Light and Fertilizer Recommendations for Production of Acclimatized Potted Foliage Plants

Return to: MREC Home Page

Return to: MREC Research Index

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Acclimatized foliage plants have become the standard of the industry and have increased consumer acceptance of interior plants with their increased tolerance of interior environments. Although many factors influence acclimatization, the most important during production of foliage plants are light intensity and fertilization level.

Light

Plants can be divided into three categories according to their physiological responses to light. The first group includes extreme shade plants, those that require moderate to heavy shade to produce attractive plants and cannot be acclimatized to high light. Examples of these plants include *Aglaonema*, *Maranta* and *Spathiphyllum*. The second category includes plants that must have high light to grow and cannot be acclimatized to low light. For the most part, none of these plants are used in the foliage industry, but would include plants such as pine trees or flowering annuals that require full sun to bloom profusely. The last category includes plants termed sun-shade, which means they can adapt or be acclimatized to a wide range of light intensities. Examples of these plants include *Brassaia*, *Ficus* and *Dracaena*; it is within this group we find the greatest application of the light acclimatization process.

Research has shown that foliage plants can be light-acclimatized in two ways: 1) plants can be grown under a specific shade level for their entire production period, or 2) they can be grown under high light or, in some cases, full sun and then converted to low light at some period during production. Extreme shade plants must always be grown under shade, while sun-shade plants can be grown with either system.

Production under Shade

Foliage plants grown under suggested shade levers from propagation to finishing have the highest degree of acclimatization. This system is the normal production system for most foliage plants and yields plants with low light compensation points, good color and an open canopy that allows the most efficient use of available light indoors. Excellent quality acclimatized foliage plants can be produced by using the light intensity recommendations in Table 1. These plants will have excellent interior longevity and provide long consumer satisfaction when produced with other good cultural practices.

Production under Sun and Conversion under Shade

Some foliage plants grow rapidly in full sun and produce a form that is considered more aesthetically acceptable to some producers, buyers and interiorscapers. A common example is Ficus cultivars which produce heavier caliper trunks and more compact crowns in full sun. Many consumers also prefer the shape of *Araucaria* and *Brassaia* qrown in full sun. Other genera used for interiors that are sometimes grown in full sun include *Chamaedorea*, *Chrysalidocarpus*, *Dracaena*, *Sansevieria* and *Yucca*. Time necessary to achieve sun-shade conversion depends on cultivar, plant size and method of production. Small plants grown in containers are able to convert much faster than large plants, with large field-grown plants taking the longest time to convert. However, we suggest shade growing for all plants in 10-inch (3 gallon) containers and smaller. Larger specialty plants such as *Brassaia* and *Ficus* can be converted and will yield good quality plants. Suggested shade levels for proper conversion are equivalent to those recommended for production (Table 1). Most plants require 8 weeks to 12 months or more to convert, depending on size.

Much has been written about the relative value and likelihood of indoor survival of sun-shade conversions, but the actual effects will probably never be known because of the widely differing conditions under which these plants are utilized. Some facts are known, however, and relate mainly to *Ficus benjamina*: 1) lowest light compensation points will only be achieved when en all sun-grown leaves have been replaced by shade leaves; 2) because of the larger trunk surface area and root volume in relation to leaf surface area, sun-grown trees will have higher respiration rates than shade-grown trees and never achieve the same level of acclimatization; and 3) sun-shade conversions appear acceptable for most interior situations except those with marginal light conditions (less than 125 ft-c).

Nutrition

Fertilization of foliage plants has a direct effect on acclimatization which may be related to respiration rate and/or high soluble salts. During production high levels of nitrogen, and to some extent potassium, have been shown to decrease ability of foliage plants to adjust to interior environments.

An understanding of the potting medium pH is necessary before fertilizer programs can be developed since it controls release of nutrients. A low pH will reduce conversion of ammonium to nitrate nitrogen, while high pH levels reduce availability of most microelements. Most foliage plants grow best when the pH is between 5.0 and 6.5 although some plants, such as *Maranta* and *Calathea*, prefer a range of 5.0 to 6.0

Low pH levels can be raised in potting media by addition of liming material, such as dolomite or calcium carbonate, while high pH levels can be lowered by addition of sulfur. The amount of liming material or sulfur needed to obtain a desired pH depends on the type of organic material present in the medium and the original pH; small amounts of lime or sulfur will change pH of sandy potting media while larger amounts are needed to change pH of peat moss. Table 2 provides a guide for adjusting pH levels of potting media during preparation.

