 2.30 | 1.2a |
| 2X/week | 48.4a | 2.5b | 0.12a | 2.37 | 1.4a |
| Fertilization schedule (1344 kg/ha/yr) | | | | | |
| 0% of shade period | 45.2b | 2.7a | 0.12b | 2.25 | 1.1a |
| 50% of[x] shade period | 49.2a | 2.7a | 0.12b | 2.36 | 1.2a |
| 100% of shade period | 47.7ab | 2.7a | 0.13a | 2.39 | 1.7a |
| Shipping | | | | | |
| Begin treatment | 45.0c | 2.8a | 0.16a | 2.39 | -- |
| Into storage | 47.6b | 2.9a | 0.12b | 2.20 | -- |
| After 14 days storage | -- | 2.4c | 0.11c | 2.22 | -- |
| End of hold | 49.7a | 2.6b | 0.10d | 2.52 | -- |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]Means in the same column of each section followed by the same letter do not differ significantly at the .05 level by BLSD.

[x]First one-half of shade period.

at the 12-week shade period. Leaf drop was not significant but did show a lower value at the longer shade period.

Better quality plants were produced at the 1X/week watering frequency but a 2X/week frequency may produce taller plants. Conover and Poole (20) found that weekly watering of Aphelandra squarrosa Nees cv. Dania produced smaller, lower quality plants than semi-weekly waterings.

Fertilization with 1344 kg/ha/yr of N, $P_2O_5$ and $K_2O$ for one-half of the time period appeared best for growth of Ficus but quality, % nitrogen and leaf drop were unaffected. Chlorophyll increased with increasing time of fertilization which agrees with Collard et al (14). Leaf nitrogen levels did agree well with the 1.8 to 2.5% range suggested by Poole et al (44) for Ficus benjamina.

Effect of the simulated shipping phase on Ficus were much the same as those of the previous experiments. Normal growth was resumed after the simulated shipping test. A decrease in quality during storage was followed by an increase but not to the original level. The continuous decrease in chlorophyll level was unexplained however. Before treatment at 94% shade, plants were established at a 54% shade level. Thus, it would seem there should be an increase in total chlorophyll during the treatment period which then would be followed by a decrease in chlorophyll content, unless the treatment light intensity (94%) was too low for sufficient chlorophyll production.

Chlorophyll content of *Ficus* was the only variable significantly, but inconsistently, affected by the interaction of shade period, water frequency and fertilization schedule (Table 19). Apparently intervals between treatments were not great enough to produce significant responses by the plants in those treatments. Vlahos and Boodley (51) determined that 50% shade for 10 weeks, watering every 5 days, and reduction in fertilization was best for interior acclimatization of *Ficus nitida*. However, they did not find any differences in acclimatization at 40 to 70% shade (from which the 50% shade recommendation was derived) except that a 5-day watering period gave better growth than a 10-day period.

Based on the results of shipping on the sun and shade-grown *Ficus* in Experiment I, a reduction in light intensity for acclimatization of the sun-grown *Ficus* appeared conducive before shipping. However, reduction in light intensity after production under 54% shade may not be necessary for *Ficus benjamina* 'Exotica'.

Chlorosis of new leaves was the only detrimental effect observed on *Ficus* after 14 days simulated shipping. Twenty-one plants of 30 of the 8-week time period and 20 plants of 30 of the 10-week period were chlorotic with the most chlorosis occurring with zero or partial fertilization. The time period of 12 weeks had only 10 out of 30 chlorotic plants. Chlorosis was generally overcome by resumption of fertilization during the post-storage holding period. This

TABLE 19.--Interaction between length of acclimatizing shade period, watering frequency and fertilization schedule with *Ficus benjamina* 'Exotica'

| Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|
| Shade[y] period | Watering frequency | Fert.[x] sched. | Height (cm) | Quality[z] | Total chlor. ($mg/cm^2$) | %N | Avg. leaf drop |
| 8 | 1X/wk | 0 | 43.4a[w] | 2.4a | 0.12cd | 2.28 | 1.0a |
| 8 | 1X/wk | 50 | 45.6a | 2.9a | 0.12cd | 2.27 | 1.6a |
| 8 | 1X/wk | 100 | 47.6a | 2.8a | 0.14ab | 2.42 | 0.2a |
| 8 | 2X/wk | 0 | 41.9a | 2.4a | 0.11d | 2.13 | 3.4a |
| 8 | 2X/wk | 50 | 62.5a | 2.6a | 0.12cd | 2.14 | 0.6a |
| 8 | 2X/wk | 100 | 60.7a | 2.6a | 0.14ab | 2.29 | 2.8a |
| 10 | 1X/wk | 0 | 47.6a | 2.8a | 0.13bc | 2.29 | 0.8a |
| 10 | 1X/wk | 50 | 51.0a | 2.7a | 0.11d | 2.11 | 1.2a |
| 10 | 1X/wk | 100 | 45.5a | 2.7a | 0.12cd | 2.37 | 2.4a |
| 10 | 2X/wk | 0 | 46.6a | 2.6a | 0.12cd | 2.38 | 0.8a |
| 10 | 2X/wk | 50 | 49.9a | 2.5a | 0.15a | 2.56 | 0.0a |
| 10 | 2X/wk | 100 | 44.0a | 2.1a | 0.13bc | 2.32 | 2.8a |
| 12 | 1X/wk | 0 | 48.8a | 3.0a | 0.12cd | 2.22 | 0.8a |
| 12 | 1X/wk | 50 | 42.0a | 3.0a | 0.11d | 2.40 | 2.8a |
| 12 | 1X/wk | 100 | 46.0a | 3.4a | 0.13bc | 2.34 | 0.4a |
| 12 | 2X/wk | 0 | 43.3a | 2.8a | 0.11d | 2.19 | 0.0a |
| 12 | 2X/wk | 50 | 44.4a | 2.4a | 0.11d | 2.70 | 0.8a |
| 12 | 2X/wk | 100 | 42.6a | 2.5a | 0.13bc | 2.60 | 1.4a |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]Weeks at 94% shade.

[x]Percent of shade period at 1344 kg/ha/yr.

[w]Means in the same column of each shade period followed by the same letter do not differ significantly at the .05 level by BLSD.

would indicate resumption of a recommended fertilization program after shipping is desirable.

Ten weeks of 94% shade prior to simulated shipping of *Schefflera arboricola* gave the best results as indicated by height and chlorophyll content (Table 20). Quality, % nitrogen and average leaf drop were not affected by shade period.

Increasing watering frequency increased plant height but decreased total chlorophyll level. Other variables were unaffected by watering frequency.

Height, quality and chlorophyll content were increased by increasing the fertilization period. Leaf drop, though not significant, did show a higher value with an extended fertilization period. Conover and Poole (22) have stressed the importance of reduction in fertilization toward the end of the production cycle to avoid buildup of soluble salts.

The effect of simulated shipping was generally consistent between *Ficus* and *Schefflera* with height showing a steady increase. Quality improved during treatments followed by only a small decrease after storage. Chlorophyll was likewise consistent with other findings but nitrogen was somewhat erratic.

Shade period, watering frequency and fertilization schedule interactions on height and quality of *Schefflera* are presented in Table 21. Height was higher in the 10-and 12-week time periods than after 8 weeks, which is expected. Quality ratings were not consistent for the 8-and 10-week

TABLE 20.--Effect of length of acclimatizing shade period, watering frequency, fertilization schedule and shipping condition on *Schefflera arboricola*

| Treatment | Height (cm) | Quality[z] | Total chlorophyll ($mg/cm^2$) | %N | Avg. leaflet drop |
|---|---|---|---|---|---|
| Shade period (94%) | | | | | |
| 8 weeks | 27.8b[y] | 2.5a | 0.15b | 2.56 | 4.1a |
| 10 weeks | 32.3a | 2.5a | 0.16a | 2.57 | 0.9a |
| 12 weeks | 33.1a | 2.6a | 0.14c | 2.92 | 1.6a |
| Watering frequency | | | | | |
| 1X/week | 29.7b | 2.5a | 0.15a | 2.67 | 2.1a |
| 2X/week | 32.4a | 2.6a | 0.14b | 2.70 | 2.2a |
| Fertilization schedule (1344 kg/ha/yr) | | | | | |
| 0% of shade period | 29.5b | 2.4c | 0.14b | 2.30 | 1.9a |
| 50% of[x] shade period | 32.0a | 2.5b | 0.15a | 2.78 | 1.7a |
| 100% of shade period | 31.8a | 2.7a | 0.15a | 2.98 | 2.8a |
| Shipping | | | | | |
| Begin treatment | 23.4c | 2.3d | 0.10d | 2.98 | -- |
| Into storage | 32.2b | 2.8a | 0.18a | 2.38 | -- |
| After 14 days storage | -- | 2.4c | 0.17b | 2.77 | -- |
| End of hold | 37.6a | 2.6b | 0.14c | 2.61 | -- |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]Means in the same column of each section followed by the same letter do not differ significantly at the .05 level by BLSD.

