Lighting For Indoor Bonsai

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Introduction

Bruce Baker suggested that fine bonsai is 55% health, 20% growth, 15% display, and only 10% styling. Good health of a tree is essential. All progress is dependent on good health. Although horticulture was not the scope of his talk, Bruce reminded us that the following must be considered for good plant health: proper light, water, good media (good water retention and good porosity), regular and complete fertilizing, and good temperatures. These all add up to creating fine bonsai. If you are uncomfortable with these aspects, take the time to learn about them.

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This discussion will emphasize proper light and touch on other environmental and horticultural principles as well. Four major plant functions are important determinants of plant growth and development:

1. Photosynthesis: Produces food using solar energy. Uses carbon dioxide and water as raw materials. Occurs only in cells containing chloroplasts. Releases oxygen. Occurs only in light.

2. Respiration: Oxidizes food, releasing energy within the plant. Occurs in all living cells. Uses Oxygen. Produces water and carbon dioxide. Occurs in the dark and in the light.

The term respiration as used here should not be confused with what we usually refer to as respiration with animals when we talk about breathing. We inhale oxygen that is transported to cells where the process of oxidation occurs. We exhale carbon dioxide, which is a by-product of oxidation.

Roots live in the dark, and they need to absorb and use oxygen. Oxygen transfuses through air 10,000 times faster than it does through water. A soil mix contains soil particles, water, and air. Too much water means too little air. Insufficient air in the soil retards plant growth. The only common agreement about bonsai soil is that it must be well drained (well aerated). Animals and plants will drown if sufficient oxygen is not available because of excess water.

3. Assimilation: Builds more complex compounds. Assimilation is costly in terms of energy consumption, so, if you see a bud or a branch starting to grow where you don't need or want it to grow, cut it off as soon as you notice it before it consumes more of the trees stored energy. This technique is referred to as energy management by some authors.

4. Transpiration: The process by which a plant loses water, primarily through pores (stomata) in the foliage. 90% of the water that enters the plant escapes in transpiration. The other 10% is used in chemical reactions and in plant tissues.

Since the primary topic of this discussion is light, our emphasis is on photosynthesis.

A leaf or a needle is, among other things, a solar panel. The active component in this solar panel is chlorophyll. Energy released from chlorophyll that is "excited" by sunlight is captured in the production of carbohydrate, and oxygen is released. This carbohydrate is analogous to a pile of wood that can burned (respiration) or used for construction (assimilation).

On earth almost all energy ultimately comes from or came from sunlight. Almost all life depends on photosynthesis that converts solar energy into food. Without chlorophyll we would all die. The plants don't need us. We need the plants, because we can't convert solar energy into food. We do respiration (oxidation), and assimilation but not photosynthesis.

Fossil fuel was once vegetation. It has been changed into its present form by millions of years of geologic process, and the carbon dioxide that was converted to carbohydrate millions of years ago by photosynthesis is now being released as we burn (oxidize) the fuel.

Roy G. Biv is a handy mnemonic to help remember the color of the visible spectrum or electromagnetic radiation.

Visible Light Spectrum

Infra Red	Red	Orange	Yellow	Green	Blue	Indigo	Violet	Ultra Violet

Warm, Low Energy — Cool, High Energy

Longer Wave Length — Shorter Wave Length

650 nanometers (Red) to 455 nanometers (Violet)

Light striking a particle or surface is either reflected or absorbed. Chlorophyll absorbs light from both ends of the visible spectrum but not from the middle (green). It <u>reflects</u> the green part of the spectrum. Seeing a green what the non-colorblind human brain perceives is reflected green light waves. It takes chlorophyll, a specific wavelength of light, and a visual center in the brain to "realize" green. So where does the "green" exist?

Chlorophyll cannot use green light. Plants do not need to be exposed to the warm side of the spectrum for vegetative growth (roots, shoots, and leaves). The warm side of the spectrum may be necessary for <u>maximum</u> fruiting and flowering, which is rarely a concern for the bonsai grower. Some fruit may be desirable, but too many flowers or too much fruit will weaken a miniaturized tree confined to a bonsai container. Thus, it is possible to grow very healthy green plants that will produce some flowers and fruit with just the cool end of the spectrum (cool white fluorescent light).

Light from Electric Power

Definitions:

The basic unit of electric power is the watt

A kilowatt represents 1000 watts

A kilowatt-hour represents 1 kilowatt used for one hour. This is the standard unit for calculating electric power cost. In Michigan the utililty charges about $0.10 per kilowatt- hour.

Light intensity generated at its source is measured in lumens.

Light falling on a surface is measured in foot-candles.

How efficiently a light source (bulb) converts electric power to light be expressed as lumens per watt. The more lumens produced per watt the more efficiently a bulb coverts electric power to light.

Lumens per watt for various light sources

100-watt incandescent - standard tungsten	17.5
Tungsten halogen	22
40 watt fluorescent	22.3
1000 watt metal halide	100
1000 watt high pressure (HP) sodium	140

Lumens per watt information is usually clearly printed on the package of most commercially available light bulbs. Notice that the standard tungsten (incandescent) bulb is the most inefficient source of artificial light available.

The lumens emitted at a light source will be distributed over a progressively larger surface as the light source is moved further from the surface. The amount of light illuminating the entire surface will not change, but the intensity of light at a given area such as a square in will diminish. It will diminish in proportion to the <u>square</u> of the distance from the light source to the lighted surface. So if surface B is twice as far from the light source as surface A the illumination per unit of area of surface B (measured in foot candles) will be 1/4th of the illumination of surface A inverse square rule.