The pH level should be adjusted prior to planting crops since changing the pH is difficult once plants are growing in the medium. The best material to raise pH after planting is calcium hydroxide (hydrated lime). However it can damage plants unless applied in solution of one pound/100 gal or less to 100 ft^2 of surface area (pots or benches). Plants can be treated again in 4 weeks if pH has not reached desired levels. Calcium carbonate applied to the potting medium surface and watered in will also raise pH, but it usually takes longer before its effect is noticeable. When pH levels are too high, sulfur can be applied at the rate of 1 lb/100 ft^2 to lower pH. Do not apply sulfur more often than every 4 weeks until the desired level is reached because plant damage may result from rapid pH changes. Irrigation after application of liming materials or sulfur application will remove residues from foliage and speed pH changes.

In addition to raising pH, dolomite also provides the essential elements calcium and magnesium, whereas the addition of sulfur to lower the pH will supply that essential element. If these elements have not been added to the media while adjusting the pH, be certain that they are added by some other means to ensure proper plant growth. Sulfur may be present in the water supply but ascertain that the proper level will be supplied.

Soluble Salts

Soluble salts should be determined prior to medium utilization. For media with high salts, addition of unnecessary fertilizer ions can be avoided by use of special fertilizer programs and plant damage can be reduced by more frequent applications of smaller amounts of fertilizer.

Microelements

In most potting media for foliage plants, microelements are needed. If good mixing equipment is available, microelements should be thoroughly incorporated into the medium at time of mixing. Many products are available for this purpose; Micromax (Sierra Chemical Co., Milpitas, CA) and Perk (Estech General Chemical Corp., Chicago, IL), both of which also contain sulfur, have given excellent results in experimental plots when added at the rate of 1 to 1-1/2 lbs/yd^3. If micro nutrients cannot be mixed into the potting medium, they may be added separately or incorporated into the fertilizer program, either as a periodic application or along with every fertilizer application.

Average amounts of 6 microelements that are needed on an annual or monthly basis to grow good quality foliage plants are given in Table 3. If a micronutrient mix is incorporated into the potting medium, annual rates should not be started until at least 6 months after potting; monthly rates may be started one month after planting.

Superphosphate

Incorporation of superphosphate into potting media for foliage crops has been a common practice. Research on foliage plants, however, has shown that incorporation of superphosphate is unnecessary for quality foliage plant production, if other sources of phosphorus are used, and can result in serious phytotoxicity on some foliage genera from excessive fluoride levels. Superphosphate contains 1 to 2% fluoride as a contaminant and this causes foliar damage on *Calathea*, *Chlorophytum*, *Cordyline*, *Dracaena*, *Maranta*, and *Yucca*. Since no unique benefit has been observed from superphosphate additions to potting media used for production of foliage plants, use of other sources of phosphorus is suggested.

Fertilizer Ratios

Relative levels of nitrogen, phosphorus and potassium in a fertilizer analysis are referred to as the N-P_20_5-K_2O ratio. Research in this area has shown that foliage plants grow very well with a 1:1:1 ratio, such as in an 8-8-8 or 20-20-20 fertilizer analysis, but will do just as well with a 3:1:2 ratio, such as a 9-3-6 or 18-6-12 analysis. The benefits of using the 3:1:2 ratio are reduced fertilizer costs per unit of nitrogen and lower total soluble salts levels which improve a plant's ability to acclimatize to interior environments. For these reasons, a 3:1:2 ratio fertilizer is suggested for foliage plant production where soilless potting media are utilized. When potting media are used that include clay-containing soils, it is suggested that a 1:1:1 ratio be used to prevent reduced availability of phosphorus and potassium.

Fertilizer Levels

Selection of the proper amount of fertilizer to apply to a specific foliage crop varies with the growing environment. Some major factors influencing fertilizer requirements include light intensity, temperature, rainfall or irrigation level, and cation exchange capacity (ability of the potting medium to retain nutrients).

