Interior Plant Selection and Maintenance

Although indoor gardening got its start in Europe in the 1800s, it was not until the 1970s that using interior ("house") plants was no longer considered a luxury. Today, plants fill both functional and aesthetic needs. As design elements, plants act as living art forms, providing a much needed antidote to the concrete and steel buildings in which present day society works and lives.

The need to bring nature indoors has defined the industry known as ***interiorscaping***. Restaurants, retail spaces, and office buildings use plants to make the indoor environment more pleasing for customers and employees. The job of the interiorscape professional is to select plants that meet the environmental and social needs of indoor spaces and that maintain aesthetic beauty for many years.

Attractive interior plantings are dependent upon:

1) An understanding of the people, activities, and environment of the planting sites.
2) Appropriately designed settings.
3) Proper selection and installation of plants.
4) Informed personnel with the skill and ability to maintain plantings.

Benefits of Interior Plants

Those who spend significant time in spaces with live plants experience great benefits, not only to their health, but to their well-being in general. The biophilia hypothesis suggests that there is an instinctive bond or positive attraction between human beings and other living systems. In 1984, Harvard biologist Dr. Edward O. Wilson introduced and popularized this human tendency and defined biophilia as a need to connect or associate with other life forms in nature. The term literally means "love of life" or love of the satisfaction that comes from being surrounded by living organisms.

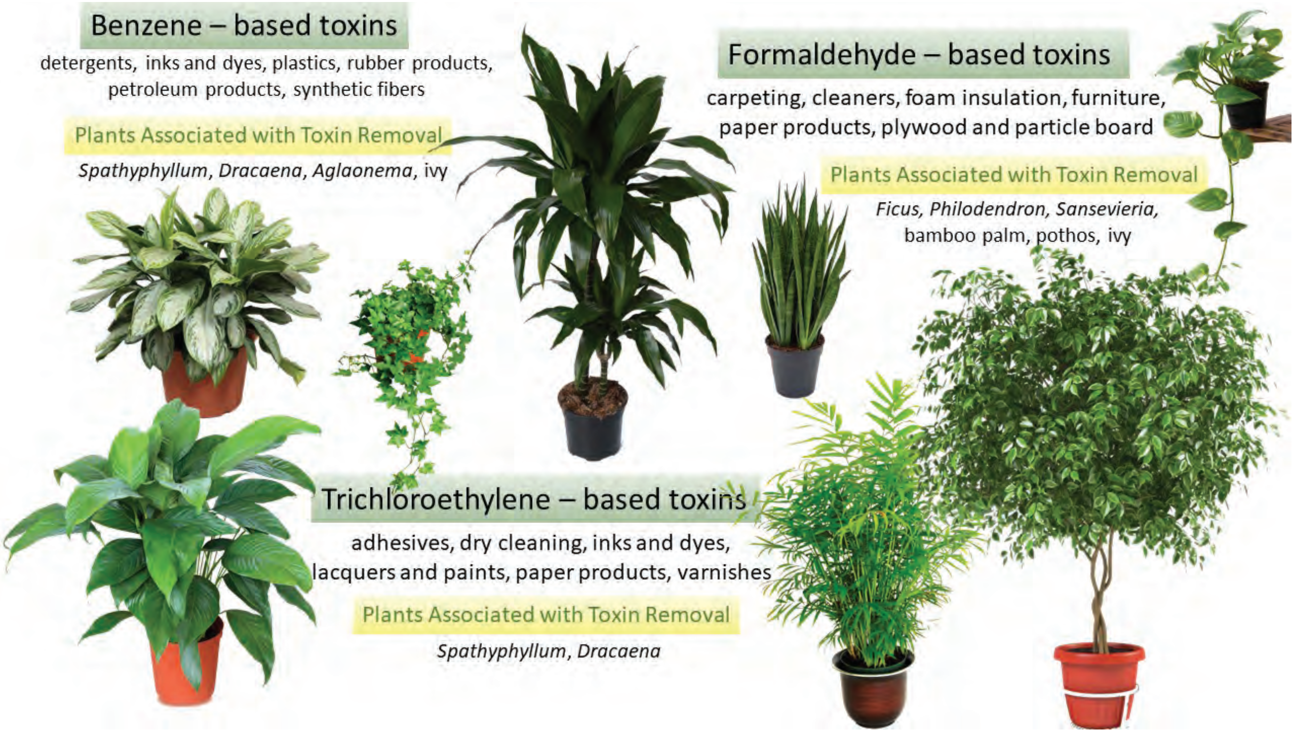
The study of ***biophilia*** is still in its early stages, but research shows that direct exposure to natural elements may impact employees in ways that result in productivity gains, less absenteeism, fewer health problems and a better sense of well-being. Biophilic design takes sustainable design to the next level by considering the inherent need humans have for nature and linking it with sustainable and universal design strategies to create environments that truly enhance life.

Yet another concept is ***biomimicry***, the science and art of emulating nature's models, systems, processes and elements to solve human problems. The term biomimicry comes from the Greek words *bios*, meaning life, and *mimesis*, meaning to imitate. Biomimetics is not a new idea. Humans have been looking at nature for answers to both complex and simple problems throughout existence. Interior plants within an attractive and functional design are a perfect example. Live indoor ***plantscapes*** demonstrate nature's hearty resolve, as well as perform the process of cleaning the surrounding air while exchanging it for fresh oxygen.

Cleaning Indoor Air

Volatile organic compounds (VOCs) are chemical compounds capable of evaporating under normal indoor temperature and pressure. Concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors. VOCs are emitted by a wide array of household products, including paints, varnishes and wax, carpets, wallpaper, curtains, paper products, office chairs, and electronic equipment, as well as cleaning, disinfecting, cosmetic, degreasing and hobby products. Indoor air contaminated by VOCs is a major cause of allergies, headaches, nausea, loss of concentration, and other ***building-related illnesses*** that are initiated by exposure to substances within airtight buildings that have poor ventilation.

