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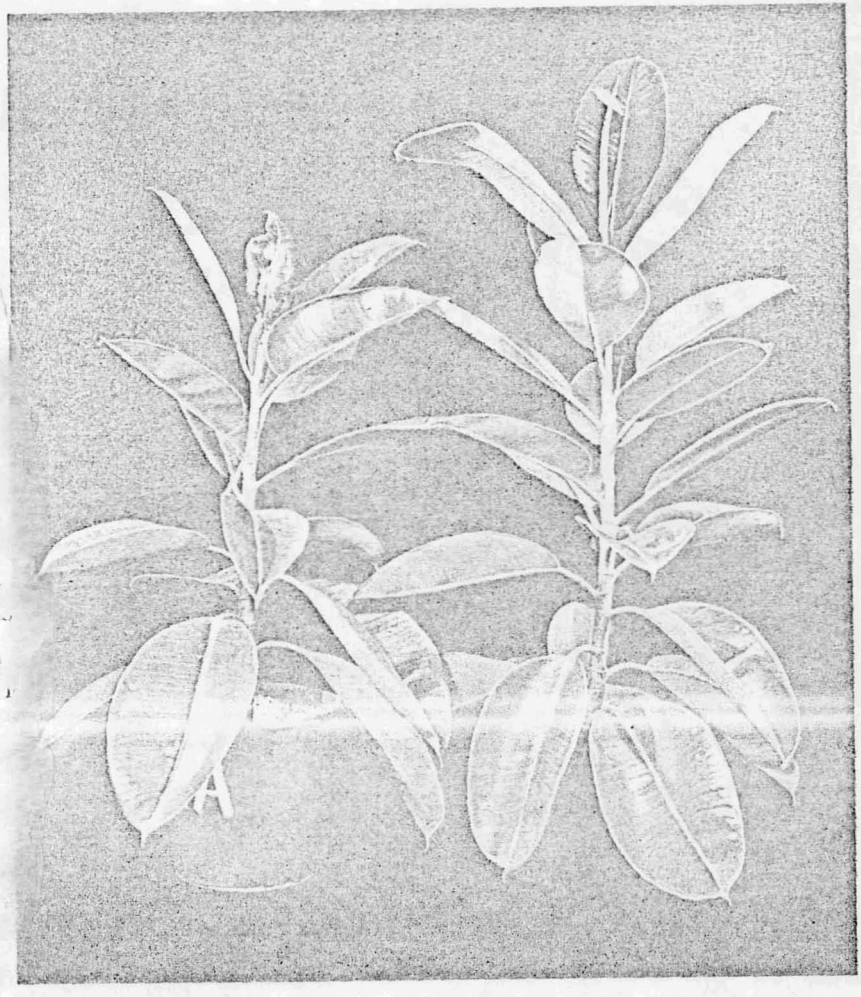
NONCONTAGIOUS DISEASES OF TROPICAL FOLIAGE PLANTS

Robert B. Marlatt



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NONCONTAGIOUS DISEASES OF TROPICAL FOLIAGE PLANTS

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INTRODUCTION

An internationally known plant pathologist, R. B. Stevens, describing nonparasitic (noncontagious) disease, in 1974 stated, "We do not know the precise toll but it is entirely likely that it equals or exceeds that of disease caused by living organisms" (119).

As early as 1909, Sorauer devoted one entire volume of his two-volume treatise on plant diseases to those not caused by pathogens (118).

Many foliage plants submitted for diagnosis by Florida nurserymen are abnormal because of unfavorable environment rather than parasitic bacteria, fungi, nematodes, or viruses.

In attempting to diagnose foliage plant disease, one can easily find information pertaining to contagious diseases, but little is available concerning those which are noncontagious. It is hoped that this manual fills this gap and that it will be useful to commercial growers, extension agents, and researchers.

In distinguishing noncontagious from contagious diseases, a few general observations may be helpful. There are exceptions to each of them, but the observations will be useful for making a preliminary diagnosis:

1. Several unrelated genera or species of plants are often affected by a noncontagious disease in the area inspected. This is rarely the case with disease caused by pathogens.
2. Noncontagious diseases may appear suddenly and be evenly distributed, whereas contagious diseases often spread from one small area of a nursery or from the edges where weed hosts occur.
3. Noncontagious diseases may be indicated if distribution of diseased plants is related to areas covered (or not covered) by sprinklers; certain types or sizes of containers; a particular shade house or greenhouse; areas adjoining pesticide or fertilizer storage, paths, or parking lots.
4. The recent cultural history of the plants often offers a clue; i.e., application of fertilizer or pesticides, irrigation, or the origin of the plants.
5. Can the problem be related to occurrence of frost, strong winds, hail, flooding, or lightning, all of which may result in disease?
6. If there is no sign of a fungus or a bacterial ooze, one can suspect a noncontagious disease or one caused by a virus. Bear in mind, however, that invasion of affected tissues by noninfective fungi and bacteria is inevitable, giving a false impression of a contagious disease.
7. Noncontagious diseases may cause no lesions. If lesions occur, they frequently have no water-soaked or chlorotic margins.

USE OF THIS MANUAL

If the foregoing procedures and information provided by the nurserymen suggest a specific cause of disease, the *Table of Contents* and *Index of Plants* will direct one to the section containing a description of its symptoms, cause, and control or prevention. Diagnosis is an art; therefore, it will be especially helpful to be familiar with the plant and local conditions.

All statements pertaining to the diseases in this manual stem from experimental results unless otherwise qualified as observations or opinions. Some of the problems discussed have only been studied in solution cultures or are rare. They are included in hopes that they will be helpful to persons growing plants hydroponically or experimentally.

MINERAL DEFICIENCIES AND TOXICITIES

Boron Deficiency and Toxicity

Symptoms. — *Chrysalidocarpus lutescens*, deprived of sufficient boron, exhibits plant stunting as well as undersized inflorescences, flowers, and fruits. Leaflets have a chlorotic mottle which begins at their tips. Narrow transverse chlorotic streaks appear interveinally; these are clustered, become more numerous, coalesce, and eventually become necrotic (Fig. 1). Immature leaves and terminal buds die and stems are abruptly tapered near their apices (71). *Dracaena godseffiana*, grown without boron, gains 3% less weight, as compared to normal plants, with no additional symptoms. However, *Dracaena sanderiana*, under similar conditions, produces leathery leaves with brown margins and weighs 16% less than normal (11). Boron deficiency symptoms of *Ficus elastica* 'Decora' include plant stunting and distortion of immature leaves (Fig. 2). Transverse splits in their upper surfaces permit latex to ooze from them and dry upon their surfaces. Terminal buds are very small and die. *Philodendron oxycardium*, deprived of boron, has short internodes, thick and brittle stems, and small, stiff leaves. *Saintpaulia ionantha* has similar symptoms (Fig. 3), and terminal leaves of *Philodendron* are discolored with irregular yellowish streaks (32).

Control. — Drenching soil with water containing 2 parts per million (ppm) boron will remedy a boron deficiency. One source recommends that borax be applied to deficient soil at a rate of 5 to 10 pounds per acre (3). These rates of application should not be exceeded because of possible toxicity.

Chrysalidocarpus lutescens, growing in the presence of excessive amounts of boron, develops severe die-back of tips of mature leaflets

Figure 1. Chrysalidocarpus lutescens frond with boron deficiency. Note the narrow transverse yellow streaks on leaflets.

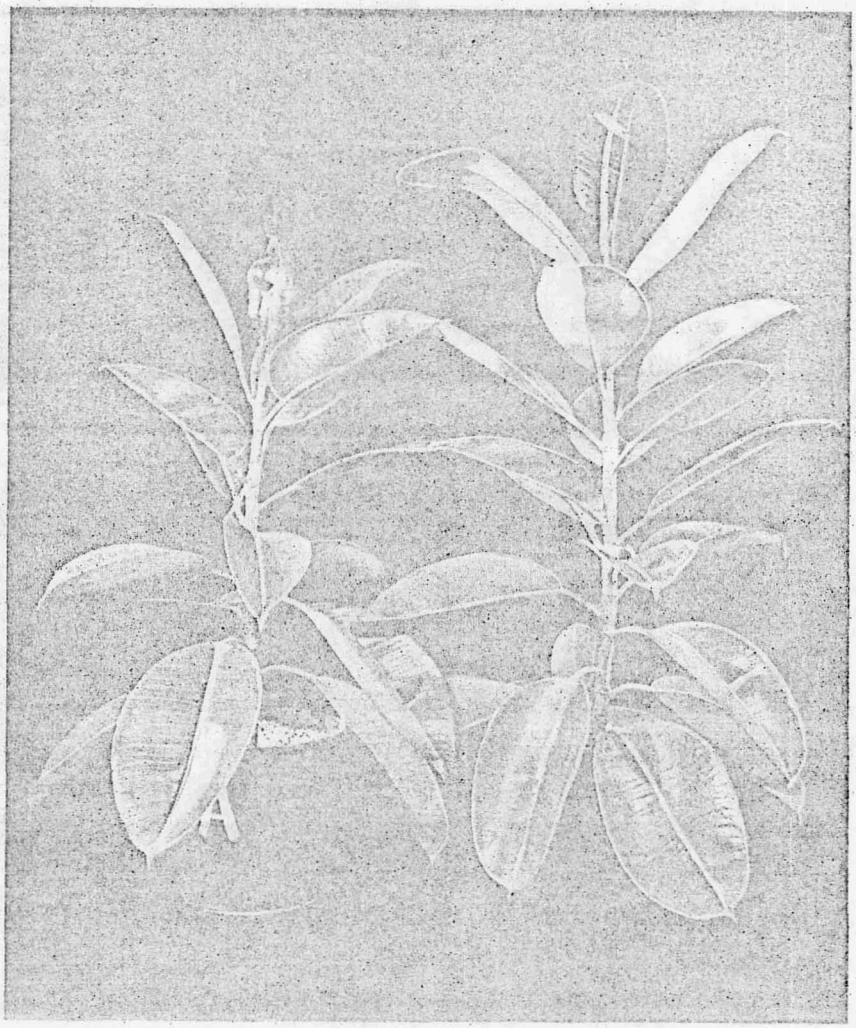

Figure 2. Boron deficient *Ficus elastica* 'Decora' is stunted, and terminal leaves are distorted.

(Fig. 4). The symptom progresses until leaves are dead except for immature fronds (71).