Light. Growth of plants can be optimized at light intensities that provide highly acclimatized plants by selection of an appropriate fertilizer level. See Table 1 for information on suggested fertilizer levels for a wide variety of foliage plants when grown under recommended light intensities: If plants are grown under higher light intensities (not recommended for production of acclimatized plants), even full sun for plants like schefflera or areca palms, the suggested fertilizer levels will have to be increased by 50% or more. If lower light intensities are present, suggested fertilizer levels can be reduced by as much as 25%.

Temperature. Most foliage plants grow slowly, if at all, when soil temperatures drop below 60°F and night air temperatures are 65°F or below; thus, maintenance of standard fertilizer levels during this time is unnecessary and can often be reduced by up to 50%. Slow-release fertilizers are only partially available to plants during periods when potting media are cold, but become available as media warm; therefore, rates can be adjusted with such fertilizers by lengthening the time between application periods. During high temperature periods (85°F to 95°F days and 75°F to 85°F nights), foliage plants grow rapidly and can utilize slightly more fertilizer than listed rates. A general rule that will account for cool and warm season foliage production is to reduce suggested fertilizer levels by 25% during December - February and raise them by 25% from June - September.

Rainfall or irrigation level. Amount of water applied to the pot, either naturally or mechanically, affects the amount of fertilizer leached from potting media. In greenhouse irrigation, rates should be selected that wet the potting medium but provide minimal or no leaching. When proper irrigation is combined with correct fertilization levels, plant quality will be maintained and contamination of ground water prevented. Leaching of the potting medium is more difficult to control for plants grown in the open or under shade, but it is important to control or limit leaching to lessen fertilizer run-off for environmental as well as economic reasons. Irrigation scheduling must factor in rainfall since addition of an irrigation sequence on already saturated media will leach fertilizer and possibly contribute to ground water pollution.

Cation exchange capacity. Cation exchange capacity determines nutrient retention ability of a medium and is a necessary factor in calculating fertilizer levels. Fertilizer levels in Table 1 are based on utilization of potting media composed primarily of organic components with high cation exchange capacity. Examples of such potting media include (1) 75% peat moss - 25% sand, (2) 50% peat moss - 25% pine bark - 25% cypress shavings, and (3) 80% peat moss - 20% perlite, polystyrene foam or similar materials. Potting media composed of greater amounts of sand, perlite, polystyrene foam or pine bark may require slightly higher fertilizer levels because of decreased nutrient retention ability.

Selection of a fertilizer includes not only the form of the fertilizer such as liquid, granular or slow-release, but also the source of the nutrients themselves.

Nutrient form. Method of fertilizer application and economics influence the action of a fertilizer form. However, another factor that has become very important is the potential for pollution of ground water by specific fertilizer sources and forms. The Department of Environmental Regulation (DER) is looking closely at nitrate contamination of ground water in relation to ornamental producers in Florida. Monitoring of nursery wells has indicated that the federal maximum of 10 ppm nitrate nitrogen (NO_3-N) in ground water has been exceeded in one Florida nursery and in several greenhouse operations in the northeastern U.S. For this reason, we are suggesting use of fertilizer forms and application methods that minimize potential for contamination. The primary fertilizer forms are liquid and slow-release. The way these fertilizer forms are utilized contributes to the potential for leachate to reach the ground water; overhead sprinkler fertilization (fertigation) has the greatest potential and slow-release or liquid fertilizers placed directly into the container offer the least potential for ground water contamination. Factors that influence selection of liquid or slow-release fertilizers is covered in "Effective and Economical Fertilizer Considerations", Agricultural Research Center-Apopka Research Report RH-80-3.

Nutrient sources. Although nitrogen, for example, is presently available in fertilizer from three primary sources - nitrate (NO_3^-), ammonium (NH_4^+), and urea [$CO(NH_2)_2$] - foliage producers have not always considered the nutrient source when selecting a fertilizer. Formerly most fertilizers contained 20% to 50% nitrate nitrogen and the remainder came from ammonium or urea nitrogen forms. In recent years fertilizer formulators have substituted urea for much of the nitrate nitrogen because of its lower cost. Recent research on foliage plants has shown that ammonium and urea nitrogen were as good as or better than the nitrate form and lower in cost. Although we found no problem in utilizing 100% urea or ammonium nitrogen sources and combinations, these have not been tested on all genera and therefore we still suggest using a small amount of nitrate nitrogen (10-15 percent). On flowering foliage crops use of 25-50 percent nitrate nitrogen is still recommended.