[x]First one-half of shade period.

TABLE 21.--Interaction between length of acclimatizing shade period, watering frequency and fertilization schedule with *Schefflera arboricola*

| Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|
| Shade[y] period | Watering frequency | Fert.[x] sched. | Height (cm) | Quality[z] | Total chlor. ($mg/cm^2$) | %N | Avg. leaflet drop |
| 8 | 1X/wk | 0 | 27.7def[w] | 2.7ab | 0.14a | 2.14 | 2.4a |
| 8 | 1X/wk | 50 | 30.0cde | 2.5bcd | 0.18a | 2.78 | 5.0a |
| 8 | 1X/wk | 100 | 26.6ef | 2.4cde | 0.13a | 2.88 | 7.8a |
| 8 | 2X/wk | 0 | 26.1f | 2.4cde | 0.13a | 1.92 | 2.0a |
| 8 | 2X/wk | 50 | 26.5ef | 2.4cde | 0.17a | 2.62 | 3.8a |
| 8 | 2X/wk | 100 | 29.8cdef | 2.8a | 0.14a | 3.04 | 3.4a |
| 10 | 1X/wk | 0 | 27.2ef | 2.2e | 0.16a | 2.12 | 1.0a |
| 10 | 1X/wk | 50 | 32.1abc | 2.4cde | 0.15a | 2.61 | 0.2a |
| 10 | 1X/wk | 100 | 31.2bcd | 2.7ab | 0.17a | 2.70 | 0.2a |
| 10 | 2X/wk | 0 | 34.7ab | 2.5bcd | 0.13a | 2.41 | 1.6a |
| 10 | 2X/wk | 50 | 34.7ab | 2.5bcd | 0.15a | 2.68 | 0.6a |
| 10 | 2X/wk | 100 | 34.4ab | 2.6abc | 0.17a | 2.92 | 1.6a |
| 12 | 1X/wk | 0 | 26.0f | 2.3de | 0.16a | 2.62 | 1.6a |
| 12 | 1X/wk | 50 | 33.4abc | 2.6abc | 0.14a | 2.96 | 0.6a |
| 12 | 1X/wk | 100 | 33.5abc | 2.8a | 0.14a | 3.19 | 0.0a |
| 12 | 2X/wk | 0 | 35.2a | 2.7ab | 0.12a | 2.48 | 3.2a |
| 12 | 2X/wk | 50 | 35.1a | 2.7ab | 0.13a | 3.00 | 0.0a |
| 12 | 2X/wk | 100 | 35.5a | 2.7ab | 0.14a | 3.16 | 4.0a |

[z]Based on a scale of 1 = poor to 5 = excellent quality.

[y]Weeks at 94% shade.

[x]Percent of shade period at 1344 kg/ha/yr.

[w]Means in the same column of each shade period followed by the same letter do not differ significantly at the .05 level by BLSD.

periods at each water and fertilization schedule but were uniformly higher in all treatments of the 12-week time period except with the 1X/week watering frequency and zero fertilization. Leaf drop, while not significantly different among treatments, was lowest during the 10-and 12-week acclimatization periods.

Some elongation of terminal growth occurred during shipping. Etiolation of this new growth was found in 16, 14 and 11 plants of the 8-, 10-and 12-week time periods respectively. Chlorosis occurred uniformly over watering and fertilization schedule but was overcome upon resumption of fertilization during holding. Some bleaching occurred in all treatments but was minimal for the 12-week time period. Injured plants in this treatment were only found at zero fertilization levels, suggesting the necessity of adequate nutritional levels for resumption of photosynthetic activity.