Research has shown that the ***pot-plant system*** (plants and potting mix combinations) can eliminate several times the maximum daily exposure concentration of common VOCs, like formaldehyde and benzene. It has been consistently shown that living, green and flowering plants can remove several toxic chemicals from the air in building interiors (Figure 15-1). Essentially, plants contribute to air purification through interactions with plant-microbe communities capable of degrading, detoxifying or isolating pollutants and promoting plant growth. When plants transpire water vapor from their leaves, air is pulled down around the roots. This process supplies associated root microbes with oxygen. The root microbes convert other substances in the air, such as toxic chemicals, into a source of food and energy. Microbes, such as bacteria, can rapidly adapt to a chemical contaminant by producing new colonies that are resistant to the chemical. As a result, these microorganisms



graphic by gale allbritton

Figure 15-1. Examples of volatile organic compounds and plants that have shown the ability to remove indoor toxins.

become more effective at converting toxic chemicals into food the longer they are exposed to these chemicals. It is also important to remember that the efficiency of plants as a filtering device increases as the concentration of chemicals in the air increases.

A study conducted in 1989 by Dr. Bill Wolverton of the National Aeronautics and Space Administration (NASA) proved that several common species of interior landscape plants have the ability to remove compounds such as benzene and hexane in the range of 50% to 75% of the total volatile organic compounds present. Again, the plant root-soil zone appeared to be the most effective area for removing VOCs.

Wolverton studies suggest interior plants are most effective in removing VOCs in energy efficient, nonventilated buildings; in highly ventilated buildings, the rapid exchange of inside and outside air makes the benefits of indoor plants mostly limited to their psychologic and aesthetic values. These studies also assessed 50 interior plants based on four criteria: 1) removal of chemical vapors, 2) ease of growth and maintenance, 3) resistance to insect infestation, and 4) transpiration rates. The assessment ranked the following plants as the top 10 interior plant air cleaners.

1) *Dypsis lutescens* (areca palm).
2) *Rhapis excelsa* (lady palm).
3) *Chamaedorea seifrizii* (syn. *C. erumpens*) (bamboo palm).
4) *Ficus elastica* (rubber plant).
5) *Dracaena fragrans* 'Janet Craig' (Janet Craig dracaena).
6) *Hedera helix* (English ivy).
7) *Phoenix roebelenii* (pygmy date palm).
8) *Ficus maclellandii* 'Alii' (banana leaf ficus).
9) *Nephrolepis exaltata* 'Bostoniensis' (Boston fern).
10) *Spathiphyllum* spp. (peace lily).

The general recommendation for the number of plants to clean indoor air is one six-inch plant per 100 square feet of interior space. Plants can be used in any home or office to improve the quality of air, and make it a more pleasant place to live and work – where people feel better, perform better, and enjoy life more.

More recently, ***green walls*** (also known as vertical planting systems, vertical gardens, plant walls or vegetated walls as in Figure 15-2) have been successfully implemented around the

Figure 15-2. A green wall used in the interiorscape setting of an office lobby.

world. In 2004, a four-story plant ***biowall*** was installed at the University of Guelph-Humber Building in Ontario, Canada. With plant life visible from nearly every floor, the wall acts as an indoor air purifier, pulling air through the wall and into the mechanical air ducts. According to the university, the biowall is capable of supplying all the building's fresh air intake needs. Irrigated by a vertical hydroponic system, the wall naturally cools the building in the summer and humidifies in the winter in a manner similar to that of an evaporative cooling system in a greenhouse.