Research has not been conducted on effects of different sources of other macro- or micro nutrients on foliage plant production. Thus, the major consideration in their selection should be their effect on pH and availability of nutrients.

Fertilizer Application Frequency

Liquid fertilizers should be applied frequently at relatively low rates at each irrigation or no more infrequently than weekly. The fertilizer should be supplied near the end of the irrigation cycle to reduce leaching. This method will supply needed nutrients to plants while limiting the amount of fertilizer ions that can be leached during heavy rainfall.

Slow-release fertilizers have a specified release period, such as 2 to 4, 3 to 4, 8 to 9, and 9 to 12 months or more. The release rate for slowrelease fertilizers is usually calculated for a soil temperature near 70°F, but may be based on a higher soil temperature depending on the manufacturer. During periods when potting media are near 65°F or lower, the release rate will be slower; if temperatures reach 80 to 100°F, the release rate will be much faster. These factors must be considered when using slow-release fertilizers in Florida since release rate of a 3 to 4 month material may be 2 to 3 months in the heat of summer or 4 to 5 months during a cool winter. Placing containers pot-to-pot or spacing plants only when some canopy has developed will reduce soil temperatures; also, actual soil temperatures under shade structures (40% shade or greater) are usually about 10°F cooler than in full sun so these factors should be considered when selecting slow-release sources.

Tailor the slow-release fertilizer release period to the crop cycle to reduce the potential for leaching and incorporate the fertilizer to prevent losses of granules from containers. Do not overfill containers at time of potting since this will increase the chance of granular materials falling off the medium surface if fertilizer reapplication is necessary. These efficient choice of the available fertilizers both in terms of decreasing pollution potential and in getting the most for your fertilizer money.

Fertilizer Rates

Suggested rates for various areas, pot size and source are shown in Tables 5-8. If fertilizer is to be applied as a ppm solution, check rates against footnotes on Tables 5-6. Suggested N, P and K levels in ppm for continuous application are 150 ppm N, 50 ppm P_2O_5 and 100 ppm K_2O (150 ppm N, 22 ppm P and 83 ppm K).

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Table 1. Suggested light and nutritional levels for production of some potted acclimatized foliage plants in Florida.