Mature leaves on *Ficus elastica* 'Decora' containing too much boron develop scattered, circular brown spots with chlorotic halos. These first are noticeable only on the undersides of leaves but eventually are visible from above. Lesions become more numerous, widely scattered on leaves, and then affected leaves drop from stems, starting with the oldest ones. Immature leaves remain normal and are clustered at the apex of the plant (71). *Saintpaulia ionantha* 'Mentor Boy' irrigated

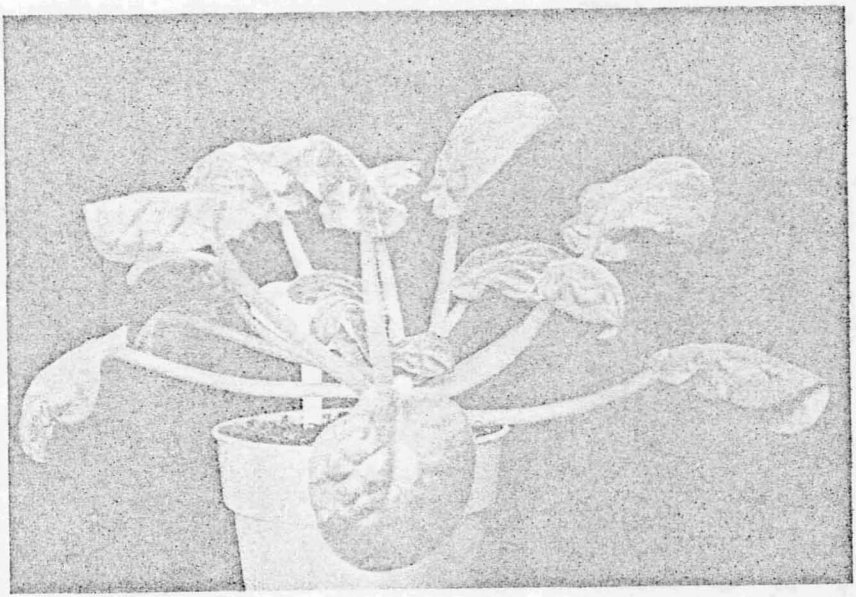

Figure 3. Saintpaulia ionantha plant with boron deficiency. Leaves are brittle and cupped.

with water containing 5 ppm boron developed dead areas around leaf margins (64). *Carissa grandiflora* is the only foliage plant listed as tolerant to excessive boron (37).

Control. — Application of lime to soil has been observed to reduce the availability of boron. If excess boron comes from irrigation water, another water source would have to be found. Sometimes well water containing too much boron can be improved by changing the well depth.

Calcium Deficiency

In addition to the following symptoms, a grower should be on the lookout for weak leaf petioles. Calcium promotes cell wall strength.

Symptoms. — *Dracaena deremensis* 'Warneckii' under greenhouse conditions shows drastic growth reduction when calcium is withheld. Both young and mature leaves become severely serrated, and many brown spots spread from leaf margins until most of the leaf is spotted. Oldest leaves develop rust-like pustules, and new shoots are weakened and have blackish leaflets. Deficient leaves have a tissue content of only 0.32% calcium as compared to 1.54% for normal leaves (113). Lack of calcium has caused *Dracaena godseffiana* to have 41% less weight, as compared to normal plants. Both *D. godseffiana* and *D. sanderiana* exhibit tipburn of young leaves followed by yellowing of

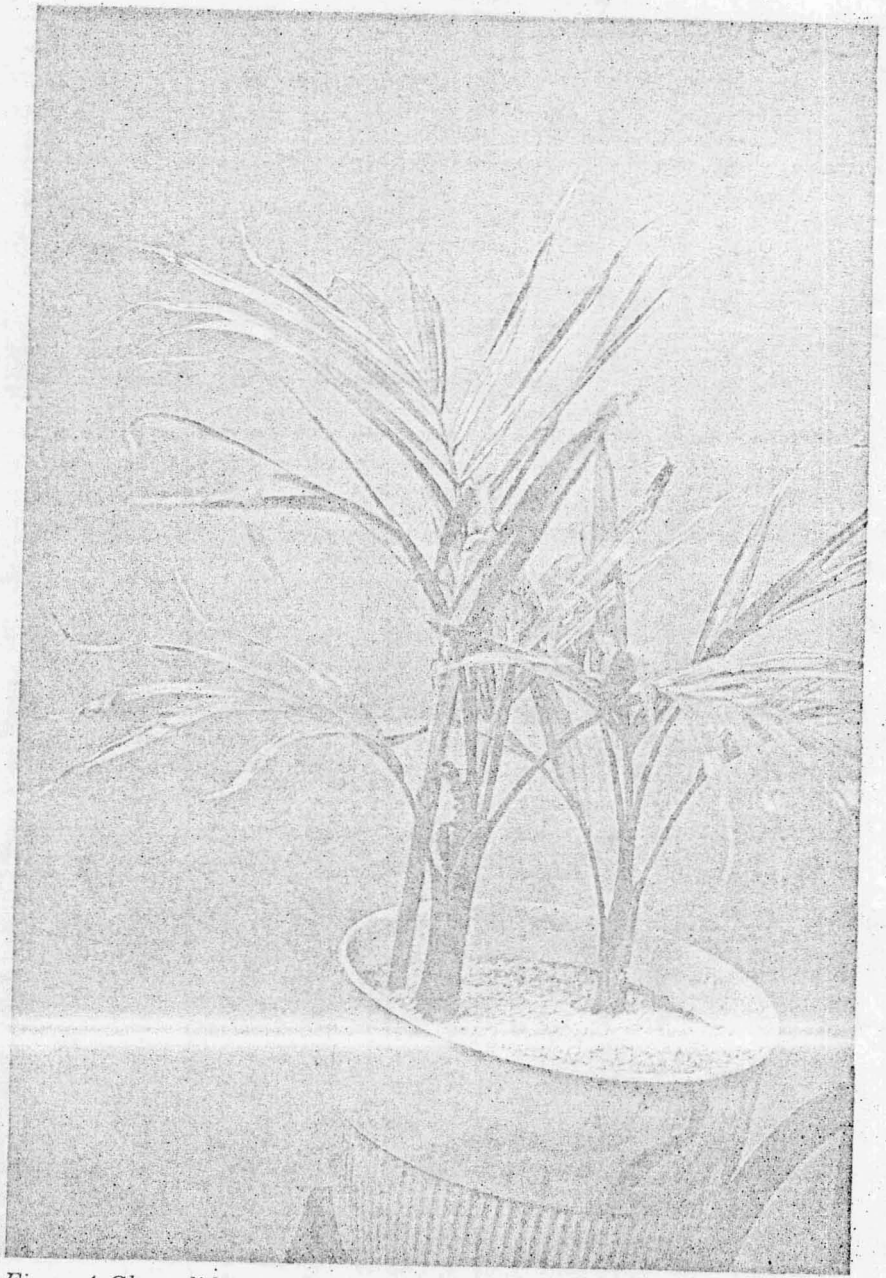

Figure 4. Chrysalidocarpus lutescens frond showing symptoms of boron toxicity. Tips of leaflets are dying back.

leaf margins (11). *Philodendron giganteum* expresses deficiency as a slight yellowing of interveinal areas. Later, yellowish areas turn brown. Axillary buds grow slowly, if at all. Finally the roots become short and brown, with knob-like tips; there are fewer branch roots (125). *Philodendron oxycardium* is affected differently; small, yellowish spots appear on basal leaves first, then all leaves are affected. Yellow spots coalesce, and leaves thicken until they feel leathery. Stems thicken and bear raised, corky areas (32).

Control. — Addition of calcium to the soil mix, such as limestone or gypsum, has been observed to diminish calcium deficiency.

Copper Deficiency

Symptoms. — Inadequate amounts of copper cause new leaves of *Aglaonema commutatum* 'Fransher' to be distorted and small (ca. 1x4 cm) with curved and rolled edges. These symptoms are particularly apparent during cool weather (108). Copper deficiency is particularly common in pure peat mixes, and yields are decreased by a lack of copper in newly cleared peat fields.

Control. — Adding copper oxide at 40 pounds per acre gives a threefold yield increase of caladiums (35). Copper deficiency of *Aglaonema* can be prevented by addition of 200 mg copper Sequestrene (13% Cu) per 15-cm container. A fungicide spray, Kocide (54% Cu), at a rate of 3.5 grams in 2 liters of water also is helpful (108).

Fluoride Toxicity

Symptoms. — In experiments devised to simulate air pollution, *Aglaonema* x 'Silver King' has shown intermediate susceptibility to HF fumigation while *Asparagus sprengeri* has been highly susceptible (129). *Araucaria heterophylla* exhibits a mild leaf chlorosis, especially in leaves under development, and *Ardisia crenata* shows a slight marginal chlorosis of mature leaves (131). *Chamaedorea elegans* is very susceptible and develops large, brown necrotic blotches with dark centers, as well as leaf margin chlorosis and necrosis (131). *Chlorophytum comosum* develops dead areas at leaf tips and margins, and dead spots infrequently occur in white areas of leaves (103). Symptoms on *Chrysalidocarpus lutescens* include leaf tip and marginal leaf scorch, streaks of interveinal chlorosis, and small tan or brown spots with dark centers randomly scattered over leaves (131). *Cordyline terminalis* 'Baby Doll' leaves bear small, brown, dead areas which enlarge and coalesce until more than half of the lower leaves are affected (14, 96). New leaf tips blacken and shrivel on *Dizygotheca elegantissima*, and margins become scorched. These injuries occur

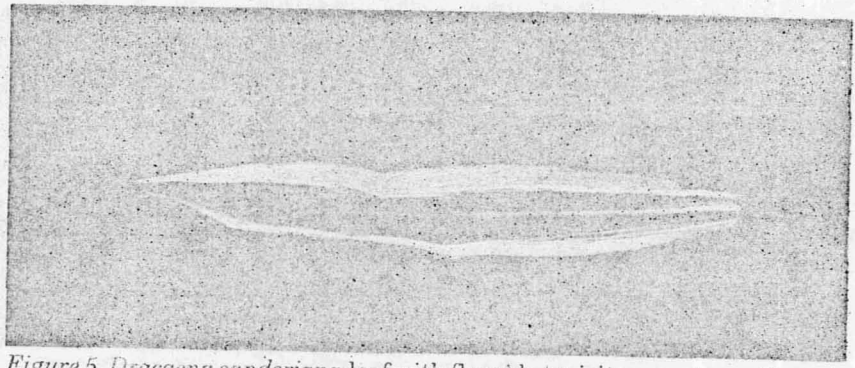

Figure 5. Dracaena sanderiana leaf with fluoride toxicity symptoms. Note oblong, brown spots in white areas.

during growth flushes, but no new damage appears once leaves are mature (131). *Dracaena deremensis* 'Warneckii' and *D. sanderiana* at first show symptoms as light brown, oblong spots within the white areas of leaves (Fig. 5). Green areas have light green spots and tip necrosis (98, 129). *D. deremensis* 'Janet Craig' exhibits dead leaf tips, usually bordered by a yellowish band, and top weight is abnormally low (104). Recently mature leaves of *Howeia fosteriana* show general chlorosis at high fluoride concentrations (10 μg F/m^3), but when the gas is less concentrated (0.4 or 2 μg F/m^3), only interveinal chlorosis appears, and eventually leaf margins and tips are necrotic and dead spots occur in leaves. *Phoenix roebelenii* exhibits random brown flecking on leaflets, and recently matured *Podocarpus macrophyllus* leaves have tip burn (131). Plants reported to be sensitive to fluorides (Table 1) include *Chlorophytum comosum*, *Cordyline terminalis* 'Baby Doll', *C. terminalis* (sport), *Dracaena deremensis* 'Janet Craig', and *D. deremensis* 'Warneckii'. Plants considered to be slightly sensitive are *Dracaena fragrens* 'Massangeana', *Maranta erythroneura*, *M. kerchoveana*, *Spathiphyllum cannaefolium*, *Stromanthe amabilis*, and *Yucca elephantipes* (105, 129). In tests to determine susceptibility of plants to fumigation with hydrogen fluoride, *Dracaena fragrans* 'Massangeana' was considered tolerant, *Aglaonema* 'Silver King' intermediate, *Dracaena deremensis* 'Warneckii' susceptible, and *Asparagus sprengeri* highly susceptible (129).

