

Instead of growing foliage plants in high light intensities, years of experience in nursery production and research have determined that those produced under lower light and fertilizer levels resulted in a final product more able to withstand interior environments. These **acclimatized** plants transition better to the indoors, plus have higher interior survival rates and longer replacement cycles. But once foliage is acclimatized to lower light levels, moving plants to higher light intensities may result in leaf burn. The following table summarizes the physical characteristics that result when plants are grown under low (shade) versus high light levels (sun) in the nursery.

Characteristics of Leaves on Shade Grown versus Sun Grown Plants

Shade Leaves	Sun Leaves
dark green color	light green color
large and thin	small and thick
few new leaves	many new leaves
leaves widely spaced	leaves close together
leaves held horizontally	leaves held upright
thin leaf petioles	thick leaf petioles



Figure 5. Leaves of indoor grown *Spathiphyllum* damaged from exposure to direct sunlight.

Light

Light is the most common limiting factor for maintaining plants indoors. Plants must receive light at levels slightly higher than the intensity at which an individual plant reaches its compensation point in order to survive and replace yellowing foliage as it ages. The **light compensation point** is the rate at which a plant uses (through respiration) as much food as it produces (through photosynthesis) in any given amount of light. When photosynthesis is greater than respiration, the plant grows. When photosynthesis is less than respiration, the plant declines. Therefore, the most important lesson is to match the plant selected to the proper environment in which it will grow best.

Light Intensity

The **light intensity** that an indoor plant receives depends on:

- 1) The light source, whether natural, artificial or a combination of the two.
- 2) Any obstructions present, natural and manmade.
- 3) The amount of reflection from light fixtures and design elements.

Light intensity or brightness is measured in units called footcandles. A **footcandle** (fc) is defined as the amount of light equivalent to the illumination produced by a source of one candle at a distance of one foot. A footcandle equals one lumen per square foot. A **lumen** (lm) is a unit of measure for quantifying the amount of light energy emitted by a light source. In other words, footcandles measure the brightness of the light at the illuminated object, while lumens measure the power of the light radiated by the light source.

Plants that can adapt to interior settings are commonly divided into three broad categories according to their physiological responses to light levels. The categories generally indicate the minimum light required for survival. Growth in each group is often best at the higher end of these suggested light ranges.

Light Levels

Plants referred to as **low light** intensity plants generally should receive a minimum level of 25 footcandles, with a preferred range of 75 to 200 footcandles. **Medium light** intensity plants need a minimum of 75 to 100 footcandles, with a preferred level of 200 to 500 footcandles.

Plants that require **high light** intensity need at least 200 footcandles, and prefer ranges of 500 to 1,000 footcandles. These plants are usually not adapted for long term indoor use unless additional light can be supplemented from natural sources such as sky lights.

Very high light intensity plants are far less satisfactory for growing under indoor artificial lights. These plants require a minimum of 1,000 footcandles, with preferred levels over 1,000 footcandles. This group should be used only for seasonal color, and thus must be rotated often.

Light intensity is measured with a light meter. Light levels are best determined by averaging light meter readings taken at various plant heights between the hours of 11:00 a.m. and 1:00 p.m. on several days (during both cloudy and sunny weather). Interiorscape professionals also become able to judge the light level of an area after some practice. An easy and practical way to approximate light intensity is to place a piece of white paper an

inch or two under a leaf. If a fuzzy but definite shadow is apparent, medium light levels are present. If a shadow is not evident, then the area has low light. A clearly outlined shadow indicates a high light level.

In general, plants with many small leaves having a compact growth habit need higher light levels. Plants having a more open canopy with fewer, but larger, dark green leaves and a less compact growth habit usually tolerate lower light. The table on the following page lists common interior plants with their associated indoor light tolerances.

Light Quality

Light particles have different amounts of energy. The amount of energy within each light particle is determined by its **wavelength** (measured in nanometers or nm). The sun emits light energy packets (called photons) in both visible and invisible wavelengths. Approximately half of the sun's energy falls within visible wavelengths. The remaining amount of energy has shorter wavelengths (such as ultraviolet light) or longer wavelengths (such as far red light and infrared radiation). Light may look white to the human eye, but is in reality composed of many different wavelengths as seen in rainbows or when light strikes a prism.