These results indicate that an acclimatization period of 10 or 12 weeks at 94% shade is optimum for Schefflera arboricola under these conditions. Based on the results of Experiment II, a 73% shade level for production should precede a 94% shade acclimatization period. Watering frequency and fertilization schedule during this time period seemed to have little influence. A 2X/week watering frequency did, however, produce a slightly taller plant.

Comparison of these results with those of Schefflera arboricola from Experiment II indicates a period of acclimatization is beneficial. The time period needed at a higher shade level may be shortened to a period less than 8 weeks allowing more time for optimum growth. A reduced acclimatization period could also allow reduction of fertilization and watering without affecting growth and quality but reducing leaf drop.

# SUMMARY

Acclimatization has been shown to be effective in producing plants which are better adapted to low light intensity environments. Increasing costs of air freight transportation to the mainland have created interest in the use of containerized surface shipping for foliage plants. Studies were initiated on the effectiveness of cultural control of foliage plants in reducing loss of quality through extended shipping periods.

An experiment using sun-grown plants of Ficus benjamina 'Exotica' and Polyscias guilfoylei 'Victoriae' and shade-grown plants of Ficus benjamina 'Exotica' was initiated to observe the response of these plants to shade treatments. Various combinations of 54% and 94% shade for 8-week periods were given to the plants before a simulated shipping treatment. Shade-grown Ficus maintained at 54% shade or given a 94% shade acclimatization treatment were shown to be better adapted and of higher quality than sun-grown plants in this experiment. A 94% shade acclimatization period gave highest quality ratings for sun-grown Polyscias.

A second experiment using three species (Schefflera arboricola, Leea coccinea and Brassaia actinophylla) in a 3 X 4 factorial design with three shade levels (54, 73 and 94%) and four fertilizer levels (672, 1344, 2016 and 2688 kg/ha/yr of N, $P_2O_5$ and $K_2O$) was used to determine the

influence of shade and fertilizer level on the growth and quality of the species prior to a simulated container shipping test. A 73% shade level was best for production of Leea, Brassaia and Schefflera. A subsequent acclimatization period at 94% appeared beneficial for Schefflera. Optimum fertilization levels were determined to be 1344 to 2016 kg/ha/yr for Schefflera and Leea and 2688 kg/ha/yr of N, $P_2O_5$ and $K_2O$ for Brassaia.

The final experiment incorporated a high shade level (94%) for maximum acclimatization to low light at periods of 8, 10 and 12 weeks, a watering frequency of 1X or 2X/week and a fertilization schedule of 0, 50 or 100% of the first one-half of the time period used prior to simulated container shipping. Two species, Ficus benjamina 'Exotica' and Schefflera arboricola, were used. Ficus was not significantly influenced by the treatments of Experiment III indicating acclimatization at a higher light intensity or foregoing the reduction in shade level would be more beneficial. Best results for Schefflera were obtained at 10 weeks of the 94% shade level with little effect from fertilization or watering frequency.

Comparison of Ficus benjamina 'Exotica' in Experiments I and III showed that reduction in shade level improved growth, quality and tolerance to simulated container shipping conditions. An additional period at 94% shade levels after production at 54% shade did not appear to be of added benefit. A similar conclusion was reached in Experiment II for Brassaia actinophylla and Leea coccinea which indicated 94% shade level treatment was not beneficial. However, Schefflera arboricola in Experiments II and III did show improved tolerance to storage conditions during shipping tests through an acclimatization period.

This study indicates that production of shade-grown plants does improve the quality and leaf retention characteristics of some foliage plants. Further reduction in light intensity below that of the production level may not be of added benefit for containerized surface shipping conditions for some species. Control of watering and fertilization practices in these experiments did not appear advantageous for the species studied.

# APPENDIX

TABLE 22.--Analysis of variance for the effect of acclimatization treatment and storage period on height of sun-grown *Ficus benjamina* 'Exotica'

| Source | df | SS | MS | F |
|---|---|---|---|---|
| Date Plot | 23 | 273.36 | | |
| Date | 3 | 119.77 | 39.92 | 5.27* |
| Replications | 5 | 39.52 | 7.90 | 1.04 |
| Error a | 15 | 114.07 | 7.60 | |
| Treatment Plot | 143 | 1261.77 | | |
| Treatments | 5 | 16.89 | 3.38 | 0.38 |
| Treatments X Dates | 15 | 92.68 | 6.18 | 0.70 |
| Error b | 100 | 878.84 | 8.79 | |

*Significant at the .05 level.