Botanical name	Light intensity (foot-candles)	shade cloth (percent)	Fertilization category[Z]
Aeschynanthus pulcher	1500-3000	70 - 80%	3
Aglaonema (cultivars)	1000-2500	80%	3
Anthurium (cultivars)	1000-2000	80%	4
Aphelandra squarrosa	1000-1500	80 - 90%	4
Araucaria heterophylla	4000-8000	30 - 60%	3
Asparagus (species & cultivars)	2500-4500	50 - 70%	2
Beaucarnea recurvata	2000-4000	60 - 80%	4
Brassaia (species & cultivars)	3000-5000	50 - 70%	5
Bromeliads (species & cultivars)	2000-3000	70 - 80%	3
Calathea (species & cultivars)	1000-2000	80%	3
Chamaedorea elegans	1500-3000	70 - 80%	3
Chamaedorea erumpens	3000-6000	40 - 70%	4
Chlorophytum comosum	1000-2500	70 - 80%	3
Chrysalidocarpus lutescens	4000-6000	40 - 60%	4
Cissus rhombifolia	1500-2500	70 - 80%	4
Codiaeum variegatum	3000-8000	30 - 70%	5
Cordyline terminalis	1500-3500	70 - 80%	3
Dizygotheca elegantissima	2000-4000	60 - 80%	3
Dieffenbachia (species & cultivars)	1500-2500	70 - 80%	3
Dracaena deremensis (cultivars)	2000-4000	60 - 80%	3
Dracaena fragrans (cultivars)	2000-4000	60 - 80%	3
Dracaena marginata	3000-6000	40 - 70%	5
Dracaena - other species	1500-3500	70 - 80%	4
Epipremnum aureum	1500-3000	70 - 80%	3
ficus benjamina (cultivars)	4000-6000	40 - 60%	5
Ficus elastica (cultivars)	4000-8000	30 - 60%	5
Ficus lyrata	2000-6000	40 - 80%	5
Fittonia verschaffeltii	1000-2500	80%	2
Hedera helix (cultivars)	1500-2500	70 - 80%	3
Howea forsterana	2500-4000	60 - 80%	3
Hoya carnosa	1500-3000	70 - 80%	3
Maranta (species & cultivars)	1000-3500	60 - 80%	2
Monstera deliciosa	2000-4000	60 - 80%	4
Nephrolepis exaltata (cultivars)	1500-3000	70 - 80%	3
Peperomia (species & cultivars)	1500-3000	70 - 80%	2
Philodendron scandens oxycardium	1500-3000	70 - 80%	3
Philodendron selloum	3000-6000	40 - 70%	4
Philodendron (species & cultivars)	1500-3500	60 - 80%	3
Pilea spp.	1500-2500	70 - 80%	2
Pittosporum tobira	3000-6000	40 - 70%	3
Podocarpus spp.	3000-6000	40 - 70%	5
Polyscias (species & cultivars)	1500-4500	50 - 80%	4
Radermachera sinica	*1500-3000*	*70 - 80%*	*3*
Saintpaulia ionantha	1000-2000	80%	3
Sansevieria (species & cultivars)	1500-6000	40 - 80%	1
Schefflera arboricola	1500-3000	70 - 80%	3
Schlumbergera truncata	1500-3000	70 - 80%	2
Spathiphyllum (cultivars)	1500-2500	80%	3
Syngonium podophyllum	1500-3000	70 - 80%	3
Yucca elephantipes	3000-5000	50 - 70%	4

1. [Z]RATE in g N/ft^2/yr using a 3-1-2 (N-P_2O_5-K_2O) ratio fertilizer to supply P and K. Categories are defined as 1 = 10 g, 2 = 13 g, 3 = 16 g, 4 = 19 g and 5 = 22 g N/ft^2/yr.

Table 2. Approximate amount of incorporated materials required to change pH of potting mixtures.

Dolomitic lime (pounds per cubic yard) or equivalent amount of liming material to raise pH of indicated medium to approximately 5.7.			
Beginning pH	50% Peat + 50% Sand	50% Peat + 50% Bark	1OO% Peat
5.0	1.7	2.5	3.5
4.5	3.7	5.6	7.4
4.0	5.7	7.9	11.5*
3.5	7.8	10.5*	15.5*
Sulfur (pounds per cubic yard) needed to lower pH of indicated media to approximately 5.7.			
Beginning pH	50% Peat + 50% Sand	50% Peat + 50% Bark	100% Peat
7.5	1.7	2.0	3.4
7.0	1.2	1.5	2.5
6.5	0.8	1.0	2.0
*Addition of more than 10 pounds of dolomite per cubic yard often causes micronutrient deficiencies.			

Table 3. Suggested application rates of micronutrients for foliage plants.

	Rate of application		
Element	gm/1000 ft^2/mo	gm/1000 ft^2/yr	lb/A/yr
Boron (B)	0.43	5.2	0.50
Copper (Cu)	4.33	52.0	5.00
Iron (Fe)	17.33	208.0	20.00
Manganese(Mn)	8.67	104.0	10.00
Molybdenum(Mo)	0.02	0.2	0.02
Zinc (Zn)	4.33	52.0	5.00

Table 4. Amounts of 9-3-6 fertilizer needed to supply suggested fertilizer levels in various sized pots for specific crops (see Table 3).

		grams[2] 9-3-6/pot/month						
Fertilizer category[1]	lb 9-3-6 /1000 sq.ft /month	4"	6"	8"	10"	12"	14"	grams 9-3-6 /sq.ft /month[3]
1	19.1[4,5]	0.1	1.7	3.0	4.7	6.8	9.2	8.7
2	25.6	1.0	2.3	4.0	6.3	9.1	12.3	11.6
3	31.9	1.3	2.8	5.1	7.9	11.4	15.4	14.5
4	38.3	1.5	3.4	6.1	9.5	13.6	18.5	17.4
5	44.6	1.8	4.0	7.1	11.1	15.9	21.6	20.3