Control. — Adjust soil pH to 6 - 6.5 by adding dolomite 5 to 10 lb per cubic yard of potting mix. Hydrated lime can be substituted for dolomite; use 80% of dolomite recommended. Superphosphate fertilizer should not be used; it contains 1.5% fluorine. Reduction of transpiration by cuttings is also helpful (105). Fluorides in perlite are readily removed if leached thoroughly two or three times with fluoride-free water, as illustrated by Table 2.

Table 1. Susceptibility of some foliage plants to fluoride air pollution.

Plant	Susceptibility
Aglaonema x 'Silver Queen'	L
Aphelandra squarrosa	L
Araucaria heterophylla	L
Ardisia crenata	M
Asparagus densiflorus 'Sprengeri'	H
Brassaia actinophylla	L
Caladium x 'Red Flag' & 'Frieda Hemple'	L
Chamaedorea elegans	M-H
Chlorophytum comosum 'Variegatum'	H
Chrysalidocarpus lutescens	L
Codiaeum variegatum	L
Coffea arabica	L
Cordyline terminalis	H
Crassula argentea	L
Dizygotheca elegantissima	M
Dracaena deremensis 'Janet Craig'	H
Dracaena deremensis 'Warneckii'	H
Dracaena fragrans 'Massangeana'	L
Dieffenbachia x 'Exotica'	L
Epipremnum aureum (Scindapsus aureus)	L
Gynura procumbens	L
Hemigraphis	L
Howeia fosteriana	M-H
Hoya carnosa	L
Maranta leuconeura erythroneura	M
Nephrolepis exaltata 'Bostoniensis'	L
Nephrolepis exaltata 'Fluffy Ruffle'	L

Continued

Table 1. Continued.

Plant	Susceptibility
Peperomia caperata	L
Peperomia obtusifolia	L
Peperomia obtusifolia 'Variegata'	L
Philodendron scandens oxycardium	M
Philodendron bipennifolium (P. panduriforme)	M
Philodendron x 'Red Emerald'	L
Philodendron selloum	M-H
Phoenix roebelenii	M
Pilea cadierei	L
Plectranthus australis	L
Podocarpus macrophyllus	M
Pteris cretica 'Albo-lineata'	H
Pteris cretica 'Mayii'	H
Pteris ensiformis 'Evergemensis'	H
Sansevieria trifasciata 'Hahnii'	L
Syngonium podophyllum	L
Zebrina pendula	L

Susceptibility H = high, M = medium, L = low (130, 131).

Table 2. Influence of sequential leaching of perlite on fluoride toxicity of *Cordyline terminalis* rooted in perlite leachate.

	Necrosis rating				
	Leachate number[z]				
Treatment	0	1	2	3	4
Deionized water	1.0				
Perlite (source A)		4.7	2.5	1.5	1.0
Perlite (source B)		4.5	1.7	1.3	1.0

[z]1 = no necrosis, 5 = severe necrosis (54).

Iron Deficiency

Iron is not distributed in plants from old to young leaves; therefore, the latter show severest symptoms. If the acidity of growing media is below pH 7, addition of iron salts or chelates will prevent deficiency; if over pH 7, frequent foliar sprays may be needed.

Symptoms. — Iron deficient *Dracaena deremensis* 'Warneckii' has extremely chlorotic immature leaves and occasional necrotic spots near the leaf bases. This spotting may eventually cover the entire leaf. Deficient leaves contain only 83 ppm iron compared to the normal 223 ppm (113). *Dracaena godseffiana* and *D. sanderiana* develop yellow immature leaves which become almost white. Deficient *D. sanderiana* plants have 75% less weight than normal plants (11). *D. godseffiana* has severe defoliation and stem tip dieback, whereas *Philodendron oxycardium* leaves demonstrate only a mild interveinal yellowing (32).

Control. — Iron-EDTA chelate applied as a spray at 1 pound per 100 gallons of water stopped the symptoms. Plants were sprayed four times at weekly intervals; iron sulfate spray caused an unsightly green spotting (114).

Magnesium Deficiency

Symptoms. — Young leaves of magnesium deficient *Dracaena godseffiana* produce dead tips and plants can be underweight as much as 41%. *D. sanderiana* also has tipburn and light blotches in dried leaves. Leaves become brittle, the older ones are cupped; plants weigh up to 31% less than normal (11). *Philodendron scandens oxycardium* plants lose vigor; stems are unusually thin with short internodes and small leaves with yellowish green markings in an inverted V-shape (32). The inverted V is typical of magnesium deficiency in many plants (See Fig. 6).

Control. — Control has been obtained by spraying foliage with a 2% to 3% solution of magnesium sulfate (Epsom salts) or mixing dolomite into the potting media.

Manganese Deficiency and Toxicity

Symptoms. — Manganese is another mineral that cannot move from mature to young leaves; therefore, symptoms of its deficiency are most severe in immature leaves. *Chrysalidocarpus lutescens* terminal fronds are stunted, twisted severely, and brownish or dead. This symptom is referred to as "frizzle top" (Fig. 7). *Dracaena godseffiana* growth rate is reduced, and new leaves near the stem tip form a

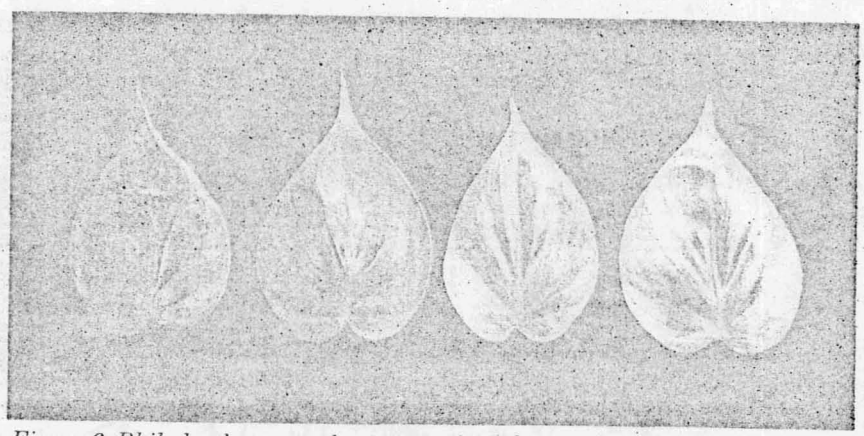

Figure 6. Philodendron scandens oxycardium leaves showing magnesium deficiency. Chlorotic area forms an inverted "V".

rosette. Later, this cluster of terminal leaves becomes yellow and dries, and the stem tip dies back. Plants weigh 15% less than normal. Older leaves of *D. sanderiana* die, beginning at their tips, and weigh as much as 26% less than normal plants (11).

Control. — Sprays of chelated manganese were observed to be beneficial in some instances, but soil application of manganese salts, chelates, and fritted materials are most commonly used and longer lasting. Reducing soil acidity to below pH 6.5 may also be effective.

Plants in general which receive excessive amounts of manganese become yellowish and stunted. Sterilizing some soils by steaming at temperatures above 180°F releases sufficient amounts of available manganese to cause this toxicity (38). Maintaining excessive moisture levels for prolonged periods may also induce manganese toxicity.

Control. — Leaching steamed soil thoroughly will remove excessive manganese caused by the steam sterilization. Manganese toxicity may also be reduced by increasing the soil acidity to pH 6.5.

Nitrogen Deficiency

Symptoms. — Insufficient available nitrogen causes the entire foliage of *Dieffenbachia picta* 'Exotica' to become very light green in color, and plants stop growing (100). Leaves of *Dracaena godseffiana* become yellowish, beginning with lower leaves. As symptoms progress leaves become bright yellow, eventually die, and fall off. Plants weigh 88% less than normal. *D. sanderiana* exhibits similar symptoms, and deficient plants weigh 70% less than healthy ones (11). *Alsophila australis* shows a general stunting and yellowish fronds, with lower leaves affected first. Brown spots eventually appear on lower

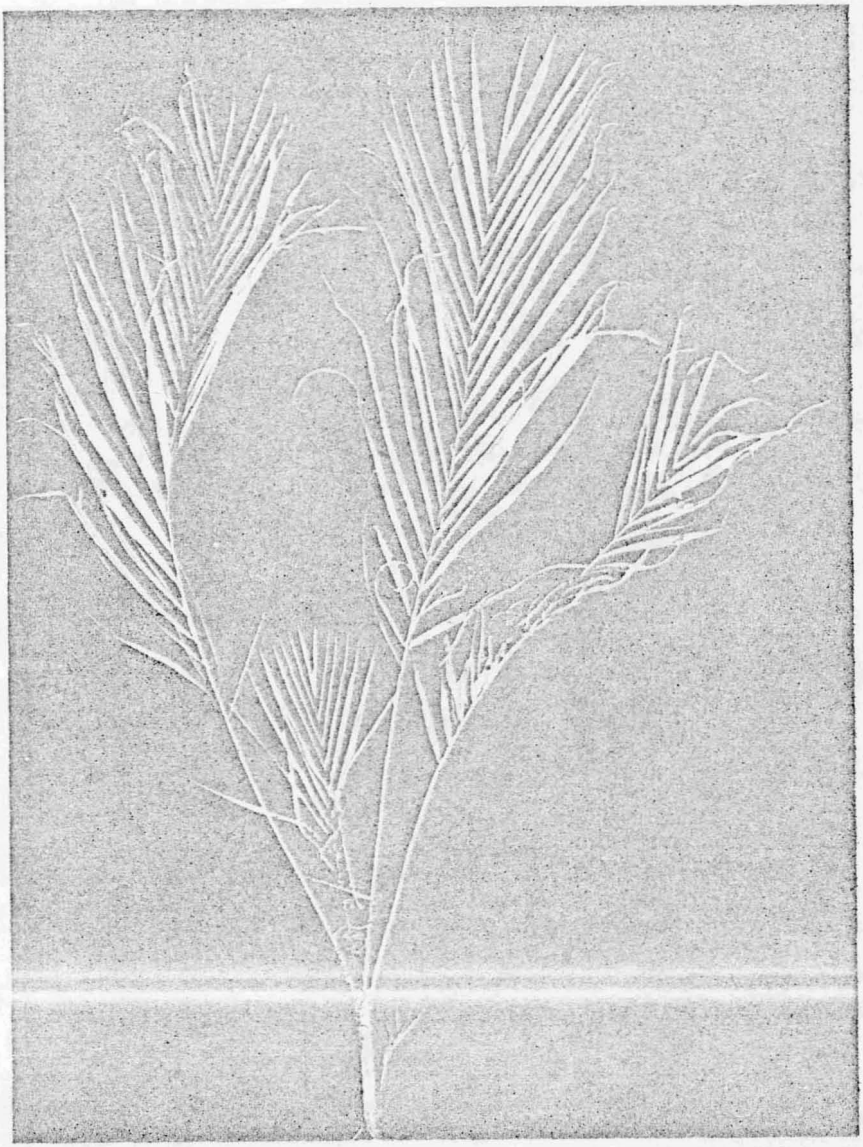

Figure 7. Chrysalidocarpus lutescens frond expressing manganese deficiency symptoms. Lower leaflets on the youngest frond are brown, twisted and dead.

fronds (43). *Dracaena deremensis* 'Warneckii' expresses nitrogen deficiency by reduced top growth, pale green foliage, and development of long, narrow young leaves with wavy margins. Some leaves develop black spots along the white marginal stripe, and new suckers are weak and few in number (113). *Philodendron micans* and *P. oxy-*

cardium express a general yellowing of terminal leaves, which are undersized. Petioles extend upward, the leaf blades bend downward, and internodes are shorter than usual. Older leaves eventually develop dead spots, which coalesce until the entire leaf dies. Aerial roots die back, and then the entire plant dies (32, 122). *Scindapsus aureus* reacts in the same manner (122). In addition to chlorotic foliage, *Syngonium podophyllum* 'Emerald Green' has reduced stem length and less top weight (100).

