WEIRD SCIENCE AND OTHER FOKELORE: LIGHTING, IT'S ALL ABOUT FOOTCANDLES!

Part 1 : Whether we call them Bonsai or Houseplants the use of containerized plants has been thriving for thousands of years. Potted foliage plants (*houseplants*) used as interior plantings has become a huge industry and *tropical* foliage plants have proven to be the most successful. The good news is that continual research (at many large universities), to support the industry, has led to a body of knowledge that can be applied to any *interior plantscaping* or "bringing plants indoors". (This would also include buying a plant that has been grown in a greenhouse.)

To understand the uniqueness of the latter, try to imagine how difficult it would be for us to suddenly have to live outside permanently. As drastic as that might seem it illustrates what we do to our plants, even if it is for a short time. In fact, the latter compounds when you consider those plants that are moved from outside to inside and back again as they must adapt twice a year. During their adaptation they must adjust to multiple changes, some more critical than others. The latter is true because as Bonsai they are already successfully adapted (hopefully) to "container growing". Changes to consider:

1. A drastic reduction in the quality and intensity of light
2. A reduction of nutrient requirements which creates a potential for "soluble salt" buildup (fertilizers).
3. A lack of air movement and rainfall (or overhead watering) allowing dust to accumulate on the leaves reducing photosynthesis.
4. Potential damage of air conditioners, central heating, cleaning chemicals, smoke, and other irritants.

AND (though not a "change", and essentially common to all Bonsai) those important to the whole equation:

5. Reduction and constriction of the root system
6. Inadequate or incorrect watering practices...under the above conditions plants may survive but seldom "grow".

Lighting

Common sense tells us that plants need light to survive but plants are brought inside and we watch as leaves drop, general health deteriorates and as we face a very sad looking Bonsai we must asked:

How much and what kind of light do our plants need and what sources of light should be used?

Light intensity

To understand light intensity, we must know how light is measured. In the US *footcandle* is used as the unit of measurement. (*lux* is the international unit) One *footcandle* (fc) is equal to the amount of light produced by a standard candle at a distance of 1 foot. Light meters are manufactured that can read up to 10,000 fc which is the illumination on a

typical clear, sunny, summer day. The challenge of bringing plants from this outdoor intensity can be illustrated with several examples. The average living room has a light intensity of 10-1,000 fc by day and as little as 5 fc by night. A good reading light—20-30 fc, desk lamp 40-50 fc—you get the idea. The key to a plant's success indoors are *acclimating* and *maintenance* of minimum light intensity. Note that survival and health are the maintenance objectives, **not** growth. *Acclimatization* is the adjustment to interior conditions (or to outdoor conditions). It involves both morphological and physiological changes in the plant that take time to occur. The *minimum light intensity* is the level of illumination necessary to allow the acclimated plant to produce new leaves to replace old leaves. The time required will depend on the plant species. Note that *acclimatization* also involves the plant's adjustment to reduced water in the soil and in the surrounding air.

Part 2

Light-intensity Acclimatization

Light intensity is reduced gradually over a period of several weeks (or months). Each change reduces the light by 50% until the desired intensity (usually 100 to 200 f.c.) is reached. The acclimatization process can not be rushed without a severe reaction by the plant; that is defoliation (or even death). Once indoors, the reduced light provided to the plants must be of sufficient duration to permit the plants' slowed photosynthesis to manufacture adequate food. Most plants require at least twelve hours of continuous light every day, including weekends. A reliable timed-lighting system is essential.

Nutrient Acclimatization

The high fertility level of soil necessary for maximum plant growth is unnecessary and even life-threatening to the indoor plants as use of soil nutrients is greatly diminished. Thorough soil leaching at the beginning of the acclimatization period and occasionally afterwards will prevent a buildup of soluble salts.

Moisture Acclimatization

The frequency of watering is reduced during acclimatization to prepare plants for their more stressful interior locale. If possible humidity levels are also gradually reduced to ready plants for the drier air of home and building interiors.

Temperature Acclimatization

Growing temperatures are usually higher to promote more rapid plant growth. During acclimatization, temperatures are gradually reduced to the range common to most interior areas, 65°F to 75°F.

Light Quality

Once acclimatized to the reduced light intensity of the interior, the plantscape may still prove unsatisfactory if the light quality is incorrect. *Light quality* is color of light emitted by a particular source. The sun emits all colors of light, some of which the human eye can perceive and others that are imperceptible to humans but beneficial to plants. The green-yellow light most comfortable for humans is of little use in photosynthesis by

plants. They depend on light from the blue and red bands of the visible light spectrum. Visible light is only a narrow region of the radiant light spectrum (Fig. 1). The unit of measurement for light wavelengths is the *nanometer*.