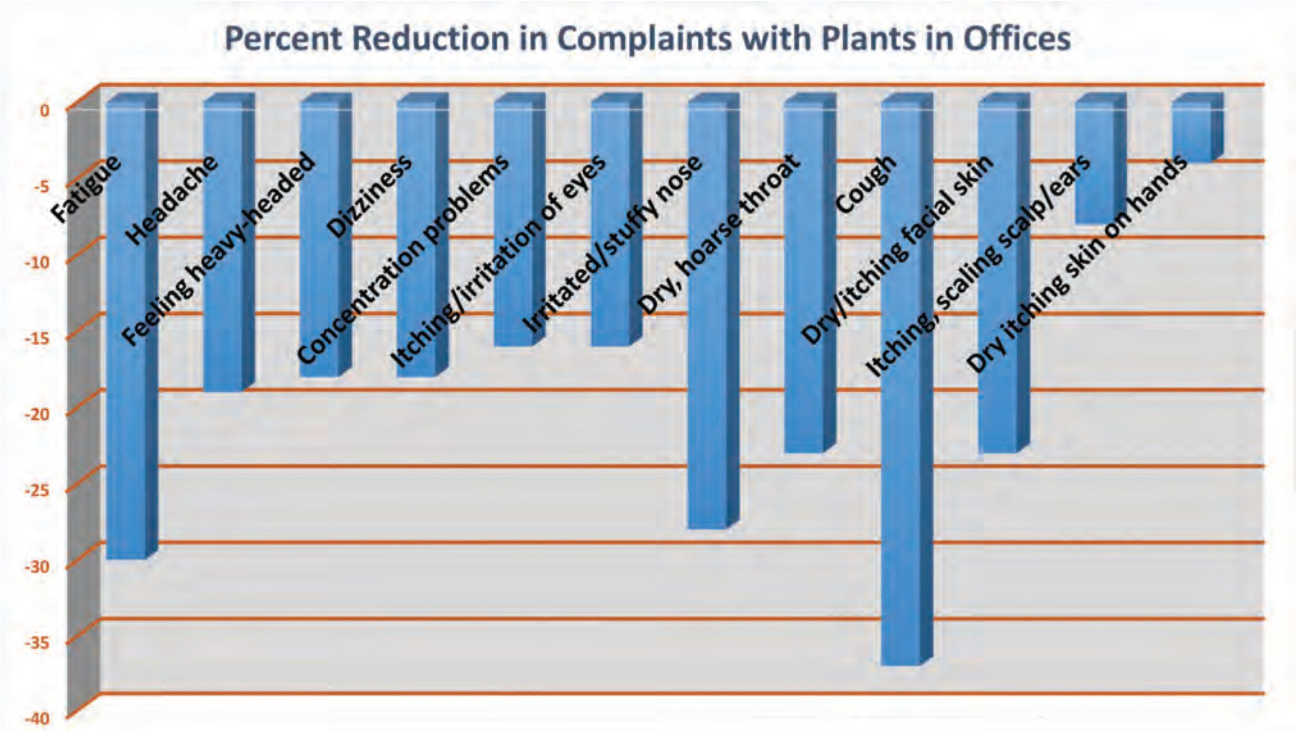
Improving Health

The degree to which interior plants can positively affect employees' health is an important issue in today's workplace . This is because ***sick building syndrome*** is a serious and expensive issue. Several studies of the office environment have proven the direct relationship between clinical health complaints and plant installations. On average, when plants were present in the office, the complaint rate for 12 common symptoms most often related to poor indoor air quality was reduced by 23% (Figure 15-3).

Concentration and productivity are negatively affected when there are elevated levels of carbon dioxide (CO_2) indoors. However, during photosynthesis, plants naturally extract CO_2 and exchange it with fresh oxygen. Based on modest estimates of existing and emerging data, it has been calculated that a minimum of 300 grams (10 oz.) of CO_2 can be eliminated from enclosed environments for every square meter of leaf surface in the area per year. Over a year's time, this amounts to a removal of six cubic feet of CO_2 gas. In areas where there exists an abundance of natural light, this process is amplified, affording even more absorption.

Enhancing Creativity

Another study explored the link between flowers and plants, and workplace productivity. Participants performed creative problem solving tasks in a variety of common office environments or conditions. During the study, both women and men demonstrated more innovative thinking, and generated more ideas and original solutions to problems in an office environment that included natural elements such as flowers and plants.



graphic by gale allbritton

Figure 15-3. Complaint rate reduction in common symptoms of sick building syndrome when plants were present.

Increasing Sales

Retailers have long understood the importance of store environments in enhancing the shopping experience. While marketers have studied the influence of product packaging and store layout on the behavior of shoppers, business people often overlook macrolevel settings (the district that surrounds the shop or office). Interior plants and landscapes create situations more favorable for retail activity (Figure 15-4). When people shop within tree versus nontree environments, they visit more frequently, stay longer, rate the quality of the products about 30% higher, and are willing to pay about 12% more for goods.

Cooling Interiors

While retractable screens have become an effective tool in shading the interior of a building, the advantage to using interior plants for shading is the retained exposure to a natural setting. The interior climate can actually be regulated by plants.

Interior plant installations can create spaces of significant shade at all times of the day and throughout the year. Whether indoor spaces include trees of 25 feet or simply small plants near a window, the need for alternative means of shading can be eliminated while maintaining a valuable natural view. This multipurpose method of shading becomes much more cost effective than the use of engineered products.

Interior Plant Growth Requirements

The ability to be a successful indoor plant manager requires knowledge about the way interior environments affect plant growth and how cultivation differs from growing plants outdoors. The two most important factors influencing foliage plant longevity in interiorscapes are light levels and fertilizer application rates. These two factors are closely associated because light level determines the rate at which plants grow and use fertilizer.

Figure 15-4. Stores on Hibiscus Street in downtown Tarpon Springs, Florida create a macrolevel environment surrounding shops that encourages more casual behavior and enhances the shopping experience.

Instead of growing foliage plants at 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 which is 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 (Figure 15-5). 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

photo by gale allbritton

Figure 15-5. 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 on 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 skylights.

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 in Figure 15-6 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 such 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)***
Aglaonema spp.	*Aechmea fasciata*	*Alocasia* spp.
Aspidistra elatior	*Anthurium* hybrids	*Aucuba japonica*
Calathea spp.	*Araucaria heterophylla*	*Bambusa* spp.
Chamaedorea elegans	*Chamaedorea seifrizii*	*Beaucarnea recurvata*
Dracaena fragrans 'Janet Craig'	*Cissus alata* (syn. *C. rhombifolia*)	*Caryota mitis*
Dracaena fragrans 'Massangeana'	*Dieffenbachia* spp.	*Chlorophytum comosum*
Dracaena reflexa	*Dracaena fragrans* 'Warneckii'	*Crassula ovata*
Epipremnum aureum	*Dracaena marginata*	*Cryptanthus bivittatus*
Guzmania spp.	*Dypsis lutescens*	*Heliconia* spp.
Homalomena 'Emerald Gem'	*Ficus* spp.	*Kalanchoe blossfeldiana*
Peperomia spp.	*Hedera helix*	*Neoregelia carolinae*
Philodendron spp.	*Heptapleurum arboricola* (syn. *Schefflera arboricola*)	*Pandanus utilis*
Sansevieria spp.	*Howea forsteriana*	*Polyscias* spp.
Spathiphyllum spp.	*Maranta* spp.	*Radermachera sinica* 'China Doll'
Syngonium podophyllum	*Nephrolepis exaltata* hybrids	*Strelitzia nicolai*
Urceolina x grandiflora (syn. *Eucharis x grandiflora*)	*Phoenix roebelenii*	*Terminalia buceras* (syn. *Bucida buceras*)
Zamioculcas zamiifolia	*Rhapis excelsa*	*Yucca gigantea* (syn. *Y. elephantipes*)

Figure 15-6. 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 (Figure 15-7). 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 the light spectrum are the most efficient for photosynthesis. Infrared light is invisible to the human eye, but influences stem elongation and seed germination.