Control. — Apply a nitrogen fertilizer.

Phosphorus Deficiency

Symptoms. — *Dieffenbachia picta* 'Exotica', deprived of sufficient phosphorus, shows no decreased weight. Young leaves of phosphorus deficient *Dracaena deremensis* 'Warneckii' are arranged in a rosette pattern, have necrotic spots in their white stripes, and have ragged margins. Young leaves in particular have serrated margins near their bases and contain 0.07% phosphorus while normal foliage has 0.22% (113). Leaves of *Dracaena godseffiana* develop a more intense green color, and plants weigh 28% less than normal. Deficient *D. sanderiana* older leaves turn yellowish at their tips and margins; then discolored areas die, and leaves drop as they become entirely yellow (11). *Philodendron scandens oxycardium* stems are unusually thin, and leaves and stems turn a dull, greyish green. Leaves are smaller and internodes shorter than those on plants receiving adequate phosphorus. Basal leaves develop tipburn, the dead area advancing to the leaf base, and older leaves are shed (32). Reduced stem length and reduced top weight result when *Syngonium podophyllum* 'Emerald Gem' is deficient (100).

Control. — Apply a phosphorus fertilizer.

Potassium Deficiency

Symptoms. — In *Aechmea fasciata*, potassium deficiency is expressed as leaf tip dieback of older leaves. In a fertilizer experiment a potash (K_2O): nitrogen ratio of 3.8:7.2 resulted in this deficiency. A ratio of 2:1 was adequate (5) to prevent deficiency. As in the case of nitrogen or phosphorus deficiency, potassium deficient *Dieffenbachia picta* 'Exotica' plants weighed less than plants receiving adequate potassium (100). *Dracaena godseffiana* with insufficient potassium shows leaf death from the tips downward to their bases. Unaffected areas of a leaf remain normal with a narrow band of yellow below the dead area. Leaves gradually die and drop from the stems, and plants weigh 63% less than normal. *D. sanderiana* shows similar symptoms except

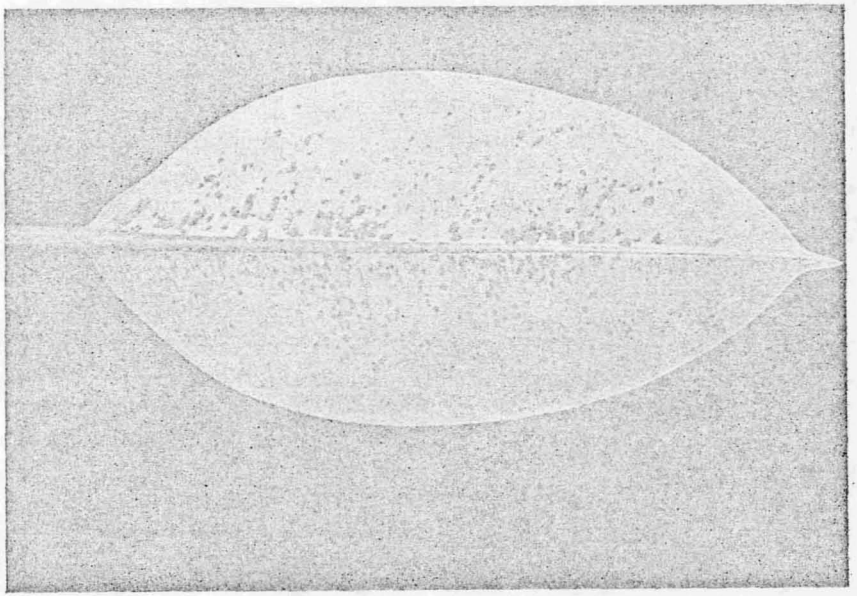

Figure 8. Ficus elastica 'Decora' leaf with potassium deficiency symptoms. Spotting is usually more severe on one side of the undersurface.

plants weigh 25% less than normal (11). *Ficus elastica* 'Decora' mature leaves bear numerous, small, angular red spots on the undersides only (Fig. 8). As spots coalesce, they become tan and eventually are visible from the leaf upperside. Air-layers are considerably more susceptible to potassium deficiency than normal branches, and plants grown in full sunlight are much more seriously damaged than shaded plants (72). *Philodendron scandens oxcardium* leaves become stunted and stems have short internodes, producing chains of small, normally green leaves. Basal leaves are affected first and develop yellow margins or become entirely yellow. Eventually, large brown dead spots occur on leaves near the bases of the plants (32).

Control. — Apply a high potash fertilizer (73). As an example, a nurseryman who had been using a 5-8-10 fertilizer on field-grown stock plants switched to a 6-6-6 formula and his *Ficus elastica* 'Decora' became unsalable because of severe symptoms of deficiency.

Sulfur Deficiency

Symptoms. — When sulphur was omitted from fertilizer, the only symptom on *Dracaena godseffiana* was 22% less weight than normal plants. However, *D. sanderiana* showed yellowing and tipburn of younger leaves and 26% less weight (11) than normal.

Miscellaneous Micro Elements

One should be aware of the fact that certain micro-element fertilizers can damage some plants. For instance, mixing the micro-element fertilizer "FTE-503" with soil at a rate of ½ pound per cubic yard has caused leaves of *Aphelandra squarrosa* and *Brassaia actinophylla* to become yellowish. A material called "Perk" also yellowed *B. actinophylla* leaves (26). Other examples of foliage plants that have been adversely affected by additions of secondary or micro-element mixtures include *Aglaonema* x 'Fransher', *Dieffenbachia picta* 'Perfection', *Maranta leuconeura* 'Red Nerve', *Philodendron oxycardium*, *Polystichum adiantiforme*, and *Scindapsus aureus*. These unfavorable responses sometimes can be explained by the fact that the trace element mixtures were too concentrated, were imbalanced, or were added to media which already contained sufficient amounts. Adding a micronutrient mixture to a medium before steam sterilization can also cause excessive amounts of some elements to be released (15, 19, 97).

Zinc Deficiency

Symptoms. — As deficiency in *Chrysalidocarpus lutescens* becomes more severe, fronds are severely stunted, and leaflets are short, thick, and closely spaced (Fig. 9).

Control. — Apply a fertilizer containing zinc.

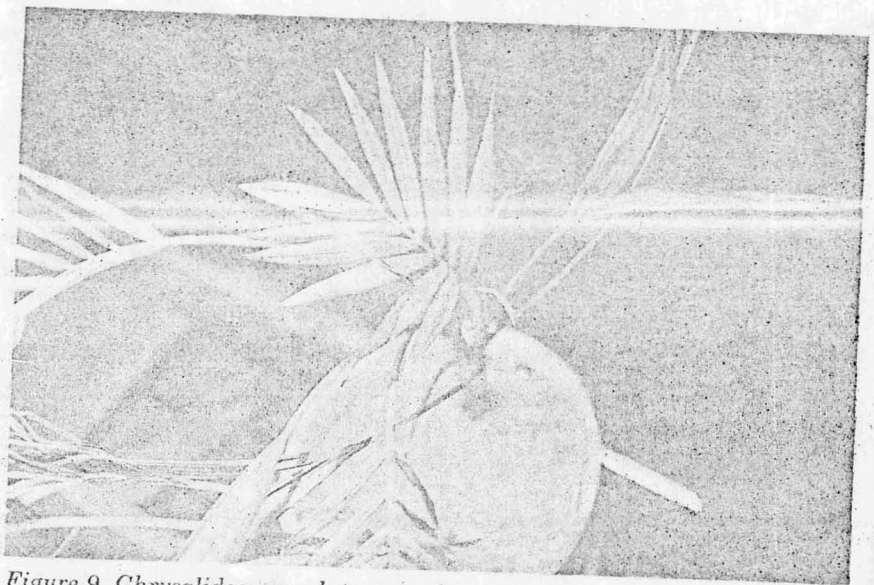

Figure 9. Chrysalidocarpus lutescens plant with zinc deficiency. Small, triangular frond is typical.

General Fertilizer Excess

Symptoms. — Regardless of specific nutrients involved, excessive fertilizer may damage plants because of toxic soluble salts in the soil solution. If excess salts are suspected, it is wise to have the growing media analysed by a reliable soils chemist. *Aphelandra squarrosa* grows well following application of a soluble form of N, P, and K at 0.9, 0.4, and 0.8 kilograms per 100 square meters per month if irrigated at least weekly. However, three times that rate kills plants, and double rates lower their quality beyond market acceptance. Soluble salts in containers of such damaged plants vary from 1,403 to 2,625 ppm (22). Excess dissolved fertilizer causes yellowish mottling and burns margins and tips of leaves of *Dracaena fragans* 'Massangeana' (24). *Ficus benjamina* often has severe leaf abscission shortly after being purchased from nurseries which do not acclimatize plants under lowered light levels and fertilization rates (23, 91). Table 3 illustrates the relative tolerance of some foliage plants to salinity.

Control — Heavily fertilized plants are likely to have root damage from soluble salts when soil dries. Plants that are growing fast require more frequent fertilizations, not heavier applications. If a potting mix contains slow-release fertilizer, it must not be stored; plant immediately after mixing. Leach fertilizer if it is too concentrated

Table 3. Salinity tolerance of foliage plants.

Plant	Salinity tolerance		
	Tolerant	Moderately tolerant	Sensitive
Codiaeum punctatis	x		
Dracaena spp.	x	x	
Euphorbia lactea	x		
Euphorbia tirucalis	x		
Fatsia japonica			x
Hedera helix	x		
Monstera deliciosa			x
Philodendron bipinnatifidum			x
Sansevieria sp.	x	x	
Yucca sp.	x		

Reference: 37.

(37). Irrigating regularly and sufficiently to keep the planting mix moist can minimize injury.

PESTICIDE INJURY

Fungicides

Symptoms. — Severity of fungicide injury may vary from yellowing of leaves to dead spots and distorted growth. Type of injury depends on plant type, plant and environmental conditions, as well as the kind of fungicide used. Damage from any pesticide may result from a single, excessively heavy application or from excess applications of a safe concentration. Injury can also occur if several applications do not have a long enough interval between them. Therefore, the specific symptoms are omitted from the following Table 4, and injury is considered to consist of any reaction that reduces salability of a plant.

The wood preservatives, creosote or pentachlorphenol, have often caused plant injury or death when used on greenhouse or shadehouse structures, benches, and flats.

Table 4. Fungicide injury to foliage plants.