1. [1]Categories are defined as 1 = 10 g, 2 = 13 g, 3 = 16 g, 4 = 19 g and 5 = 22 g N/ft^2 /yr
[2]One teaspoon 9-3-6 equals approximately 5 gms.
[3]Use to calculate rates for larger containers.
[4] If fertilizing with each irrigation is desired, divide by expected number of irrigations during the month.
[5]One quarter inch of 100 ppm N applied ten times monthly equals approximately 12.8 lbs 9-3-6/1000 ft^2.

Table 5. Amounts of 20-20-20 fertilizer needed to supply suggested fertilizer levels in various sized pots for specific crops (see Table 3).

		grams[2] 20-20-20/pot/month						
Fertilizer category[1]	lb 20-20-20 /1000 sq.ft /month	4"	6"	8"	10"	12"	14"	grams 20-20-20 /sq.ft /month[3]
1	8.6[4,5]	0.4	0.8	1.4	2.1	3.1	4.1	3.9
2	11.5	0.5	1.0	1.8	2.8	4.1	5.5	5.2
3	14.4	0.6	1.3	2.3	3.5	5.1	6.9	6.5
4	17.2	0.7	1.5	2.7	4.3	6.1	8.3	7.8
5	20.1	0.8	1.8	3.2	5.0	7.2	9.8	9.2

1. [1]Categories are defined as 1 = 10 g, 2 = 13 g, 3 = 16 g, 4 = 19 g, and 5 = 22 g N/ft2 /yr.
[2]One teaspoon 20-20-20 equals approximately 5 gms.
[3]use to calculate rates for larger containers.
[4]If fertilizing with each irrigation is desired, divide by expected number of irrigations during the month.
[5]One quarter inch of 100 ppm N applied ten times monthly equals approximately 6 lbs 20-20-20/1000 ft2.

Table 6. Amounts of 14-14-14 Osmocote[1] needed to supply suggested fertilizer levels in various sized pots for specific crops (see Table 3).

	surface application						
	grams[3]/pot/3 months						
Fertilizer category[2]	4"	6"	8"	10"	12"	14"	grams/ft^2 /3 months[4]
1	1.5	3.3	5.8	9.1	13.1	17.8	16.8
2	1.9	4.4	7.8	12.2	17.5	23.7	22.3
3	2.4	5.5	9.7	15.2	21.9	29.6	27.9
4	2.9	6.6	11.7	18.2	26.3	35.6	33.5
5	3.4	7.7	13.6	21.3	30.6	41.5	39.1

1. [1]Sulfur coated slow-release formulations can be substituted at equivalent rates. For urea formaldehyde slow-release formulations increase rates by 25%
[2]Categories are defined as 1 = 10 g, 2 = 13 g, 3 = 16 g, 4 = 19 g, and 5 = 22 g N/ft^2 /yr.
[3]One level teaspoon = approximately 5 gms.
[4]Use to calculate rates for larger containers.

Table 7. Amounts of 19-6-12 Osmocote[1] needed to supply suggested fertilizer levels in various sized pots for specific crops (see Table 3).

	Surface application						
	grams[3]/pot/3 months						
Fertilizer category[2]	4"	6"	8"	10"	12"	14"	grams/ft^2 /3 months[4]
1	1.1	2.4	4.3	6.7	9.6	13.1	12.3
2	1.4	3.2	5.7	8.9	12.9	17.4	16.4
3	1.8	4.0	7.2	11.2	16.2	21.8	20.5
4	2.2	4.8	8.6	13.5	19.4	26.2	24.7
5	2.5	5.7	10.0	15.7	22.6	30.6	28.8

1. [1]Sulfur coated slow-release formulations can be substituted at equivalent rates. For urea formaldehyde slow-release formulations increases rates by 25% or more.
[2]Categories are defined as 1 = 10 g, 2 = 13 g, 3 = 16 g, 4 = 19 g and 5 = 22 g N/ft^2 /yr.
[3]One level teaspoon= approximately 5 gms.
[4]Use to calculate rates for larger containers.