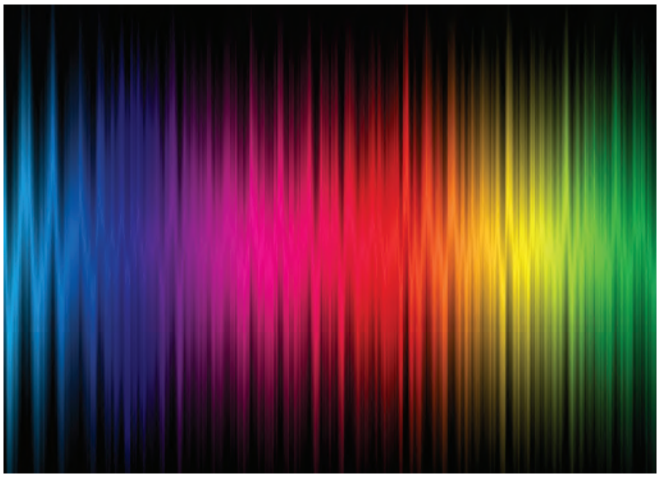


Figure 15-7. Abstract illustration of wavelengths within the visible spectrum of light.

Since all necessary light colors are included in natural sunlight, it is the 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 15-8. Comparison of the initial costs for incandescent, fluorescent and LED light bulbs.

Figure 15-9. Comparison of operating 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. Consequently, 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 two and one-half times more efficient at converting electrical energy into light energy than incandescent sources and 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 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 florescent bulbs. The price of LED systems (Figure 15-8) is currently high when compared to other sources, but the long life and energy saving qualities of these lights may outweigh the initial expense (Figure 15-9).

The different light bulb emission spectra are plotted on the same axis in the graph found in Figure 15-10. While none of the bulbs exactly reproduce natural daylight, the LED bulb is clearly the best approximation. All the emission from LED sources occurs within the visible range, making the device very efficient.

photo by daniel smith, comsol.com

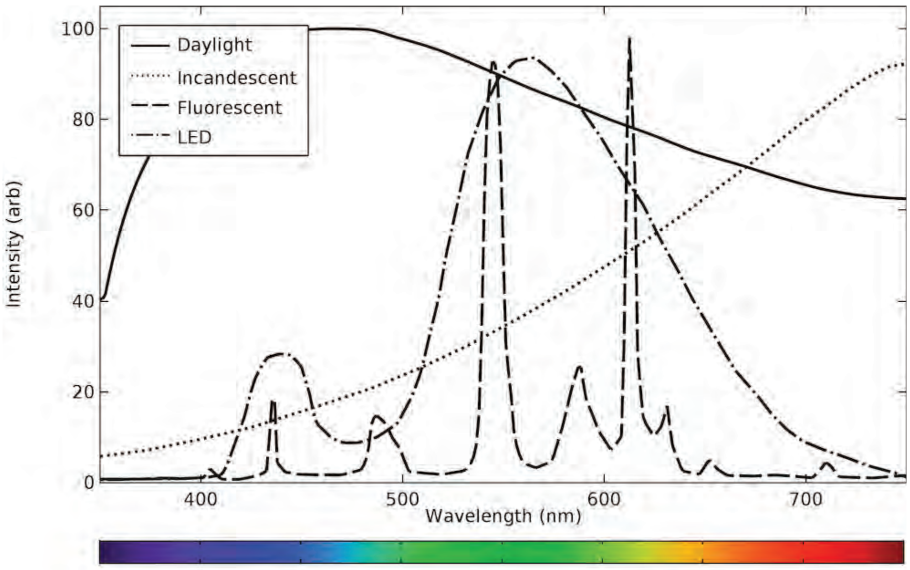


Figure 15-10. Graphic representation of the emission spectra from daylight and typical incandescent, fluorescent, and LED bulbs.

Light Duration

Light duration refers to the amount of time during a 24-hour period that plants are exposed to light. Duration is critical because a longer exposure can compensate for unsatisfactory light intensities. When intensity is inadequate, increasing light duration will help plants adjust. Conversely, when intensity is too high, a shorter exposure time may solve lighting problems. Research has shown that plants maintained indoors grew better when they received between 12 and 18 hours of light daily, while continuous 24-hour lighting was detrimental to some species. Light intensity and duration are the two primary factors affecting indoor plant survival and should be carefully determined before foliage plants are purchased and installed. Only plants able to survive in the existing light conditions should be considered suitable for that site.

Temperature

Indoor living and working environments are heated and cooled with human comfort in mind. Fortunately, the temperature range preferred by humans is remarkably similar to those of the understory, shade-loving tropical plants used in the interiorscape. Daytime temperatures of 70^0 to 80^0F and a nighttime range of 60^0 to 70^0F are usually maintained throughout the year and are satisfactory for most foliage and flowering plants. However, many flowering plants bloom longer at the lower end of these day-night temperature ranges.

One room in a building may be cooler, while another may be warmer. Variations may occur even within a single room and may change in the course of a day or during the year. Such differences are called ***microclimate variations***. A minimum/maximum thermometer will pinpoint such differences. These temperature variations should be considered when placing plants indoors.

Temperatures can fluctuate over time more than realized, especially if air conditioning and heating units are turned off at night and on weekends. Generally, temperatures lower than 50^0F and higher than 90^0F cause plant damage. Sudden temperature changes caused by drafts can be harmful to interior plants. Cold drafts occur most commonly during the winter near windows or entrances. In summer, air conditioning vents can cause a cold spot. Plants affected by cold often have leaves that turn pale green with margins curling downward.