Plant	Damaging fungicide
Anthurium crystallinum	Dexon 150 ppm
	Difolatan 50 ppm
	Terrazole 12.5 ppm
Aridia crenulata	Terrazole 50 ppm
Asparagus sprengeri	Flurasil (F + Zn) wood preservative
Begonia sp.	Flurasil
Brassaia actinophylla	Agristrep 200 ppm
	Basic copper sulfate 1.5 lb/100 gal
	Benlate 1 lb/100 gal
	Captan 1.5 lb/100 gal
	Daconil 1 lb/100 gal
	Difolatan 1 qt/100 gal
	Dithane M-45 3 lb/100 gal
	Maneb 2 lb/100 gal
	Manzate D 3 lb/100 gal
	Mertect 0.75 lb/100 gal
	PCNB 50 lb/acre
	Zineb 2 lb/100 gal

Continued

Table 4. Continued.

Plant	Damaging fungicide
Chamaedorea elegans	Agristrep 400 ppm Basic copper sulfate 1.5 lb/100 gal Captan 50 ppm Dexon 150 ppm Terrazole 50 ppm
Dieffenbachia exotica	Mertect 3 lb/100
Dizygotheca elegantissima	Difolatan 100 ppm Terrazole 25 ppm
Epipremnum aureum	Mertect 3 lb/100 gal
Nephrolepis exaltata	Agrostrep 200 ppm Basic copper sulfate 3 lb/100 gal Dithane M-45 1.5 lb/100 gal Mertect 3 lb/100 gal
Peperomia caperata	Dexon 150 ppm Terrazole 100 ppm
P. obtusifolia	Dexon 25 ppm
P. obtusifolia variegata	Terrazole 50 ppm
Philodendron scandens oxycardium	Basic copper sulfate 3 lb/100 gal
P. wendlandi x lacineatum	Streptomycin 800 ppm
Pilea cadierei	Maneb 2 lb/100 gal Zineb 2 lb/100 gal
Plectranthus australis	Benomyl 100 ppm in soil
Polystichum tsussimense	Dexon 75 ppm Difolatan 100 ppm Terrazole 50 ppm
P. adiantiforme	Agristrep 200 ppm Basic copper sulfate 1.5 lb/100 gal Difolatan 1 qt/100 gal
Scindapsus aureus	Mertect 3 lb/100 gal
Syngonium podophyllum	Mertect 3 lb/100 gal

References: 2, 34, 62, 63, 79, 80, 83.

Herbicides

Symptoms. — Leaves of *Aglaonema commutatum* are shorter and narrower following soil application of 1 lb/acre glyphosate (88). *Asparagus plumosus nanus* is damaged by calcium endothal and CIPC, 20 lb active ingredient (ai) per acre; DBCP, 45 lb ai/acre; 2,4-D, 20 lb ai/acre; monuron, 16 lb ai/acre; PCP, 60 lb ai/acre; sodium TCA, 50 lb ai/acre; and 2,4,5-T, 5 lb ai/acre (52). *Araucaria heterophylla* leaves were moderately distorted on new growth by dicamba at 2.2 kg (4.8 lb) ai/acre (87). Similar symptoms appeared on *Asparagus densiflorus* 'Sprengeri', *A. plumosus nanus, Brassaia actinophylla,* and *Chrysalidocarpus lutescens* (87). Prometone at 10 lb ai/acre killed leaf margins of *Cissus* sp.; leaves of *Codiaeum variegatum* were stunted and narrowed by 10 lb/acre glyphosate, which also killed terminals of *Dizygotheca elegantissima*, whereas 2.2 kg (4.8 lb) ai/acre of dicamba merely distorted its leaves, as it did those of *Dracaena marginata, Ficus benjamina,* and *F. retusa* (87). *Philodendron macrophyllus, P. selloum*, and *P. tobira* leaves were distorted by dicamba at 2.2 kg (4.8 lb) ai/acre (87). Casoron at 4 lb ai/acre severely reduced growth of *Philodendron scandens oxycardium* (121). *Hedera* sp. was killed by prometone, 10 lb ai/acre, and leaf margins of *Kalanchoe* sp. were burned as were those of *Pilea* sp. (127).

Insecticides and Miticides

Symptoms. — Insecticide or miticide injury includes leaf spotting, yellowing, deformation, or abscission. Each of these symptoms may vary from slight to severe. In Table 5 the lowest concentration that damaged plants is given and symptoms are not specified. Figure 10 shows symptoms of insecticide damage to *Brassaia actinophylla*, a plant that is extremely susceptible to pesticide spray injury.

Nematicide

Symptoms. — Nemagon, DBCP, is used as a soil drench for living plants. Six foliage plants were tested for tolerance and results are shown in Table 6. Symptoms include abnormally small plants, leaf stunting, yellowing, and slight spotting (45, 57).

OTHER TOXIC MATERIALS

Gases

Symptoms. — *Asparagus sprengeri* has been found to be highly resistant to chlorine, nitrogen peroxide, and sulfur dioxide; but *Begonia*

Table 5. Insecticide-miticide injury to foliage plants.

Plant	Damaging insecticide-miticide
Adiantum cuneatum	Malathion, 1.5 lb tech./100*
Aphelandra squarrosa	Dursban 2E, 0.25 lb ai/100 Omite 30W, 0.45 lb ai/100 Orthene 75S, 0.5 lb ai/100 Science aerosol Vydate 2L, 0.5 lb ai/100
Ardisia sp.	Dylox 80% SP, 2 lb/100 Dylox LS, 4 lb/gal
Asparagus sprengeri	I-Bomb aerosol Phosvel 2.7EC, 1.5 lb ai/100 Raid aerosol Science aerosol
Brassaia actinophylla	Acaraben 4EC, 1 pt/100 Azodrin 5EC, 1 lb ai/A** Cygon 2EC, 1 qt/100 Delnav 4EC, 1 pt/100 Diazinon 4EC, 0.5 lb ai/100 Dicofol 18.5EC, as recommended Dimethoate 25EC, 2 pt/100 Dursban 2E, 0.25 lb ai/100 Dylox 80SP, 2 lb/100 Dylox LS, 4 lb/gal, 3 pt/100 Enstar, as recommended Fundal 95SP, 0.5 lb/100 Fundal 4EC, 0.5 lb ai/100 Furadan 4F, 1.5 lb ai/100 Gardona 75WP, 2 lb/100 I-Bomb aerosol Kelthane 35 WP, 1.3 lb/100 Kelthane 18.5EC, 2 pt/100 Lannate 90SP, 9 oz/100 Malathion 57EC, 2 pt/100 Meta-Systox R, EC, 1.5 pt/100 Monocrotophos as recommended Morestan 25WP, 1 lb/100 Omite 30W, 0.45 lb ai/100

Continued

* 100 refers to 100 gal water.
** A refers to acre.

References: 8, 36, 41, 44, 46, 47, 60, 62, 89, 90, 110, 116, 117.

Table 5. Continued.

Plant	Damaging insecticide-miticide
	Orthene 75WP, 2.6 lb/100
	Orthene 75SP, 1.3 lb/100
	Oxythioquinox, 2 oz/100
	Phosvel 2.7EC, 1.5 lb ai/100
	Phosvel, 3 lb/gal, 4 pt/100
	Plictran 40WP, 6 oz/100
	Resmethin 7EC, 0.25 lb ai/100
	Science aerosol
	Sevin 80WP, 2 lb/100
	Volk oil, 1.6 gal/100
	Vydate 2L, 0.5 lb ai/100
Chamaedorea elegans	Acaraben 4EC, 1 pt/100
	Aramite 15WP, 2 lb/100
	Cygon 2EC, 1 qt/100
	Fundal 95SP, 0.5 lb/100
	I-Bomb aerosol
	Kelthane 35WP, 1.3 lb/100
	Kelthane 18.5EC, 2 pt/100
	Meta-Systox R, EC, 1.5 pt/100
	Morestan 25WP, 1 lb/100
	Oil emulsion, 2%
	Omite, 30WP, 1.5 lb/100
	Orthene 75WP, 1.3 lb/100
	Plictran 50WP, 6 oz/100
Codiaeum variegatum	Malathion as recommended
	Phosvel 2.7EC, 1.5 lb ai/100
	Raid aerosol
Codiaeum variegatum 'Bravo'	Dylox 1L, 1.5 lb ai/A
Codiaeum variegatum 'Gold Dust'	Furadan 4F, 0.5 lb ai/A
Collinia elegans	Kelthane 35WP, 1 lb/100
	Omite 30WP, 1.5 lb/100
Crassula argtenea	Raid aerosol
Dieffenbachia exotica	Cygon 2EC, 1 qt/100
	Delnar-4EC, 1 pt/100
	Malathion 57EC, 2 pt/100
	Morestan 25WP, 1 lb/100

Table 5. Continued.

Plant	Damaging insecticide-miticide
	Omite 30WP, 1.5 lb/100
	Orthene 75WP, 2.6 lb/100
	Volk oil, 1.6 gal/100
Dieffenbachia picta 'Perfection'	Omite 30W, 0.45 lb ai/100
	Raid aerosol
Dizygotheca elegantissima	Azodrin 5EC, 1 lb ai/A
Dracaena godseffiana	Lannate 90SP, 9 oz/100
Dracaena marginata	Dylox LS, 4 lb/gal, 3 pt/100
	I-Bomb Aerosol
	Science Aerosol
Dracaena sanderiana	Diazinon 25EC, 2 pt/100
Ficus benjamina	Dursban 2EC, 1 lb ai/100
	Dylox 1LS, 1.5 lb ai/100
	Furadan 4F, 0.5 lb ai/100
	I-Bomb aerosol
	Raid aerosol
	Resmethrin aerosol
	Vydate 2EC, 0.5 lb ai/100
Ficus retusa	Carzol 95WP, 0.5 lb ai/100
	Dursban 2EC, 1 lb ai/100
	Dylox 1LS, 1.5 lb ai/100
	Fundal 4EC, 0.5 lb ai/100
	Furadan 4F, 0.5 lb ai/100
	Phosvel 2.7EC, 1.5 lb ai/100
	Sevin 4L, 1.5 lb ai/100
	Vydate 2EC, 0.5 lb ai/100
Ficus triangularis	Orthene 1.3EC, 0.5 lb ai/100
Hedera helix	Raid aerosol
	Science aerosol
Hoya carnosa	Diazinon 25EC, 2 pt/100
Maranta leuconeura	Cygon 2EC, 1 qt/100
	Fundal 95SP, 0.5 lb/100
	Orthene 75WP, 1.3 lb/100
Nephrolepis exaltata	Cygon 2EC, 0.375 lb ai/100
	Diazinon 25EC, 2 pt/100

Continued

Table 5. Continued.