General Light Levels Based on Orientation to Windows



High Light: areas within four feet of large south, east, and west facing windows.

Medium Light: locations in a range of four to eight feet from south and east windows, and west windows that do not receive direct sun.

Low Light: areas more than eight feet from windows as in the center of a room, a hallway or an inside wall. Northern exposures often fall into this category, even when close to the window.

Many locations that receive only artificial light are also low light situations.

Average Light Tolerances of Select Interiorscape Plants		
Low Light (50 fc to 100 fc)	Medium Light (100 fc to 300 fc)	High Light (above 300 fc)
<i>Aglaonema</i> spp.	<i>Aechmea fasciata</i>	<i>Alocasia</i> spp.
<i>Aspidistra elatior</i>	<i>Anthurium</i> hybrids	<i>Aucuba japonica</i>
<i>Calathea</i> spp.	<i>Araucaria heterophylla</i>	<i>Bambusa</i> spp.
<i>Chamaedorea elegans</i>	<i>Chamaedorea erumpens</i>	<i>Beaucarnea recurvata</i>
<i>Dracaena deremensis</i> 'Janet Craig'	<i>Cissus rhombifolia</i>	<i>Bucida buceras</i>
<i>Dracaena fragrans</i> 'Massangeana'	<i>Dieffenbachia</i> spp.	<i>Caryota mitis</i>
<i>Dracaena reflexa</i>	<i>Dracaena deremensis</i> 'Warneckii'	<i>Chlorophytum comosum</i>
<i>Epipremnum aureum</i>	<i>Dracaena marginata</i>	<i>Crassula ovata</i>
<i>Eucharis x grandiflora</i>	<i>Dypsis lutescens</i>	<i>Cryptanthus bivittatus</i>
<i>Guzmania</i> spp.	<i>Ficus</i> spp.	<i>Heliconia</i> spp.
<i>Homalomena</i> 'Emerald Gem'	<i>Hedera helix</i>	<i>Kalanchoe blossfeldiana</i>
<i>Peperomia</i> spp.	<i>Howea forsteriana</i>	<i>Neoregelia carolinae</i>
<i>Philodendron</i> spp.	<i>Maranta</i> spp.	<i>Pandanus utilis</i>
<i>Sansevieria</i> spp.	<i>Nephrolepis exaltata</i> hybrids	<i>Polyscias</i> spp.
<i>Spathiphyllum</i> spp.	<i>Phoenix roebelenii</i>	<i>Radermachera sinica</i> 'China Doll'
<i>Syngonium podophyllum</i>	<i>Rhapis excelsa</i>	<i>Strelitzia nicolai</i>
<i>Zamioculcas zamiifolia</i>	<i>Schefflera arboricola</i>	<i>Yucca elephantipes</i>

Figure 6. Suggested light levels for commonly used interior plants.

Light quality refers to the light spectrum distribution; in other words, blue, green, red, far red and other portions of the light spectrum emitted from a light source. Visible light is made up of all colors. Biological processes that need light make use of some colors more efficiently than others. For example, leaves reflect and derive little energy from the yellow and green wavelengths of the visible spectrum. In contrast, blue and red wavelengths of



Figure 7. Abstract illustration of wavelengths within the visible spectrum of light.

the light spectrum are the most efficient for photosynthesis. Infrared light is invisible to the human eye, but influences stem elongation and seed germination.

Since all necessary light colors are included in natural sunlight, it is the most preferred light source. In settings where plants receive little or no natural light, additional light from artificial sources must be provided for adequate plant growth. Artificial light source bulbs emit various electromagnetic wavelengths (light spectra or colors). Since plants use red and blue light for energy and growth, these wavelengths in particular need to be provided by indoor lights.