Heat injury causes plants to wilt, with lower leaves turning yellow and developing brown edges or tips; older leaves may also fall off (Figure 15-11). If a plant is positioned near a window, it should be protected from heat and intense sunlight during the day and from cold, drafty conditions at night. Use shades and curtains or move the plant far enough away from the window to avoid temperature and light extremes. Never place plants near heat registers, fireplaces, air conditioning vents, on heat emitting devices, or in other areas where heat or cold extremes may occur. Examples

photo by roy speetiens, creative commons license

Figure 15-11. Leaf drop occurring on *Ficus elastica* (rubber tree) as a result of exposure to high indoor temperatures.

Temperature Adaptations of Select Interior Plants			
Cold Tolerant Plants (to at least 45°F)		***Heat Tolerant Plants (to at least 95°F)***	
Aglaonema spp.	aglaonema	most of the true palms	
Aucuba japonica	gold dust plant	tree ferns	
Chlorophytum comosum	spider plant	many cacti	
Cordyline fruticosa	ti plant	*Alpinias* spp.	ginger plants
Dracaena fragrans 'Warneckii'		*Beaucarnea recurvata*	ponytail palm
Ficus elastica	rubber tree	*Cordyline fruticosa*	ti plant
Hedera helix	English ivy	*Dracaena fragrans* 'Massangeana'	corn plant
Howea forsteriana	kentia palm	*Epipremnum aureum*	golden pothos
Nephrolepis exaltata hybrids	ferns	*Ficus elastica*	rubber tree
Platycerium bifurcatum	staghorn fern	*Nephrolepis* spp. and other ferns	
Phoenix roebelenii	pygmy date palm	*Phoenix roebelenii*	pygmy date palm
Plectranthus verticillatus	Swedish ivy	*Radermachera sinica*	radermachera
Rhapis excelsa	lady palm	*Schefflera* spp.	schefflera
Schefflera spp.	schefflera	*Sedum morganianum*	burro's tail
Schlumbergera spp.	holiday cactus	*Spathiphyllum* spp.	peace lily
Spathiphyllum spp.	peace lily	*Syngonium podophyllum*	nephthytis
Yucca gigantea	spineless yucca	*Yucca gigantea*	spineless yucca
Zamioculcas zamiifolia	ZZ plant	*Zamioculcas zamiifolia*	ZZ plant
Information adapted from Professional Interior Plantscaping			

Figure 15-12. Interior plants that adapt to temperature ranges outside the average indoor office or home environment.

of plants that adapt to colder or warmer temperatures are included in the table above (Figure 15-12).

Humidity

Relative humidity refers to the amount of moisture held in the air. Most tropical plants prefer a relative humidity (RH) level above 80%, but the indoor environment is often closer to 20% RH. Humidity may determine whether certain plants native to moist tropical regions will do well in the average indoor location. Fortunately, most commonly used interiorscape plants can tolerate 25% RH except for ferns and those with thin leaves. In dry air, the leaves of these plants turn yellow or show brown tips and margins. Some fail to flower while others produce flower buds that shrivel and drop suddenly from the plant. In a moderate humidity range of 20% to 40%, it is possible to grow a variety of flowering and foliage plants. However, cacti and other succulents do well in a humidity range of 5% to 15%. A ***hygrometer*** can be used to determine the relative humidity of different indoor locations throughout the year.

One of the simplest ways to increase the humidity around plants is to group them close together. Water constantly evaporates into the air from leaf pores (stoma) and from soil surfaces, creating a humid microclimate in the immediate area of plant groupings. Another technique for increasing humidity is to place watertight saucers or trays holding an inch or two of pebbles under plant containers, and add water to the saucer or tray to a point just below the surface of the pebble layer. Humidity increases around the plant as this water evaporates. Make sure the water level in the saucer never rises to the bottom of the pot. If this happens, the container soil will remain constantly wet, toxic salts will accumulate on the soil surface, and roots will be damaged.

Air conditioners tend to make indoor air drier during the summer cooling season. Cool mist vaporizers or room humidifiers (Figure 15-13) provide an effective means of adding moisture to the air. In a home environment, sensitive plants can be grown in more naturally humid rooms such as the kitchen, bathroom or laundry room.

Figure 15-13. Cool mist vaporizer used to increase humidity near plants in a single room.

Media

A typical potting medium for interior use does not contain soil (sand, silt or clay), but is composed of sterile, well drained components like peat moss, pine bark, coir, perlite or vermiculite (Figure 15-14). There are many media mixture choices available to meet specific growing requirements. In addition to good drainage, interior potting media should have a wetting agent added for easier management. A ***wetting agent*** is a chemical that allows water to be absorbed into the medium faster and more uniformly. A good growing medium should also have properly adjusted amounts of trace nutrients and other amendments to assure soil pH is in the correct range. Most foliage plants grow best when the pH of the medium is between 5.0 and 6.5; most commercially produced potting mixes are within this range.

High quality, physically stable growing media, along with proper care, provides a growth environment that can support an interior plant for five or more years. Low quality media is more costly in the long run because it increases replacement costs and the additional labor required to manage interior plants. Regardless, growing media components will decompose and shrink over time, becoming more compact and changing the air to water ratio between soil particles. Interiorscape professionals should be aware of these changes to effectively maintain the health of indoor plant roots. Plants may need to be placed in a larger pot or perhaps carefully lifted so that fresh, non-compacted media can be placed at the bottom of the pot. Never place more medium on top of the settled medium surface; this only worsens compaction and improper aeration conditions.

Interior Plant Maintenance

Since the indoor climate is characterized by low light levels compared to the outdoor climate, careful adjustments in plant management must be made. Some of these adjustments are more practical than others. If adjustments cannot be made, rotations to replace plants will be needed more often.

1) Watering should gradually be reduced because plants do not dry out as easily in low light.

photo by bob cook

Figure 15-14. Example of a porous, well drained, commercially produced interior potting media. The mixture contains peat moss, bark, perlite, vermiculite, dolomitic lime and a long-lasting wetting agent.