Plant	Damaging insecticide-miticide
	Dimethoate 25EC, 2 pt/100
	Dursban 2E, 0.25 ai/100
	Dylox 80SP, 2 lb/100
	Dylox LS, 4 lb/gal, 3 pt/100
	Gardona 75WP, 2 lb/100
	Malathion 57EC, 2 pt/100
	Malathion tech., 1.5 lb/100
	Omite 30W, 0.45 lb ai/100
	Orthene 75SP, 1.3 lb/100
	Phosvel, 3 lb/gal, 4 pt/100
	Raid aerosol
	Resmethrin 1%
	Science aerosol
Peperomia obtusifolia	Diazinon 25EC, 2 pt/100
	Gardona 75WP, 2 lb/100
	Meta-Systox R, 25EC, 1.5 pt/100
	Omite 30WP, 1.5 lb/100
	Phosvel, 3 lb/gal, 4 pt/100
Peperomia obtusifolia variegated	Diazinon 25EC, 2 pt/100
	Dimethoate 25EC, 2 pt/100
	Gardona 75WP, 2 lb/100
	Lannate 90SP, 9 oz/100
	Omite 30W, 0.45 lb ai/100
	Phosvel, 3 lb/gal, 4 pt/100
	Vydate 2L, 0.5 lb ai/100
Philodendron friedrichstahli	Aramite 15WP, 2 lb/100
	Malathion 25WP, 4 lb/100
Philodendron oxycardium	Oil emulsion 2%
	Thimet 47.5EC, 1 qt/100
Pilea cadierei	Aramite 15WP, 2 lb/100
	Diazinon 25EC, 2 pt/100
	Dimethoate 25EC, 2 pt/100
	Lannate 90SP, 9 oz/100
	Malathion 25WP, 4 lb/100
	Parathion 15WP, 1.5 lb/100
Rheo discolor	Lannate 1.8L, 0.5 lb ai/A
	Orthene 1.3L, 1 lb ai/A
	Sevin 80WP, 3 lb ai/A

Table 5. Continued.

Plant	Damaging insecticide-miticide
Scindapsus aureus	Aramite 14WP, 2 lb/100 I-Bomb aerosol Malathion 57EC, 2 pt/100 Omite 30WP, 0.45 lb ai/100 Raid aerosol
Syngonium podophyllum	Dylox 80SP, 2 lb/100 Malathion 57EC, 2 pt/100 Omite 30WP, 1.5 lb/100
Syngonium podophyllum 'Emerald Gem'	Dylox LS, 4 lb/gal, 3 pt/100 Malathion 57EC, 2 pt/100
Syngonium podophyllum 'Green Gold'	Dylox LS, 4 lb/gal, 3 pt/100 Malathion 57EC, 2 pt/100

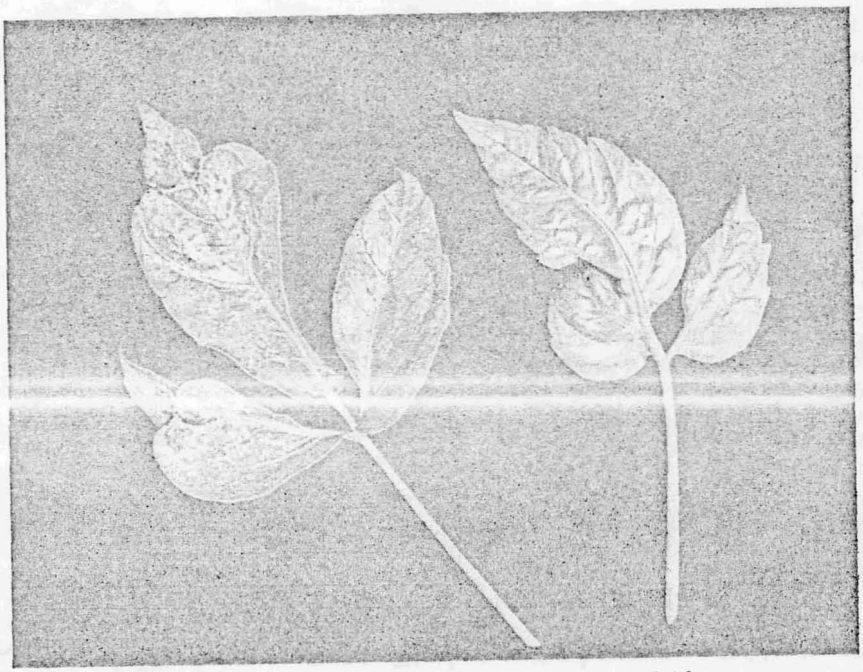

Figure 10. Brassaia actinophylla leaves distorted by insecticide sprays.

Table 6. Nematicide injury to foliage plants.

Plant	Damaging nematicides
Maranta sp.	Nemagon, 8.6E, 5oz/100
Philodendron laciniatum	Nemagon, 8.6E, 10 oz/100
P. pertussum	Nemagon, 8.6E, 1 oz/100
P. rubrum	Nemagon, 8.6E, 5 oz/100
P. sp. 'Emerald Queen'	Nemagon, 8.6E, 10 oz/100
Spathyphyllum sp.	Nemagon, 8.6E, 5 oz/100

Reference: 57.

gracilis is susceptible to all three gases (28). Hydrogen sulfide gas readily damages young leaves of *Nephrolepis exaltata* (27).

Ethylene gas at a concentration of 5 ppm causes *Aphelandra* sp. and *Euphorbia leuconeura* 'Fournieri', to drop almost all of their leaves within 1 or 2 days. The same plants retain most of their leaves under similar conditions in the presence of 25 g of aluminum oxide impregnated with potassium permanganate (Purafil) (95). In an experiment, plants were subjected to 2, 5, or 10 ppm of ethylene for 10 days, and an injury index rating of several foliage plants was devised, the higher ratings denoting more severe symptoms. Injury to *Sansevieria trifasciata* 'Laurentii' was rated only 19 in severity. *Chamaedorea elegans* was rated 21, *Begonia* 'Coralina Lucern' received an injury rating of 54, and *Philodendron scandens oxycardium* a rating of 59 (51). Ethylene injury of some other plants has consisted of leaf loss; examples include *Begonia coccinea* 'Lucerna', *Bryophyllum* sp., *Chamaedorea elegans*, *Kalanchoe blossfeldiana* 'Cherie', *Philodendron scandens oxycardium*, and *Sansevieria* sp. (51, 56, 76, 77). Artificial illuminating gas causes *Sansevieria* sp. to develop small leaflets and aerial roots on leaves, and in some plants chlorophyll is destroyed (61).

Growth Regulators

Growth regulators are applied to foliage plants in order to give them the compact appearance consumers prefer. However, some plants are injured by these chemicals. Chlormequat, 3000 ppm, has reduced branch development and caused severe yellowing of young leaves of *Cyanotis kewensis*. It also yellowed young leaves of *Pellionia pulchra*, *Philodendron scandens oxycardium*, *Pilea cadierei*, and *P. involucrata* (53). Surfaces of *Epipremnum aureum* leaves were experimentally killed by 200 ppm of PBA (81). Kinetin at a concentration of 100 ppm prevented root formation of *Saintpaulia* sp. (93).

Three growth regulators — "Maintain", 20 and 40 ppm; maleic hydrazide, 3,240 ppm; and "Ethrel", 2,000 and 4,000 ppm — were applied to three foliage plants. In *Philodendron scandens oxycardium*, *Epipremnum aureum*, and *Syngonium podophyllum*, symptoms of "Maintain" injury included production of lateral branches at some nodes with deformed apical and lateral growth. Apical meristems died on *P. scandens oxycardium* and *E. aureum* following treatment with maleic hydrazide. "Ethrel" caused *P. scandens oxycardium* and *E. aureum* to lose some leaves and develop long, thin yellow nodes. *S. podophyllum* had erratic growth (94).

To induce flowering of *Aechmea fasciata*, 15 ml of a 1% solution of BOH (2-hydroxyethylhydrazine) was added to the hollow crowns of the plants; poorly formed flowers resulted (33). Foliar damage resulted when *Kalanchoe blossfeldiana* was treated with "Embark": N-2, 4-dimethyl-(5-(trifluoromethyl) solfonyl aminophenylacetamide to cause flowering (123).

Leaf Shining Materials

Five leaf shining materials were applied experimentally to *Philodendron oxycardium*, and treated plants were compared to untreated plants. Materials included "Floraglow," "Leaf Glow," "Leaf Lustre Black Magic," "Lustre Leaf Plant Polish," and "Schultze Plant Shine." Foliage was treated biweekly for nine months. Plants which received no treatments developed more leaves and longer shoots, were heavier, and had fewest dead leaves; however, they were not as shiny (92).

Guttation

Philodendron hastatum has been found occasionally to develop yellowish leaf spots on lower surfaces. Spots with dead centers usually measure less than 2 mm in diameter. Spots are most numerous on old leaves and sometimes nearly cover the entire leaf surface. Symptoms appear two to three weeks after leaves unfurl. Stomates contain a plant exudate containing 93% sugar on old leaves and 28% on immature leaves. Spotting is controlled by removing the exudate with distilled water thrice weekly. Black, sooty mold growing on the exudate is controlled with a fungicidal spray (84).

Wood Preservatives

Symptoms. — *Brassaia actinophylla* leaves develop chlorotic margins when only the fumes of pentachlorophenol spread to the plant (36).

Control. — Wood can more safely be treated with copper nephthenate, which does not volatize and is much less phytotoxic (4).

RADIATION

Insufficient Light

Symptoms. — Light may be of insufficient intensity, hours of exposure per day may be insufficient, or the wave length may be improper. Plants which receive no light will have long, slender, white stems and yellow and white leaves. However, plants that receive somewhat less than optimum light will express more subtle symptoms.

If *Aphelandra* sp. receives less than 300 to 400 foot-candles (ft-c), it will not bloom. Flowers will appear in about 16 weeks under 500 to 600 ft-c and within 8 weeks under 1000 to 1500 ft-c (102). *Cordyline terminalis* 'Baby Doll', under 80% shade, does not develop brilliant pink color as under 40% or 60% shade. Cutting yields decrease under 40% shade, as compared to 80%, and *Dieffenbachia exotica* cuttings are similarly affected (16). The latter plant becomes stunted when it receives 1000 to 2000 ft-c but grows vigorously under 5000 to 6000 ft-c (102). Corky callosities and pustules appear on the undersides of *Ficus elastica* leaves when grown in poor light (124).

Nitrogen fertilizer may complement light intensity. The same number of *Maranta* sp. cuttings have been produced under 2000 ft-c plus 240 lb nitrogen per acre per year as under 4000 ft-c with no additional nitrogen (102). *Monstera deliciosa* under insufficient light intensity fails to split (9). As shade increases from 30% to 90%, leaf chlorosis of *Philodendron scandens scandens* and *P. scandens oxycardium* decreases if nitrogen levels are below normal. As light increases, stem length is reduced and leaf area decreases, a common plant response. *Epipremnum aureum* reacts similarly (122). One hundred ft-c for 6 hr per day cannot support vegetative growth of *Saintpaulia* sp.; however, the same light for 12 hr per day is sufficient (49). *Epipremnum aureum* cuttings grow much less under 80% than under 40% shade (16). Plants are stunted when exposed to less than 1000 ft-c but grow well under 5000 ft-c (102). *Syngonium podophyllum* fails to develop its normal foliage color when given insufficient light (1).

Begonia tuberhybrida 'Helen Harms' and 'Ami Jean Bard' grow slowly when they receive 25 ft-c for 12 hr, but growth stops when exposure time is reduced to 11 hr daily. In addition to no growth, the apical meristem sometimes abscises (68).

Leaves of *Chrysalidocarpus lutescens* grown in full sunlight often are a faded green with dead leaf tips, whereas plants in 40% shade

develop normal, green leaves (101).

Leaves of *Dracaena marginata* have an increasingly intensified green color as shade increases from 0 to 40% to 80% (21). High light intensity while plants are being forced results in poor adaptation to the consumers' low light, with ensuing leaf drop (20). When shade is removed, *Dracaena godseffiana* exhibits mild iron deficiency symptoms (11).