TABLE 23.--Analysis of variance for the effect of shade, fertilizer and storage period on height of *Leea coccinea*

| Source | df | SS | MS | F |
|---|---|---|---|---|
| Date Plot | 14 | 9285.86 | | |
| Date | 2 | 8844.12 | 4422.06 | 293.24* |
| Replications | 4 | 321.06 | 80.26 | 5.32* |
| Error a | 8 | 120.68 | 15.08 | |
| Shade Plot | 44 | 10732.53 | | |
| Shade | 2 | 603.04 | 301.52 | 10.44* |
| Date X Shade | 4 | 150.42 | 37.60 | 1.30 |
| Error b | 24 | 693.21 | 28.88 | |
| Fertilizer Plot | 179 | 13904.17 | | |
| Fertilizer | 3 | 401.75 | 133.92 | 6.56* |
| Date X Fert. | 6 | 170.43 | 28.40 | 1.39 |
| Shade X Fert. | 6 | 280.31 | 46.72 | 2.29* |
| Date X Shade X Fert. | 12 | 112.79 | 9.40 | 0.46 |
| Error c | 108 | 2206.36 | 20.43 | |

*Significant at the .05 level.

TABLE 24.--Analysis of variance for the effect of length of acclimatizing shade period, watering frequency, fertilization schedule and storage period on height of _Schefflera arboricola_

| Source | df | SS | MS | F |
|---|---|---|---|---|
| Date Plot | 14 | 15986.38 | | |
| Date | 2 | 9292.41 | 4646.20 | 1319.94* |
| Replications | 4 | 6665.80 | 1666.45 | 473.42* |
| Error a | 8 | 28.17 | 3.52 | |
| Time Plot | 44 | 18579.47 | | |
| Time | 2 | 1519.59 | 759.80 | 26.56* |
| Date X Time | 4 | 386.78 | 96.70 | 3.38* |
| Error b | 24 | 686.72 | 28.61 | |
| Water Plot | 89 | 21646.25 | | |
| Water | 1 | 490.46 | 490.46 | 9.64* |
| Date X Water | 2 | 301.30 | 150.65 | 2.96 |
| Time X Water | 2 | 378.67 | 189.34 | 3.72* |
| Date X Time X Water | 4 | 64.48 | 16.12 | 0.32 |
| Error c | 36 | 1831.87 | 50.88 | |
| Fertilizer Plot | 269 | 26460.27 | | |
| Fertilizer | 2 | 351.69 | 175.84 | 7.13* |
| Date X Fert. | 4 | 199.11 | 49.78 | 2.02 |
| Time X Fert. | 4 | 71.62 | 17.90 | 0.73 |
| Water X Fert. | 2 | 253.46 | 126.73 | 5.14* |
| Date X Time X Fert. | 8 | 23.43 | 2.93 | 0.12 |
| Date X Water X Fert. | 4 | 6.89 | 1.72 | 0.10 |
| Time X Water X Fert. | 4 | 300.35 | 75.09 | 3.04* |
| Date X Time X Water X Fert. | 8 | 58.28 | 7.28 | 0.30 |
| Error d | 144 | 3549.18 | 24.65 | |

*Significant at the .05 level.

LITERATURE CITED

1. Akamine, E. K. and T. Goo. 1977. Test shipment of Hawaii-grown ornamentals by surface transportation. HAES Departmental Paper 52.

2. Anderson, J. M., D. J. Goodchild and N. K. Boardman. 1973. Composition of the photosystems and chloroplast structure in extreme shade plants. Biochem. and Biophys. Acta 325:573-585.

3. Ballantine, J. E. M. and B. J. Forde. 1970. The effect of light intensity and temperature on plant growth and chloroplast ultrastructure in soybean. Amer. J. Bot. 57(10):1150-1159.

4. Björkman, O. 1969. Carboxydismutase activity in shade-adapted and sun-adapted species of higher plants. Carnegie Inst. (Wash.) Yearbook 67:487-488.