2) Fertilization should be reduced or possibly not provided at all, since a lower rate of photosynthesis and growth occurs indoors.
3) Room temperature should be reduced to around 60⁰ to 70⁰F if possible because low light plants prefer cooler temperatures normally found in the understory where they naturally occur outdoors. These lower temperatures also reduce the chances of spider mite infestation.
4) Humidity should be increased if possible. This not only replicates a more natural environment, but reduces the need for watering and prevents spider mites.
5) Select slow growing plants since they require less light than fast growing ones.
6) Select plants with dark green leaves. Plants with variegated leaves need higher light since they have less chlorophyll and need more light to photosynthesize. When placed in low light areas, the variegation tends to disappear.

Watering

Plants have varying water needs. Those in good light and at the proper temperature will require more water than the same plant in a lower light and cooler temperature environment. Plants that need high light typically have dense, fibrous root systems that dry out quickly and require more water. Plants that tolerate lower light have fewer, thicker roots that store water and do not need water as often.

Another factor that affects watering practices is the type and size of the container in which a plant is growing. Clay pots are porous and require more water than nonporous glazed or plastic pots. Plants in large containers of any material would generally require less frequent watering than the same size plant in a smaller pot of similar material. Very simply, there is less available water in the soil of a small container as compared to a large container with more soil.

As a result, planning a watering program for interiorscape plants involves an awareness of the overall effect associated environmental factors have on plant needs and a knowledge of the basic water requirements of different plants. A rigid schedule will cause some plants to be overwatered while others may dry out from a lack of water. Be prepared to water plants on an individual, as needed basis.

Interior watering success is basically a matter of knowing how often and how much (Figure 15-15). Problems from underwatering are somewhat more common than those from overwatering. Often, more time spent on maintenance involves tasks that improve the immediate appearance of plants, such as removing yellowed leaves, brown leaf tips, replacing plants, or other grooming and cleaning operations. Professional interiorscapers realize that time spent managing proper watering saves time on other tasks in the long run.

Although there is no foolproof method, the most accurate watering schedule relies on inspecting the individual plant's foliage for signs of wilting and then feeling the soil for moisture. Most plants start to show subtle signs of water stress when they need water, such as dull looking foliage and a slight droop of the leaves. Moist growing media is cool or damp to the touch; nonetheless, moisture content will vary from top to bottom of a container, so total moisture content should never be determined solely on the basis of the way a medium surface

photo by dramm corporation

Figure 15-15. Professional interiorscape technicians use portable equipment to make the watering task more efficient.

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, the 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 at which various plants are maintained. Typically, this causes plants at lower light levels to be damaged by excess salts accumulating in the growing medium, while plants at 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 (Figure 15-16) 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 and cause 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 15-16. 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	½ teaspoon per gallon
Growth	300 – 1,000 fc	2 – 4 times per year	¾ – 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 The Healthy Indoor Plant: A Guide to Successful Indoor Gardening			

Figure 15-17. 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 the 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 salt 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 65⁰F or night air temperatures are 70⁰F or below. Under these lower temperature conditions, fertilizer applied at maintenance levels listed in the table above (Figure 15-17) 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 (Figure 15-18) 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 solution, alcohol or other

Figure 15-18. Dusting *Ficus elastic* (rubber tree) leaves.

safe disinfectant after each use to prevent the spread of pests and disease. Retractable ostrich feather dusters tend to collect and hold dust best, while also maintaining their shape after disinfection.

A soft cloth or sponge (Figure 15-19) moistened with warm water and/or an insecticidal soap solution can be used to clean both upper and lower leaf surfaces. Wipe leaves carefully from the base to the tip with enough pressure to remove the dust, but not enough to damage the leaf. To be most effective, rinse or replace the cloths or sponges regularly. This method should not be used on plants with prominent leaf hairs. Plants that are small enough to move can be sprayed with a mild soap wash and rinsed over a sink, in a shower or outdoors in warm weather (Figure 15-20).

Figure 15-19. Cleaning dust from *Ficus elastica* (rubber tree) leaves with a soft cloth and mild insecticidal soap solution.

Figure 15-20. Rinsing dust from *Dracaena fragrans* 'Massangeana' (corn plant) leaves in a shower.

Leaf shine products can be used when cleaning plants, but they have a tendency to inhibit transpiration, attract dust and slow plant growth. These products are not necessary and often work against attempts to clean leaves and preserve plant health in the first place. Some species are even damaged by leaf shine products. For the most part, plant leaf shine materials should be avoided. Use a water and soap solution instead to maintain natural, glossy leaf cuticles.

Trimming

Leaves occasionally become unattractive from environmental stresses or health problems and must be removed. Leaves turn yellow as a result of

1) Insufficient light.
2) Natural aging processes.
3) Overwatering.
4) Insufficient nitrogen, especially seen in high light areas.
5) Insects and disease.
6) Heat or chilling injury.

Some plants, such as *Spathiphyllum* spp. and *Dracaena* spp., develop tip burn on mature foliage. This area is characterized by brown or gray leaf tips followed inwardly by an area of yellow. Tip burn may be caused by

1) Allowing the soil to become too dry.
2) Low humidity.
3) Toxic levels of fluoride from treated water sources or certain media components.
4) Chloride toxicity, particularly noted in swimming pool areas.
5) Boron toxicity, if fertilizers are applied too liberally.

Leaves that are totally dead or more than half yellow should be removed at the point of attachment. If only a small portion of a leaf photo by gale allbritton

Figure 15-21. Trimming *Spathiphyllum* leaf margins following the leaf edge as a guide to maintain natural shape.