Many large cuttings are shipped to the U.S.A. from the tropical Americas and Caribbean islands. Some contain low food reserves because they were grown in insufficient sunlight, and thus they may fail to grow when replanted. Lack of light in shipping containers also is detrimental. Such shipments must be potted immediately after receipt, because each day beyond the fourth day in a dark container reduces cutting quality 20% to 25%, mainly by exclusion of light (13).

Excessive Light

Variegated *Chlorophytum elatum* green leaf areas are injured by as little as 1000 lux (93 ft-c) of light. Since oxygen's presence is required for injury, the process is considered to be photoxidation sensitized by chlorophyll (67). In another experiment 20,000 lux (1860 ft-c) of light turned the same species' green areas brown (69).

Other Excessive Radiation

Symptoms. — X-ray radiation of two doses of 2300 R each to tiny plantlets growing from leaves of *Kalanchoe tubiflora* caused the plants to remain smaller than nontreated plants (67).

RELATIVE HUMIDITY

Insufficient Humidity

Symptoms. — Wilting or leaf abscission can be a sign of insufficient relative humidity as well as not enough irrigation. As an example, *Codiaeum variegatum* cuttings often drop their leaves when cuttings are being rooted. Desiccation is suspected, because more abscission takes place as the period between taking cuttings and sticking them is lengthened. A 3-day period results in less leaf drop than 5 days. Continuous mist for 12 hr during the warmer part of the day saves more leaves than 15 sec mist every 30 min for 24 hr a day. Air-layers or cuttings from plants grown under full sun drop twice as many leaves during rooting as those grown in 30% to 50% shade (25).

Cissus rhombifolia, Peperomia obtusifolia, and *Epipremnum aureum* have darker green leaves and larger chloroplasts when grown in an

average relative humidity of 91.9% as opposed to 34.4%. The plants have greater fresh weight, dry weight, and leaf area and thickness in the higher humidity (126). As an extreme example of high humidity requirement, one author claims a relative humidity of 99% is inadequate for *Begonia maculata*, which has extremely large leaf cells; in fact, its cell volume:cell surface ratio is 21:4, whereas *Hedera helix* tolerates a lower relative humidity and has a volume:surface ratio of 4:2. Drought-killing relative humidity of *Hedera* is 85% (50% of plants die) (67). *Dieffenbachia picta* 'Perfection' tip cuttings suffer collapse and yellowing of lower leaves when relative humidity is low. To prevent desiccation, cuttings must be planted the same day as cut and misted 15 sec every 30 min until rooting is sufficient (18). A major cause of leaf loss of imported foliage plants with large leaves is desiccation because of low humidity (13).

Excessive Humidity

Many plants suberize injuries best at relative humidities approaching 100%; however, caladium tubers suberize better at 75% than 90% (75).

TEMPERATURE

Excessive Heat

Symptoms. — In partial shade the killing temperature for *Asplenium* sp. is 45-46°C (114°F) for 30 min. One indicator of plant lethal temperatures is failure of cell protoplasm to resume streaming after temperature has dropped from a certain level. This was 56°C (133°F) for *Chlorophytum elatum* and 54.6°C (130°F) for *Ficus radicans*. A plant will sometimes tolerate more heat when it is flowering than otherwise. For instance, the lethal temperature for *Kalanchoe blossfeldiana* is 50°C (122°F) for flowering and 47°C (117°F) for vegetative plants (67). When *Ficus elastica* is subjected to too much heat, the upper leaf epidermis detaches from large areas of the leaf (115).

Foliage temperature is partially related to air movement through the foliage. As wind velocity increases, air-to-leaf temperature gradients decrease. Plant heights of *Begonia semperflorens, Codiaeum variegatum* 'Aucubafolium,' *Philodendron scandens oxycardium, Saintpaulia ionantha*, and *Sansevieria trifasciata* increase as wind velocity increases. Chlorophyll content in leaves of the plants is directly proportional to air velocity. Except for *Begonia*, plants grow faster at wind speeds up to 4.4 miles per hour. Variegation of *Codiaeum* decreases with increased wind, and *Codiaeum, Philodendron*, and *Sansevieria* leaves become larger with increased air speed (10).

Brief periods (6 hr) of partial dehydration leading to water-saturation deficits of 22% to 27% raised heat-killing temperatures by about 3°C (37°F) in leaves of *Commelina africana, Hedera helix*, and *Phoenix reclinata* (48).

Submerging plants in hot water is sometimes practical to kill internal infectious organisms such as bacteria and nematodes. *Aglaonema modestum, Caladium bicolor, Philodendron hastatum, P. imbe*, and *Sansevieria zeylanica* tolerate submersion for 10 min in water at 50°C (122°F). Many plants cannot tolerate such treatment, as shown in Table 7 (7).

Caladium tubers were stored for 8 days at 40°C (104°F) before planting. During the subsequent six weeks the heated tubers produced fewer than 9 leaves, whereas tubers stored at room temperature yielded an average of 13 leaves (86).

Control. — One method of lowering soil temperature in containers exposed to sunlight is by choice of color. Coolest temperatures occur in silver or white pots, and heat injury is more prevalent in black, green, red or rusty containers (39).

Table 7. Tolerance of foliage plants to submersion in water at 50°C for 10 min.

	Survival %	
	Check	Treated
Aglaonema modestum	100	100
Ardesia crenata	10	35
Caladium biocolor (8 var.)	100	100
Crassula arborescens	90	70
Cryptanthus sp.	90	100
Dracaena godseffiana	100	100
Dracaena sanderiana	100	100
Epipremnum aureum	85	15
Epipremnum aureum 'Wilcoxii'	100	10
Maranta leuconeura	100	0
Peperomia obtusifolia	100	10
Peperomia sandersii	100	0
Philodendron hastatum (leafy)	100	100
Philodendron hastatum (canes)	100	100
Philodendron imbe (canes)	100	100
Pilea involucrata	100	30
Sansevieria zeylanica	90	100
Sansevieria zeylanica 'Laurentii'	60	50
Syngonium podophyllum	100	100

Reference: 7.

Freezing

There are two types of low temperature damage. One is caused by tissues being frozen, and the second is injury due to temperatures above those sufficient to freeze. Adverse effects of freezing are visible soon after tissues are thawed or are revealed by subsequent growth. An example of the latter is death of frozen leaf margins. The dead margins may go unnoticed until growth causes puckering and distortion because margins cannot expand with the uninjured leaf blade (Fig. 11).

Symptoms. — During an experiment, foliage plants were stored in shipping boxes held in a room adjusted to −17.8°C (0°F) for 1, 2, and 4 hr. In decreasing order of susceptibility to freezing, they were: *Philodendron scandens oxycardium, Epipremnum aureum*, and both *Peperomia obtusifolia* 'Variegata' and *Syngonium liberica*. Freeze injury was slight after 1 hr, moderate after 2 hr, and severe after 4 hr. Plants in the bottom corners of a box were most severely injured, whereas plants in the center were least damaged. Among types of boxes used, only the best insulated ones protected plants for 2 hr (31).

Begonia metallica, when subjected to −5°C (23°F) for 2 min, suffers death of the old leaves. When held at −10°C (14°F) for the same length of time, all leaves fall from the plants. *Fittonia argyroneura*

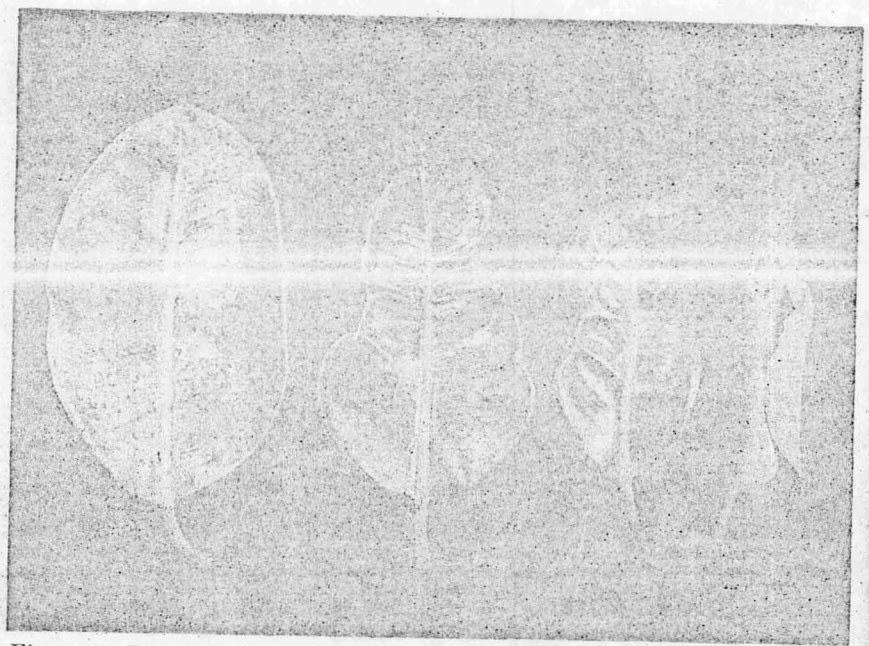

Figure 11. Ficus elastica 'Decora' leaves that were deformed by freezing temperatures.

Figure 12. Sansevieria trifasciata 'Laurentii' damaged by freezing.

wilts when subjected to −10°C (14°F) (66). *Sansevieria* species react differently to freezing temperature. *S. trifasciata* 'Laurentii' is least susceptible, but freeze injury does occur (Fig. 12). *S. trifasciata* and *S. longiflora* are moderately susceptible, and *S. thyrsiflora* is the most damaged. Frozen leaves do not resume growth (40) but become black in a few days.

Investigation of *Asparagus* ferns revealed that, during a breeze, still air in a slathouse can be colder than outside air. Outdoor air is being stirred with upper, warmer air. With no breeze, slathouse air can be up to 7.2°C (13°F) warmer (29). Damage occurs to new foliage of *Asparagus plumosus nanus* when frost forms on plants or air temperature remains at −2.2°C (28°F) for 2 hr (30).

Chilling

Symptoms. — Many tropical foliage plants are injured by low temperatures well above 0°C (32°F). For instance, leaves of *Saintpaulia* sp., when chilled by air or water at 18°C (64.4°F), develop coarse, yellow or brownish rings and line patterns on upper surfaces. Some leaves contain larger yellow areas, becoming brown and leathery, with collapse of tissues (55). A similar report states that wetting *Saintpaulia* sp. leaves with cold water results in yellowish spots (120).

Some foliage plants are severely damaged by a temperature of 4.5°C (40°F). *Aphelandra squarrosa* chilled at that temperature for 2

days develops dead leaf tips and interveinal tissue. Chilling for a week causes more severe necrosis, and 10 days later, many leaves drop. *Maranta leuconeura* exhibits wilted and spotted leaves and eventually dies. Two days' chilling causes *Scindapsus pictus* leaves to immediately become gray to black and water-soaked; parts of leaves die within the following week. If chilled for 4 days, all leaves die but plants survive; 8 days' chilling kills all of these plants (82). Large white areas and a slight curling of leaves of *Sansevieria trifasciata* 'Laurentii' follows exposure to 2° to 8°C (35.6° to 46.4°F). Sunlight following chill hastens symptom appearance.

Sometimes areas of chilled leaves, such as those of *Dracaena fragrans* 'Massangeana,' are shaded from sunlight by overlapping leaves, and the shaded parts recover from the chill, in sharp contrast to leaf areas that received direct sunlight hours afterward and lose their green color (Fig. 13). Failure to develop chlorophyll is a common result of chilling, as in *Sansevieria trifasciata* (Fig. 14). Symptoms continue to develop for one month after plants have been chilled (70).