As long as both humans and plants can derive their light energy from the sun, the needs of each are satisfied. Indoors, however, where light energy is usually created by artificial means, the quality of the light can vary considerably. Light preferred for an interior plant should maintain its health. To choose you need to the types of lamps available and the quality of light that they provide. Categories and examples of lamps that have some use in interior plant illumination (and some f.c. values) are shown in Table 1. Table 2 compares the lamps in all areas important to interior plant survival.

Selection of the proper lamp for the illumination of an interior planting will depend upon the answers to several questions:

- How extensive is the area?
- Are the plants to be encouraged to grow or merely to be maintained at their current size?
- Will the plants receive any sunlight? If so, how much and for how long?
- How far will the artificial light source be from the plants?
- What types of lamps are being used for general lighting of the area and what is the intensity of surface illumination provided?

For example, consider a possible area for plant in a typical house. The plants could be permanently located or in movable planters. Ceilings are an average of 8 or 10 feet high. Side windows or a skylight may admit some natural light. In such a setting, cool, white fluorescent lighting would be ideal for both general lighting and the growth of the plants since they would receive the right quality of light for photosynthesis. If additional lighting is needed, incandescent lights installed beneath the plants and directed upward (called *uplights*) can be used. Some benefit will accrue to the plants from the addition of lighting at the base. However, if it seems that supplemental lighting is needed for photosynthesis, it is more efficient to use additional overhead lights because chloroplasts are concentrated in the upper leaf surface.

Natural Light

Most important of all light sources for interior plantscapes is natural sunlight when it can be planned for (by location) and depended upon. Each footcandle of illumination that nature provides is one less that has to be provided by artificial lighting. However, knowledge of how to maximize the benefits of natural light is vital; otherwise, more heat energy is lost through inefficient windows than is gained in light energy.

Natural light is most beneficial when high levels of illumination can be expected throughout most of the year. Traditionally sunny areas like the Southeast can make better use of natural light year-round than areas like the Northeast or Midwest where cloudy skies can be the reality through much of the winter season.

Sunlight entering from overhead is of greater use in the illumination of interior plantings than light entering form the side, although both are helpful. In either situation the natural light will not be as intense as outside light. It will be significantly reduced by the glass glazing through which it passes and the distance it travels between the point of entry and the leaf surface. Little usable light passes more than 15 feet beyond glass and since usable light enters at a 45 degree angle plants must be placed within the narrow beam if they are to benefit. However, they can not be too close to the glass as excess heat will accelerate plant growth, dry out a plant too quickly and the foliage may burn. In this situation an alternative choice of natural side light can be of great value. With natural light and interior plantings, the wide floodlight effect is most desirable.

Selecting the Correct Lighting

In summary, no single recipe for correct lighting can be given. There will be varied settings, needs, and objectives to accommodate including the quality of illumination. When plants are considered, a lamp should be selected that provides the typical yellow-green visible light, while still providing sufficient blue and red light to allow photosynthesis to exceed respiration in the plants. The cool white fluorescent lamp is ideal for such a situation provided that the ceiling is not too high and that growth of the plants is not an objective. If growth is desired, additional incandescent lighting can be focused directly on the plants or the distance from light to plant is reduced. The use of more expensive growth lamps is unnecessary since they have not been proven superior to the ordinary cool white fluorescent in maintaining plant health. Any natural light that can be used advantageously will reduce the cost of lighting the interior planting.

As for light intensity, not all plants have been carefully studied to determine the minimum at which they will survive and maintain a “good” appearance. Lighting minimums in footcandles would be ideal, not in general terms as high, medium and low. When plants are brought indoors without knowledge of their lighting requirements, the situation is risky at best, and the plants must be watched carefully to determine if additional lighting is needed. To assure the lighting is of the right intensity and duration, a simple timing device may be necessary. The lights must shine on the leaves for enough time each day (twelve hours minimum) to allow adequate photosynthesis to occur. Should the hours of lighting have to be reduced for some reason, the intensity of the lighting must be increased to compensate. It does not seem to matter whether foliage plants receive their needed lighting over a short or long period as long as the cumulative photosynthetic activity balances and slightly exceeds respiration. With flowering plants, day length often plays a critical role in determining if and when the blossoms will appear (gradual decrease of increase will trigger the proper hormones). If your plants produce foliage only, varied day length is of limited importance.