Figure 15-22. Pollen bearing flower parts of *Spathiphyllum* will shed white pollen on the dark green leaves beneath the flower.

is discolored, use sharp scissors to trim off the discolored portion (Figure 15-21), being sure to match the normal shape of the leaf to maintain a natural appearance. Unfortunately, this practice will need to be continued because it will create a new area of leaf injury resulting in necrosis.

Flowers should be removed as soon as they are faded. *Spathiphyllum* and other flowers that shed pollen should have the anthers or pollen-bearing parts removed as soon as they

Figure 15-23. Pot bound, dry plant susceptible to other problems.

appear to keep the leaves cleaner (Figure 15-22). Trimming will also be needed on hanging plants to balance the shape of the plant and to keep vines short enough not to interfere with any work areas below. Pruning tools should always be disinfected after use.

Managing Pests

An understanding of the optimal growing conditions for the species of plants involved is required to maintain healthy interior plants. Providing proper light, temperature, humidity, soil moisture and pH conditions becomes challenging when an interior landscape can contain 20 or more species of plants in a variety of environments.

Indoor plants are susceptible to attack by different types of pests. In addition, plants are often under stress due to less than optimal growing conditions (Figure 15-23). Interior plants may also be mistreated, such as having coffee, soda or cleaning liquids poured on them. Under these stressful conditions, plants are more susceptible to pests and less capable of recovering from an attack.

When damage or poor plant health is detected, the interior technician needs to photo by david cappaert, michigan state university

Figure 15-24. A very high population of two-spotted spider mites and webbing on leaves.

photo by scot nelson, creative commons license

Figure 15-25. Mealybug infestation on *Dracaena marginata* (red edge dracaena).

determine what cultural or environmental conditions, diseases, insects, mites, or human activities are responsible. Since there is often more than one damaging influence, all conditions that may have stressed the plant should be identified.

Common pests in the interiorscape typically include spider mites, mealybugs, scale, and fungus gnats. Whiteflies and aphids are occasionally brought in on new arrivals. Sometimes, thrips are brought in on seasonal flowering plants. Yet, certain plant species are more prone to a specific pest problem. *Ficus* are susceptible to scales, *Schefflera* are susceptible to mealybugs, palms are susceptible to spider mites, ferns are prone to bacterial leaf spots, and *Dracaena* are prone to root and stem rots. Inspect the whole plant, especially the undersides of leaves, stems and twigs. If possible, carefully remove the plant from its container to examine root and soil conditions. Inspecting the root environment is often difficult, but necessary.

The most common pest in the interiorscape is the two-spotted ***spider mite*** (Figure 15-24) because hot, dry conditions are conducive to their development. These very small pests congregate in clusters on the undersides of leaves, pierce foliage and feed on the sap. Populations are usually very high before an infestation is detected. ***Mealybugs*** (Figure 15-25) are encountered far less often, are easier to spot but harder to eradicate. They often occur in hard to reach places, such as in the narrow leaf axils of *Aglaonema*. ***Scale*** (Figure 15-26) are the third most important pest in the interior landscape. Immature crawlers are very small and difficult to detect. Once scale

photo by gilles san martin, creative commons license

Figure 15-26. Scale insects on a softwood stem.

photo by katja schulz, creative commons license

Figure 15-27. A fungus gnat found on the surface of potting soil.

become obviously visible, they are mature and very difficult to eradicate. ***Fungus gnats*** (Figure 15-27) are bothersome when they fly around plants. They prefer constantly moist, highly organic soils. Control can be difficult, but not impossible. Proper water management is crucial in controlling these pests. When soil stays moist, the environment becomes very conducive for the development of fungus gnat populations. Secondly, many interior plant maintenance contracts require pots to be top dressed with bark nuggets; this material, placed on a moist soil surface, can also contribute significantly to a gnat problem.

Although ***fungal, bacterial, and viral infections*** can be common in production environments, the interior plantscape environment is generally not favorable for disease organisms when appropriate cultural and environmental conditions are provided. Keeping foliage dry and relative humidity low, both common conditions in indoor landscapes, is perhaps the best control for foliar diseases. Root rot can be a problem for indoor plants, but generally only when the roots are first damaged by overwatering (Figure 15-28) or underwatering, or high levels of soluble salts in the soil. Therefore, if a root problem occurs, evaluate watering and fertilizing practices as well as the drainage conditions of the soil and container.

Abiotic diseases generally occur because of poor maintenance practices, environmental extremes, chemical phytotoxicity or poor growing media. They are non-infectious, but weaken a plant and may allow secondary infections and/or infestations to develop. The symptoms of these problems are diverse and include leaf yellowing, necrosis, water-soaked spots, distorted growth, wilting, or foliage drop. Diagnosing an abiotic disease is difficult as many of the symptoms resemble those of infectious diseases. The most effective method of controlling or eradicating environmental disease is to change the conditions that caused the disease to develop.

Monitoring

Monitoring for plant pests or poor growing conditions should be an integral part of each site visit. While performing routine maintenance, be alert to general plant health and watch for signs or symptoms of pest infestations. Early detection allows for more efficient management of pests or alteration of environmental conditions before host plants suffer serious injury. In addition, low levels of a pest infestation are typically easier to manage and the use of less toxic management strategies will still be an option. Washing the foliage with a 2% soap solution, pruning the problem out, or correcting a poor site condition may eliminate the problem without use of a pesticide.

Sanitation practices are aimed at eliminating pests and pathogens or restricting their development. Removing fallen or damaged leaves, removing infected plants from a planting bed, examining new plants and holding them in quarantine prior to installation, plus avoidance of splashing water are just a few common sanitation practices useful for managing diseases and pests of the interior landscape. Cultural practices that reduce stress, such as modifying room temperature or changing the watering schedule, along with sanitation practices provide a basic approach that is almost always beneficial.

Figure 15-28. *Yucca elephantipes* (spineless yucca) exhibiting signs of stem (cane) and root rot from overwatering.