Light Sources

There are a number of electric light sources used to illuminate interiorscapes. Various light sources commonly used indoors influence how plants look to the viewer and how they grow over a period of time. Three common sources of artificial light used to enhance plant growth indoors include incandescent, fluorescent, and light emitting diodes (LEDs).



Figure 8. Comparison of the initial costs for incandescent, fluorescent and LED light bulbs.

As a single light source for plants, **incandescent lights** are not particularly good. They are a rich source of red light, but a poor source of blue. Additionally, they produce too much heat for most plants; so they must be located some distance from plants, thus reducing the intensity of light plants receive.

Fluorescent lights provide one of the best artificial light sources available for interior plants. They are about 2½ times more efficient in converting electrical energy into light energy than are incandescent sources and are relatively long lasting, making them less expensive to operate. Additionally, fluorescent tubes produce relatively little heat and are available in types that emit primarily red and blue light. Cool white fluorescent tubes are the most popular choice for interior use, but warm white fluorescent tubes also seem fairly effective. Fluorescent tubes listed as white



Figure 9 Comparison of operating costs for incandescent, fluorescent and LED light bulbs

or daylight are less desirable for indoor plant growth. Cool white tubes produce a small amount of red light, in addition to orange, yellow-green and blue, though usually not enough for plant growth unless windows or other artificial lights (such as incandescent bulbs) provide additional red light. Fluorescent tubes developed specifically for growing plants have a higher output in the red range to balance the blue output.

Light emitting diodes (LEDs) represent the newest source of supplemental light for plants. They are extremely energy efficient and very long lasting. LED lights can be customized to produce the wavelengths of light desired. For example, LED plant lights emit only the red and blue light needed by plants. They emit very little heat and require no ballasts or reflectors as do fluorescent bulbs. The price of LED systems is currently high when compared

to other sources, but the long life and energy saving qualities of these lights may outweigh the initial expense.

The different light bulb emission spectra are plotted on the same axis in the adjacent illustration. While none of the bulbs do exactly reproduce natural daylight, the LED bulb is clearly the best approximation. All of the emission from the LED source occurs within the visible range, making the device very efficient.

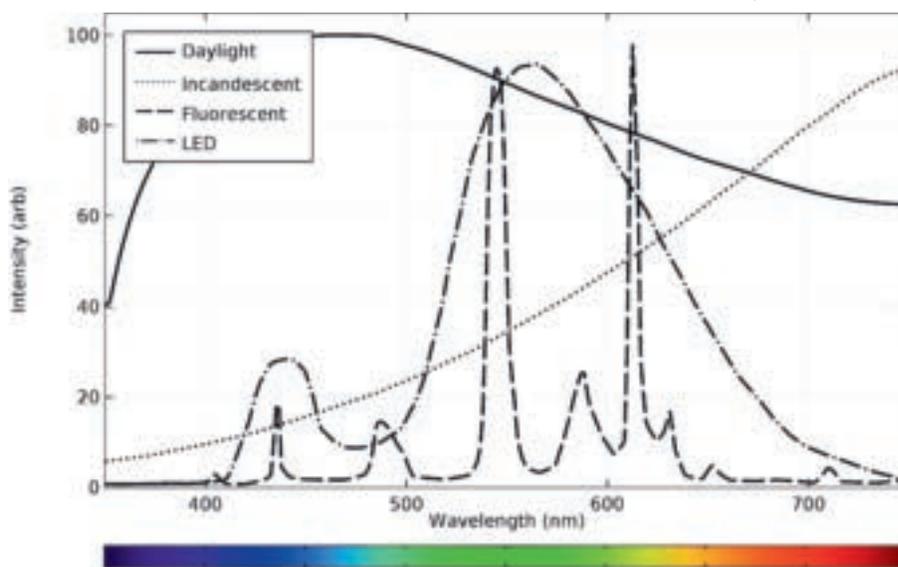


Figure 10. Graphic representation of the emission spectra from daylight and typical incandescent, fluorescent, and LED bulbs.

feels. Growing media probes (such as bamboo sticks) or core samplers are useful ways to assess conditions at or near the bottom of a large container. Some interior containers may have clear, vertical tubes installed at the edge of the container so moisture levels can be more easily observed.