FIGURE 8-1.
Electromagnetic spectrum and spectral distribution of visible light (From J. Boodley, *The Commercial Greenhouse,* © 1981 by Delmar Publishers Inc.)

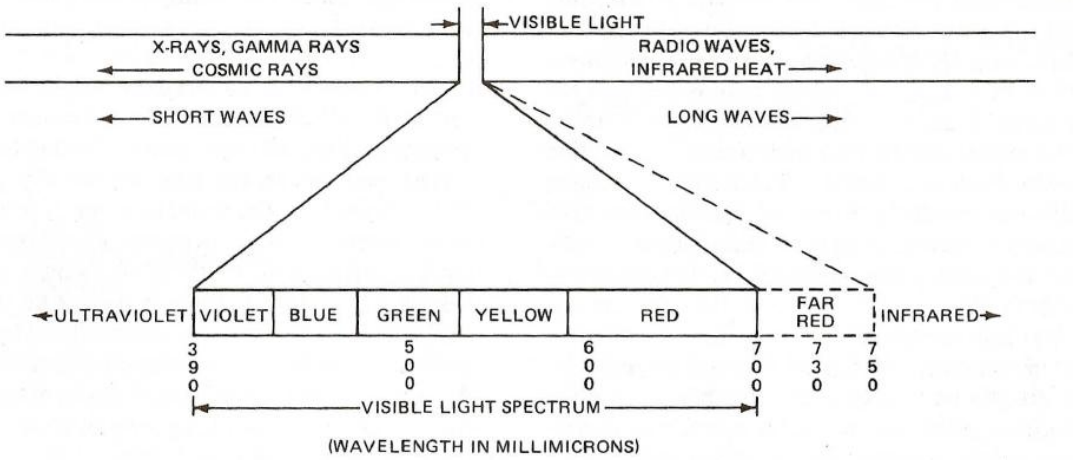


Table 1

Lamps for Interior Plant Illumination
1. **Tungsten filament incandescent lamps**
• Standard
• Reflector (spot or flood lights)
• Incandescent Plant lamps (not proven to be any better than standard)
2. **Fluorescent Lamps**
• Cool white
• Warm white
• Plant Lamps
• Wide spectrum plant lamps

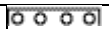
Light output (in foot-candles) measured at various distances below **fluorescent lamps**. All lamps are standard 40-watt tubes.			
Distance	**Type of fixture**		
			
0.5 foot	500	700	900
1 foot	260 (200)*	400 (260)*	600
2 feet	110 (100)*	180 (150)*	330
3 feet	60 (60)*	100 (90)*	
4 feet	40	60	100
Output in parentheses is measured 1 foot on either side of a line directly below the lamps.			

Table 2: A Comparison of Artificial Lighting Sources of Interior Plantscapes

Lamp Type	How light is produced	Quality of light produced	Percent of visible light radiation	Initial / operating cost	Life of lamp Hrs	Placement Ht above plants	Plant responses	Major advantages	Major disadvantages
Incandescent (all types)	Current flows through tungsten filament	High in red light; low in blue	7-11	Low/high	750-2000	At least 3ft to avoid foliage burn	Plants become long and spindly with pale foliage. Flowering is promoted and senescence is accelerated	Compact source of light and simple installation	Energy inefficient; heat produced, light does not distribute evenly, frequent replacement is needed
Cool white fluorescent	Radiation from mercury arc excites phosphor coating	High is blue and yellow-green; low in red	22	Moderate/ moderate	Up to 20,000	10ft or less	Plants stay short and compact. Side shoots develop. Flowering extends over a longer period		Light does not focus well, they are difficult when line voltage drops or humidity is high; installation is expensive; special fixtures are needed
Warm white fluorescent	...mercury arc...	Low in blue and green light; more yellow and red	22	Moderate/ moderate	Up to 20,000	10ft or less	Same as CW		Same as CW
Fluorescent plant growth lamps	Same as other fluorescents; special phosphors transmit most light energy in blue and red light regions of the spectrum	High in red and blue; low in yellow-green	22	Moderate/ moderate	Up to 20,000	10ft or less	Rich green foliage color. Large leaf size. Side shoots develop. Plants stay short. Flowering is delayed		Same as CW; greater expense with little increase in benefit to plants
Wide spectrum plant growth	Same...special phosphors...	Less blue and red than standard plant growth lamps; more far-red and yellow-green	22	Moderate/ moderate	Up to 20,000	10ft or less	Stems elongate. Side shoots are suppressed. Flowering is promoted; plants age rapidly		Same as CW; growth may not be desired