Interior Plant Problems

Symptoms	*Potential Causes*
brown or scorched leaf tips or edges	► poor root health from overwatering ► excessive soil dryness (especially between waterings) ► excessive fertilizer or other soluble salts in the soil ► specific nutrient toxicities (fluoride, copper or boron) ► low humidity ► pesticide or mechanical injury
leaf spots, blotches, blemishes, blister, or scabby spots	► intense light (sunburn) associated with a recent move ► excessive soil dryness coupled with high temperatures ► pesticide injury ► overwatering ► fungal or bacterial infections
yellow-green older leaves	► insufficient fertilizer, especially nitrogen ► senescence (natural aging process)
yellow-green newer leaves	► poor root health due to compacted soil or poor drainage
yellow-green foliage overall	► insufficient light
leaf drop	► soil pH imbalance ► trace element imbalance ► too much light ► insufficient fertilizer ► high temperatures, especially when associated with dryness ► scale, mealybug or mite infestation ► root rot disease
wilting or drooping foliage	► poor root health from overwatering, excessive dryness, or excessive fertilizer ► sudden change in light, temperature or relative humidity ► root rot disease ► low humidity ► inadequate light
roots brown in color, soft or rotted	► poor root health from overwatering, excessive dryness, excessive fertilizer or other soluble salts in the soil ► compacted soil, or a poorly drained container ► a toxic chemical poured into the soil ► root rot disease
yellowed leaves with tiny speckling, later bronzed and dried out; webbing occurs near growing points	► spider mite infestation
leaves or stems covered with a sticky substance; mold growing on leaves; tiny brown or white objects seen on leaves or in crotches of branches; leaf drop	► mealybug infestation ► scale infestation ► aphid infestation
leaf or growing point distorted	► mite or thrips infestation ► pesticide toxicity ► trace element imbalance ► mechanical injury
Source: The Healthy Indoor Plant, A Guide to Successful Indoor Gardening	

Figure 15-29. Symptoms of commonly occurring problems on plants used in the interiorscape.

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 a 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 found in Figure 15-29.

photo by gardening solutions, creative commons license

Figure 15-30. 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 (Figure 15-30). 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's 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's top. Fill media around the root ball and gently press it into place; add a small amount to the top of the root ball to replace the soil that was removed. Water thoroughly to settle the media (Figure 15-31).

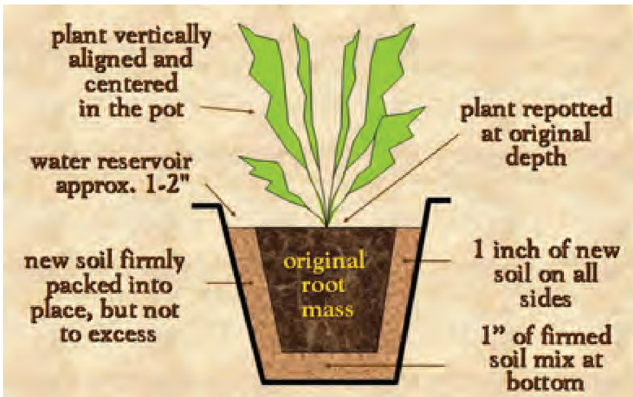


photo by university of georgia

Figure 15-31. Graphic illustration of the repotting procedure.

Rotating

Plants should be turned regularly if possible to expose all sides to light coming from one direction. Soft stemmed plants such as *Spathiphyllum* and *Aglaonema* are more likely to show a tendency to grow toward a light source (Figure 15-32). Woody plants like *Ficus* grow more gradually toward the light. Turning or rotating plants encourages a more uniform shape. The need for rotation is one of the best arguments against placing indoor plants directly in beds where they obviously cannot be moved.

Replacing

Interior plant professionals must replace plants as they mature and become ineffective, or after they serve a special effect, like seasonal interest. Flowering plants are used in interior plantscapes because of the flower color; these plants should be removed as soon as they begin to fade. Other plants, such as poinsettias and Easter lilies, are used for seasonal effects and should be removed when the season is over.

Plants should be replaced when they are no longer healthy or when they have grown too large for the space. Commonly, the same plant species is used as the replacement. However, different species can be used to create different looks or because they are better suited to the environment. Remember, interiorscapes are designed to provide visual enhancements based on size, form, character and color. Selected replacements should maintain those aesthetic qualities and not disturb the overall design intent (Figure 15-33).

Replacing plants as a regular part of maintaining the interior plantscape gives the added benefit of an attractive and effective planting. This practice will reduce maintenance problems and should lead to improved appearance, satisfied customers, and better public relations.

Summary

The use of interior plants is seen as a way of making the indoor environment more welcoming and friendly by introducing natural elements, adding color and fragrance, and giving people a sense of well-being. Planted areas can be one decorative container (Figure 5-34), a series of planters (Figure 15-35) or

photo by creative commons

Figure 15-32. *Phalaenopsis* orchid leaning toward light from the window (phototropism). The plant should be rotated to encourage uniformity as the plant grows.

Figure 15-33. When necessary, plants should be replaced with the same species or one with similar physical characteristics to maintain the original design integrity.

specially created beds. Many new building projects incorporate areas such as atriums where plants can be grown in order to enhance the more open environment and the building architecture (Figure 15-36).

Success in maintaining indoor plants involves first and foremost an awareness of the environmental needs required to remain healthy. Indoor growing sites can be created or improved with light, air movement, temperature and humidity control, etc. Plant needs, such as quality soil, water and nutrients must be provided. Pests must be managed as problems arise and plants must be routinely groomed, repotted or replaced to remain attractive and function optimally.

Figure 15-34. A single decorative plant in a residential setting.

Figure 15-35. A grouping of decorative plants in an office setting.

Figure 15-36. Interior plants used in an airport atrium to help define functional zones within the space.

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