Caladium tubers do not sprout well and fewer leaves develop following storage at 10° or 15.6°C (50° or 60°F) for 10 days. When stored at 4.4°C (40°F) for 10 days, tubers do not sprout readily during a 68-day period after planting. Storage at 21.1°C (70°F) is optimal (74). In another study, tubers stored 7 weeks at 4.4° and 10°C (40° and 50°F) failed to grow. Other tubers were stored at 23.9°C (75°F) for 0, 3, 6, and 12 weeks. Incidence of sprouting and number of shoots per tuber increased as the storage period increased (78).

Seeds, as well as tubers, can be adversely affected by chilly storage. Seeds of *Chamaedorea elegans* stored at 4.4°C (40°F) do not germinate as well as those stored at 23.9°C (75°F) (99).

Control. — *Saintpaulia* leaf spots can be prevented by avoiding getting the leaves wet when watering, especially if the water is cool (55). Continuous sprinkling during a freeze prevents injury to *Asparagus plumosus nanus*; however, sprinklers must keep the plants wet even after ice forms on them. When sprinkling is stopped after ice forms, damage is more severe than if plants are not sprinkled (30). Foliage stock plants grown out-of-doors in southern Florida have expressed chilling injury for several months following low temperature. For this reason, nurserymen are advised to wait several weeks before evaluating the extent of damage. It is important to prune back into live wood so that healing can occur and to keep soil moist and lightly fertilized during recovery (58).

Sansevieria trifasciata, S. longiflora, and *S. thyrsiflora* are less likely to freeze when clean cultivation is practiced (40). Diminishing the amount of nitrogenous fertilizer during fall and winter also results in less chilling injury to *S. trifasciata* 'Laurentii' (21, 70).

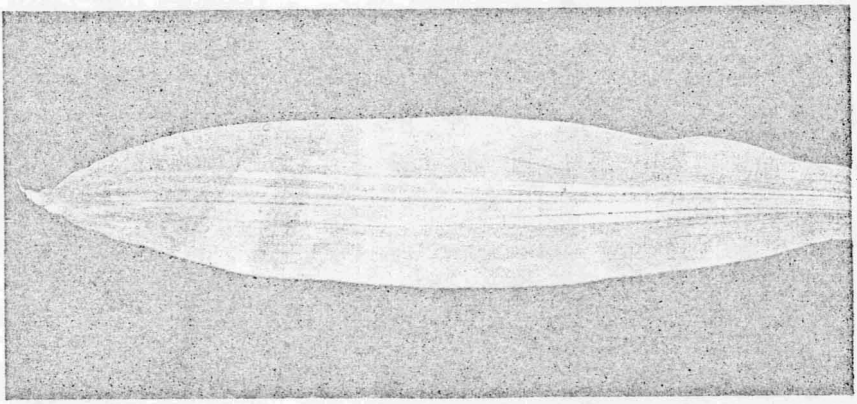

Figure 13. Dracaena fragrans 'Massangeana' leaf that was chilled sufficiently to lose its chlorophyll in areas exposed to sunlight.

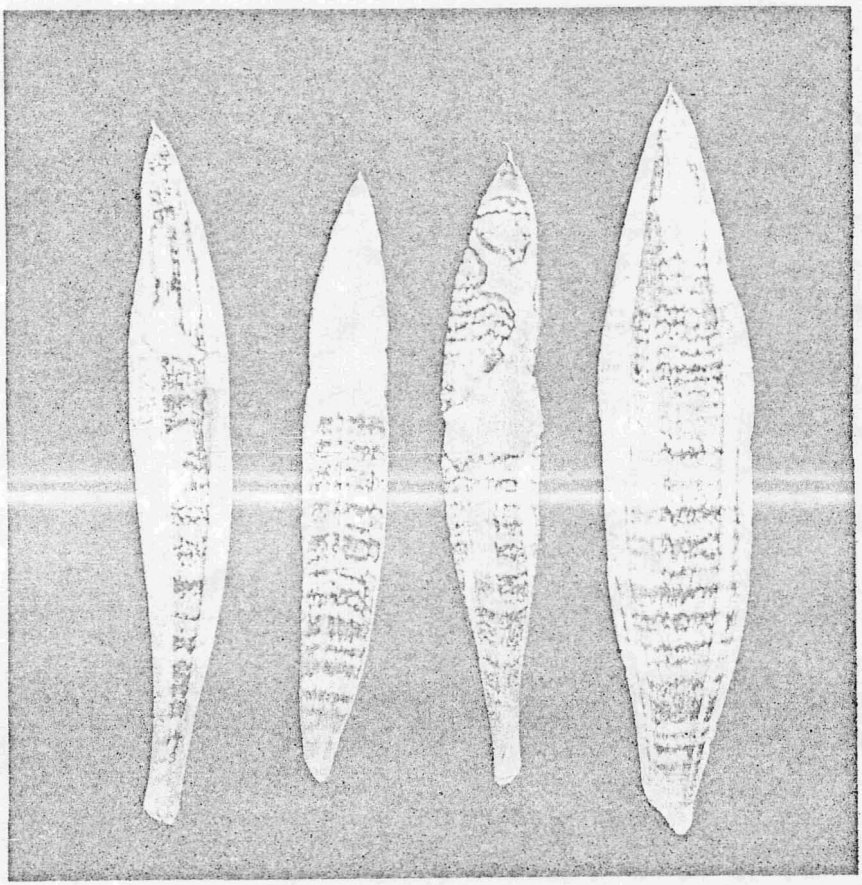

Figure 14. Sansevieria trifasciata leaves that were chilled sufficiently to lose their chlorophyll.

Temperature — Miscellaneous

Ardisia crenata is subject to a very unusual disease. The plants require the presence of one or two species of bacteria to provide cytokinins for optimum growth. When the bacteria are killed by heating the seeds, their absence results in gall formation at the lower stem nodes 3 to 4 months after seed is planted. Seed germination at 30°C (86°F) results in much more galling than germination at 25°C (77°F) (111).

Some plants are injured by sudden changes in temperature. *Dracaena massangeana, Ficus elastica, Monstera deliciosa*, and *Philodendron hastatum* are among those so affected. For instance, if the temperature rises from 15.6° to 35°C (60° to 95°F) within 48 hr, an apical leaf may become blackened and the growing tip of the stem dies. Similarly, a sudden drop from 35° to 15.6°C (95° to 60°F) causes the same symptoms as illustrated in Table 8 (42).

Table 8. Temperature changes that result in apical injury.

	Temperatures		
Plant	15.6°-35°C (60°-95°F)	15.6°-35°-15.6°C (60°-95°-60°F)	35°-15.6°-35°C (95°-60°-95°F)
Dracaena massangeana	+	+	0
Ficus elastica	+	+	+
Monstera deliciosa	+	+	+
Philodendron hastatum	+	+	0

+ = apical death and blackening of apical leaf.

Reference: 47.

GENETIC

Reversion of Mutants

Symptoms. — The cultivar 'Laurentii' is a mutant of *Sansevieria trifasciata* that has yellow leaf margins. As long as 'Laurentii' is propagated by small plants bearing a piece of root, the yellow margins remain. However, if propagation is by leaf cuttings, the variety reverts to *S. trifasciata*, with no yellow margins (50). Similarly, *S. trifasciata* 'Emeralda,' if propagated by leaf cuttings, reverts to *S. trifasciata* (128).

Dieffenbachia picta 'Rudolph Ruehrs' has greenish white leaves bordered with dark green. Frequently plants have been observed to be gradually reverting to *D. picta*, which has dark green leaves with white spots (Fig. 15).

Figure 15. Dieffenbachia picta 'Rudolph Ruehrs' plant showing part of it reverting to the original parent type shown beside it.

Albinos

Albinos are seedlings which cannot develop chlorophyll. A common example is the occasional appearance of white seedlings in plantings of Norfolk Island pines, *Araucaria heterophylla* (Salisb.) Franco (Fig. 16).

IRRIGATION

Improper irrigation is a common problem in foliage plant nurseries. For efficiency and economy, two or more sizes of containers in the same bed may receive the same irrigation regime. As a result the large, tall containers may receive insufficient water, and small containers may get too much. Improperly constructed containers may continually be wet near the bottom, resulting in root death. Containers with corrugated bottoms or those with single bottom-holes or with side holes not flush with the bottom may remain too wet because of inadequate drainage (39). If adequate irrigation for a plant such as *Ficus elastica* 'Decora' is suddenly diminished, leaf margins may die (Fig. 17).

Dizygotheca elegantissima, according to one report, wilted severely because roots had been killed by excessive irrigation (85). Corky callosities and pustules form on the leaf undersurfaces of *Ficus elastica*

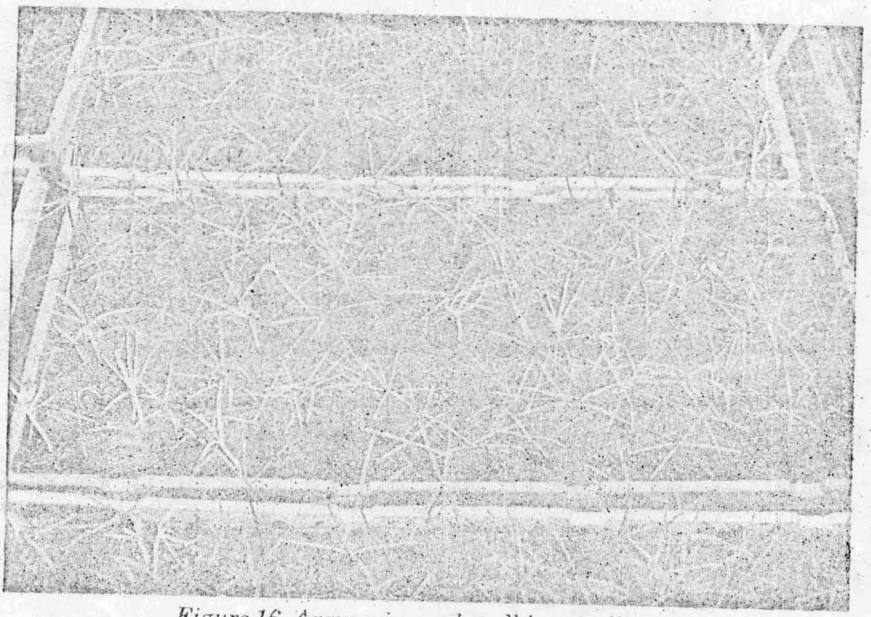

Figure 16. Araucaria excelsa albino seedlings.

Figure 17. Ficus elastica 'Decora' leaves with their margins killed by a sudden drought.

following excessive irrigation (124).

Dracaena fragrans 'Massangeana' canes are shipped to nurseries in the United States from Central and South America. To prevent them from drying out enroute, ends of canes are coated with wax. If wax is not removed from the bottom ends of planted canes, only 6% of them develop buds near the top of the cane. In contrast, canes which have 1 cm cut from the bottom before planting are able to absorb much more water, and 68% of these produced buds in one experiment. Likewise, canes with their tops soaked in water before planting had only a 68% survival after planting, whereas those with the bottoms soaked had a 92% survival rate (109).

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