5. Björkman, O., N. K. Boardman, J. M. Anderson, S. W. Thorne, D. J. Goodchild and N. A. Pyliotis. 1972. Effect of light intensity during growth of *Atriplex patula* on the capacity of photosynthetic reactions, chloroplast components and structure. Ann. Rep. Carnegie Inst. (Wash.) Stanford, Ca. 1971-72:115-134.

6. Björkman, O. and P. Holmgren. 1963. Adaptability of the photosynthetic apparatus to light intensity in ecotypes from exposed and shaded habitats. Physiol. Plant. 16:889-914.

7. Björkman, O. and P. Holmgren. 1966. Photosynthetic adaptation to light intensity in plants native to shade and exposed habitats. Physiol. Plant. 19:854-859.

8. Boardman, N. K. 1977. Comparative photosynthesis of sun and shade plants. Ann. Rev. Plant Physiol. 28: 355-377.

9. Bohning, R. H. and C. A. Burnside. 1956. The effect of light intensity on rate of apparent photosynthesis in leaves of sun and shade plants. Amer. J. Bot. 43 (8):557-561.

10. Boodley, J. W. 1976. Foliage plant acclimatization. N. Y. St. Flower Ind. Bull. 76(3):4-7.

11. Bruinsma, J. 1963. The quantitative analysis of chlorophylls a and b in plant extracts. Photochem. and Photobiol. 2:241-249.

12. Burnside, C. A. and R. H. Bohning. 1957. The effect of prolonged shading on the light saturation curves of apparent photosynthesis in sun plants. Plant Physiol. 32:61-63.

13. Cataldo, D. A., L. E. Schrader and V. L. Youngs. 1974. Analysis by digestion and colorimetric assay of total nitrogen in plant tissues high in nitrate. Crop Sci. 14:854-856.

14. Collard, R. C., J. N. Joiner, C. A. Conover and D. B. McConnell. 1977. Influence of shade and fertilizer on light compensation point of Ficus benjamina L. J. Amer. Soc. Hort. Sci. 104:447-449.

15. Conklin, E. 1970. A guide to Interior Plantings. Everett Conklin and Co., Montvale, N. J. 25 p.

16. Conover, C. A. 1975. Acclimatization of tropical foliage plants. Amer. Nurseryman 142(5):64, 65, 68-71.

17. Conover, C. A. 1976. Postharvest handling of rooted and unrooted cuttings of tropical ornamentals. HortScience 11:127-128.

18. Conover, C. A. and R. T. Poole. 1973. _Ficus_ _benjamina_ leaf drop. Flor. Rev. 151(3925):29, 67-68.

19. Conover, C. A. and R. T. Poole. 1975. Influence of shade and fertilizer levels on production and acclimatization of _Dracaena_ _marginata_. Proc. Fla. State Hort. Soc. 88:606-608.

20. Conover, C. A. and R. T. Poole. 1975. Acclimatization of tropical trees for interior use. HortScience 10: 600-601.

21. Conover, C. A. and R. T. Poole. 1975. Acclimatization of tropical foliage plants. Flor. Rev. 157(4069): 39, 62-65.

22. Conover, C. A. and R. T. Poole. 1977. Influence of fertilization and watering on acclimatization of _Aphelandra_ _squarrosa_ Nees cv. Dania. HortScience 12: 569-570.

23. Conover, C. A. and R. T. Poole. 1977. Effects of cultural practices on acclimatization of _Ficus_ _benjamina_ L. J. Amer. Soc. Hort. Sci. 102:529-531.

24. Conover, C. A., R. T. Poole and R. W. Henley. 1975. Growing acclimatized foliage plants. Fla. Fol. Grower 12(9):1-7.

25. Duncan, D. B. 1965. A Bayesian approach to multiple comparisons. Technometrics 7:171-222.

26. Forteno, W. C. and E. L. McWilliams. 1978. Light compensation points and acclimatization of four

tropical foliage plants. J. Amer. Soc. Hort. Sci. 103: 52-56.

27. Gammel, W. A. Sr. 1973. Conditioning Florida foliage plants. Landscape Industry Feb/Mar 1973:24-25, 56.

28. Gauhl, E. 1969. Differential photosynthetic performance of Solanum dulcamara ecotype from shaded and exposed habitats. Carnegie Inst. (Wash.) Yearbook 67: 482-488.