The amount of water applied at each watering depends on the degree of media dryness, size of the container, method of watering and specific plant requirements. Watering plants from the surface and allowing water to percolate through the growing media is the best way to irrigate indoor plants, after which the soil should be allowed to dry as much as possible without stressing the plant or allowing it to wilt. This method leaches any accumulating soluble salts that shorten the life of interior plants. However, plants should never be allowed to sit in this excess water (or **leachate**) and seep back into the root environment. If catch basins or saucers under pots are large enough, leachate usually evaporates and does not need to be pumped out.

Many interiorscapes are watered using subirrigation systems. In such systems, water seeps into the root environment from below through a wick or by allowing the growing media to come into contact with water in a reservoir at the bottom of the container. Obviously, leaching does not occur in these systems, but they do require less attention. The key to managing a subirrigation system is to carefully control fertilizer levels because excesses will quickly result in high soluble salts in the growing medium.

Fertilizing

Plant nutritional requirements change with indoor light intensity. When light levels are very low (below 75 footcandles), the natural decomposition of peat moss and/or bark in potting mixes alone can provide sufficient nitrogen for most foliage plant species. At such low light levels, plants grow very slowly and use very small amounts of fertilizer.

Proper fertilization depends on the type of plant, amount of growth, quality of container medium, watering practices, quality of water used, season of the year, and results from soil tests (such as salinity, pH, nutrient levels, etc.). A common mistake made by interior technicians is preparing one fertilizer solution for all plants in the indoor environment, disregarding the different light levels in which various plants are maintained. Typically, this causes plants in lower light levels to be damaged by excess salts accumulating in the growing medium, while plants in the highest light levels produce pale, weak, unattractive growth caused by underfertilization. Overfertilization can be difficult to control, especially once plants begin to show signs of damage from high salinity levels in the root zone. For this reason, most professional interiorscapers fertilize lightly or not at all. If soil tests indicate more fertilizer is needed, it can be quickly and properly added.

It is best to use a complete, soluble fertilizer so that dosage can be controlled. In moderate or low light situations, or when irrigation water is cold, a soluble fertilizer that contains nitrogen in nitrate (NO_3) form is less likely to burn or accumulate in the leaves causing tip burn than products in an ammonia (NH_4) form. Slow-release pellet type fertilizer products are designed for infrequent application, but they are not well suited for indoor plants because of the difficulty of changing dosage quickly if problems develop. Release of nutrients from slow-release fertilizers will also be uneven where plants are kept on the dry side.



Figure 16. Common soluble fertilizer used for indoor plants.

Fertilization Guide for Interior Plants using a soluble 20-20-20 product			
Light Level	Footcandles (fc)	Interval of Application	Amount of 20-20-20
Survival	50 – 100 fc	0 times per year	do not fertilize at all
Maintenance	100 – 300 fc	1 – 2 times per year	1/2 teaspoon per gallon
Growth	300 – 1,000 fc	2 – 4 times per year	3/4 – 1 teaspoon per gallon
Note: More concentrated fertilizer solutions used for growth may burn leaves if not washed off immediately after application.			
Information adapted from <i>The Healthy Indoor Plant: A Guide to Successful Indoor Gardening</i>			

Figure 17. Fertilizer application rate and frequency recommendations for interior plants based on light levels.

Fertilizer applications should only occur when the growing medium is moderately moist. Then, drench the fertilizer into the growing medium with enough water to distribute it evenly. Drain excess fertilizer solution away from the bottom of the pot. The amount of water applied to the pot at each watering affects the amount of fertilizer leached from the potting medium and thus affects fertilizer application rates. In most interiorscapes, moderate to heavy leaching is impractical and sometimes impossible to perform; consequently care must be taken to avoid soluble salts buildup in the medium from a dosage that is too high.