29. Gauhl, E. 1970. Leaf factors affecting the rate of light saturated ps in ecotypes of Solanum dulcamara. Carnegie Inst. (Wash.) Yearbook 68:633-636.

30. Goodchild, D. J., O. Björkman and N. A. Pyliotis. 1972. Chloroplast ultrastructure, leaf anatomy, and content of chlorophyll and soluble protein in rain-forest species. Ann. Rep. Carnegie Inst. (Wash.) Stanford, Ca. 1971-72:102-107.

31. Grime, J. P. 1965. Shade tolerance in flowering plants. Nature 208:161-163.

32. Hawaii Agricultural Reporting Service. 1978. Hawaii flowers and nursery products--Annual Summary 1977. Hawaii Department of Agriculture.

33. Henley, R. W. and C. A. Conover. 1974. Acclimating tropical foliage plants. Fla. Foliage Grower 11(6):5-7.

34. Hughes, M. 1978. Keys to production and handling for green plant and industry survival. Flor. Rev. 161 (4185):29, 42-45.

35. Joiner, J. N., C. A. Conover and R. T. Poole. 1977. Factors affecting acclimatization of foliage plants. Unpublished manuscript.

36. Joiner, J. N. and W. E. Waters. 1970. The influence of cultural conditions on the chemical composition of six tropical foliage plants. Proc. Trop. Reg. Amer. Soc. Hort. Sci. 14:254-267.

37. Loach, K. 1967. Shade tolerance in tree seedlings. New Phytol. 66:607-621.

38. Lomagin, A. G. and T. A. Antropova. 1966. Photodynamic injury to heated leaves. Planta 68:297-309.

39. Leider, M. J. 1976. Acclimatization is the process of adapting a plant to an environment different from the one in which the plant was grown. Flor. Rev. 158 (4093):103-105, 160.

40. Meidner, H. 1970. Light compensation points and photorespiration. Nature 228:1349.

41. Mott, R. C. 1971. Foliage plants for retail sales. Part I. The selection of foliage plants. Flor. Rev. 148(3835):33, 73-74.

42. Noggle, G. R. and G. J. Fritz. 1976. Introductory Plant Physiology. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

43. Poole, R. T. and C. A. Conover. 1975. Light requirements for foliage plants. Flor. Rev. 155(4024):44-45, 94-96.

44. Poole, R. T., C. A. Conover and J. N. Joiner. 1976. Chemical composition of good quality tropical foliage plants. Proc. Fla. State Hort. Soc. 89:307-308.

45. Rabinowitch, E. I. 1951. Photosynthesis and related processes, Vol. 2, Part 1. Interscience, New York.

46. Rathmell, J. K. Jr. 1978. Enterprising Kohala Nursery increases floral production. Flor. Rev. 162(4190):22, 60-61.

47. Salsedo, C. A. 1976. Acclimatization of foliage plants. Conn. Greenhouse Newsletter 72:1-4.

48. Staby, G. L., J. L. Robertson and D. C. Kiplinger. 1976. Proc. Nat. Conf. on Commodity Handling. Ohio Florists' Assn., Columbus, Ohio, pp 64, 67.

49. Thomas, M. D. 1955. Effect of ecological factors on photosynthesis. Ann. Rev. Plant Phys. 6:135-136.

50. Van Lierop, W. 1976. Digestion procedures for simultaneous automated determination of $NH_4$, P, K, Ca, and Mg in plant material. Can. J. Soil Sci. 56:425-432.

51. Vlahos, J. and J. W. Boodley. 1974. Acclimatization of _Brassaia actinophylla_ and _Ficus nitida_ to interior environmental conditions. Flor. Rev. 154(3989):18, 19, 56-60.

52. Wassink, E. C., S. D. Richardson and G. A. Pieters. 1956. Photosynthetic adaptation to light intensity in leaves of _Acer pseudoplatanus_. Acta Botan. Neerl. 5(3):247-256.

53. Wetherell, D. F. 1976. Foliage plant conditioning. Conn. Greenhouse Newsletter 71:1-7.

54. Wylie, R. B. 1951. Principles of foliar organization shown by sun-shade leaves from ten species of deciduous dicotyledonous trees. Amer. J. Bot. 38:355-361.