In addition to light levels, other factors that must be considered when establishing the amount of fertilizer plants use include temperature and watering frequency. Most foliage plants originated in the tropics and therefore grow very slowly when media temperatures drop below 65°F or night air temperatures are 70°F or below. Under these lower temperature conditions, fertilizer applied at maintenance levels listed in the table above could cause unused fertilizer salts to accumulate in the growing medium; therefore, application rates should be reduced until warmer conditions return.

Finally, when preparing soluble fertilizer solutions, always remember that liquid fertilizer formulations containing higher rates of nitrogen may burn foliage. Foliage should be rinsed clear to remove the fertilizer.

Grooming

The leaves of indoor plants can become coated with a heavy layer of dust in a surprisingly short time. This dust interferes with normal leaf functions and makes the plant less attractive. A clean plant uses sunlight energy more efficiently for photosynthesis. Attention given to plants to keep them clean also makes it more likely that insect or disease problems will be recognized at the first signs and treated promptly.

Feather dusters do a thorough and speedy job of removing loose dirt and dust from leaves for less severe accumulations, especially on plants with many small leaves. Gently move the feathers across leaf surfaces, being careful not to break or crack the leaves. Feather dusters should be sprayed with a 10% bleach



Figure 18. Dusting *Ficus elastic* (rubber tree) leaves.

Biological control can be very useful in interiorscapes because of restrictions on indoor plantscape pesticide applications, pesticide costs, limited control with pesticides, phytotoxicity, and potential human health hazards. To implement a successful biological control program, knowledge of pest and natural enemy biology, a good monitoring program, patience, and commitment to the program are important.

If a pesticide is needed, use care to avoid causing plant damage. Phytotoxic effects may occur if the temperature is too hot, if pesticides are applied too heavily or mixed with some adjuvants. Certain pesticide formulations may also result in phytotoxic effects on sensitive plants.

Monitoring and proper identification of the problem is very important. Several factors should be considered when attempting diagnosis, including plant location in relation to light and air flow, frequency of watering and fertilizing, and plant age. Common symptoms of interior plant problems and possible causes are provided in the table on the following page.



Figure 29. Repotting a pot bound aglaonema.

Repotting

The root system gets larger as the upper portion of a plant grows, eventually filling all the available space in the container and becoming pot bound. When this happens, plant growth will be restricted unless more room for root growth is provided by repotting. The frequency of repotting depends upon the rate of growth of a particular plant.

Water the plant thoroughly several hours before removing it from the container. Moist media holds together better when the root ball is disturbed. Select a pot with a diameter one size larger than the pot in which the plant was previously grown. Put growing medium in the bottom of the new pot in order to elevate the plant if the new pot is deeper than the original.

Place the plant on its side and tap on the pot sides and bottom to loosen the growing medium, then gently pull it free keeping the root ball intact. Small plants can be turned upside down and the root mass removed by gently tapping the top edge of the pot on a hard surface. If the roots are matted around the root ball (pot bound), force the roots apart and cut the entangled roots. Holding the root ball, lower the plant carefully into the new pot. Remove a small amount of potting mix from the top of the root ball to scrape off any accumulated soluble salts. Bring the top of the root ball within about one inch of the container top. Fill media around the root ball and gently press into place; add a small amount to the top of the root ball to replace that removed. Water thoroughly to settle media.

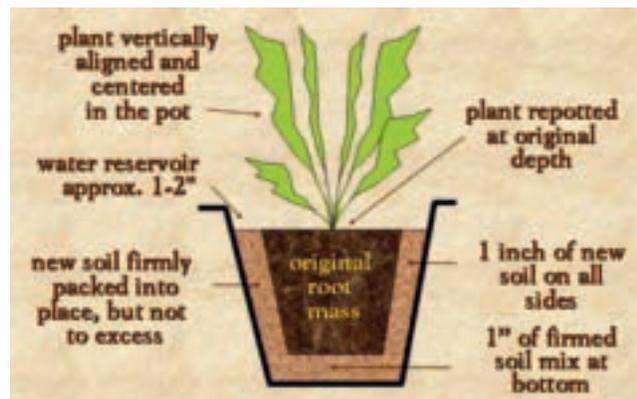


Figure 30. Graphic illustration of the repotting procedure.