An artificial lighting system places the light source within 1 inch to several feet from the top of the tree; so the foliage on the lower branches receives (reflects and absorbs) much less light than the foliage at the top of the tree. The further the light source is from the top of the tree the lower the impact of the inverse square rule, but the whole tree is exposed less overall light.

The sun is millions of miles away so the impact of the inverse square rule is infinitesimal. Metal halide lights are usually placed at least one foot above the top of the plant so the inverse square rule effect applies. Cool white fluorescent tubes are placed one or two inches from the top of the plants so the effect of the inverse square rule is considerable. Thus the height limit for small plants, including the pot, under cool white fluorescent lights is 8 inches assuming that only top lighting is used.

Jack Wikle positions fluorescent tubes about 9 inches above his bench surface and about 1 inch from the top of his tree. It follows that the tree-pot height limit with Jack's system is about 8 inches. Since cool white fluorescent lights emit mainly the blue end of the visible spectrum, the top of a plant will not burn if placed very close to the bulb.

Metal halide lights emit a full spectrum of light. The red end of the visible spectrum is warm, and the light emitted at a metal halide source creates so much heat that the plants must be placed at least 6 inches and usually a foot or more from the bulb. In fact, so much heat is generated that a ventilation system may be necessary depending on the total wattage of the metal halide lights and the size of the room.

Light, oxygen, water, temperature level, soil aeration, and nutrients need to be present within optimum ranges for maximum health to be realized. Why waste electricity on a waterlogged, under fertilized plant? Fortunately all living things are adaptable so a range rather than an exact number is sufficient.

The indoor gardener has some advantages over the outdoor gardener. If she is willing to incur the necessary expense, she can achieve a much higher level of control of critical factors such as heat, light, moisture, carbon dioxide level, air movement, and pest exposure (including human thieves) than the outdoor grower can hope to achieve.

However, the most effective HID lights produce only half the light intensity of the sun on a cloudless day, so the indoor grower must deal with limited light intensity. During S. E. Michigan winters days are short and usually cloudy, so the indoor gardener may achieve more light intensity with artificial lights than is available in a greenhouse.

The brightest source of indoor light is High Intensity Discharge (HID) lighting, either high pressure (HP) sodium or metal halide light bulbs. Metal halide lighting most closely simulates sunlight. HP sodium lighting has an unpleasant yellow color and is best for supplementing sunlight in a greenhouse.

How much light is enough? The total light to which a plant is exposed is a function of light intensity times light duration. There are several ways to measure light. Let us use foot-candles. The question then becomes how many foot-candles for how many hours?

The most efficient use of supplemental artificial light is to turn it on when the sun goes down and thereby increases the duration of light (photoperiod) and to stop using the supplemental light when the sunlight reaches the intensity of the HID light.

Sunlight is free, and artificial light is expensive. How expensive is it? In 2004, electric power cost about $0.10 per kilowatt-hour. When it went from 9 cents to 10 cents per kilowatt-hour a spokesman from DTE claimed that the increase was only a penny per kilowatt-hour. He neglected to mention that a penny was a 10% increase!

OK, I'm excited! I want to get into indoor bonsai growing. How much is it going to cost me?

80-watt shop light system

Shop light with 2 cool white fluorescent tubes	$20
Annual tube replacement cost *	$5
Monthly operation cost @ 16 hrs/day	$3.84

400-watt metal halide system

Fixture, ballast, and 1 bulb	$210 to $250
Bulb replacement about every 6500 hours*	$50
Monthly operating cost at 16 hr/day	$19.20

1000-watt metal halide system

Fixture, ballast, and one bulb	$280-$250
Bulb replacement about every 6500 hrs*	$80
Monthly operation costs @ 16 hrs/day	$48

**Standard tungsten lights burn out suddenly. Fluorescent and metal halide lights will* *loose significant lumen output after a certain number of hours and the lumens /watt ratio will be reduced accordingly. They must be changed at regular intervals. Don't wait for them to completely fail, or you will waste expensive electricity.*

Watts	Kilowatts (Watts/1000)	Hrs/Day	Cost/HR @ $0.1/KWR	Cost/ Day	Cost/Month
80	0.08	16	$0.01	$0.13	$3.84
400	0.4	16	$0.04	$0.64	$19.20
1000	1	16	$0.10	$1.60	$48.00

Two 40-watt fluorescent bulbs 9 inches above bench surface will effectively illuminate an area of 4 ft. by 1.75 feet or 7 square feet. So it costs $3.84 to light 7 square feet for one month or $0.55/sq.ft. /month.

A 1000-watt metal halide light will effectively light 100 square feet, which would cost $48/100 square feet or $0.48/square foot.

The above cost estimates will vary with hours of operation, the use of a light-moving device, and the optimum use of reflection. Remember, light intensity diminishes according to the inverse square rule. If its reflected back to the foliage significant increases in efficiency can be achieved.

Reflector Materials

Material	% Light Reflected
Reflective Mylar	90-95
Flat White Paint	85-93

Semi-gloss	75-80
Flat yellow	70-80
Aluminum foil	70-75
Black	Less than 10

A 4 by 25 foot sheet of 1 mil Mylar costs about $25. A small amount of flat white paint is nearly as effective. The gloss on semi-gloss paint absorbs some light. A surface painted with flat white paint is rougher than a glossy surface, so there is more surface area to reflect the light.

Plants can adapt to different intensities of light within certain limits. The limits are different for each species. Many bonsai enthusiasts will put their trees in the shade for several days before a show. The trees adapt by producing more chlorophyll to compensate for the lower light level, so the amount of photosynthesis occurring will tend to stabilize. When the trees arrive at the show they look healthier because they are greener.

Some times when these trees go back into full sunlight without a gradual period of adjustment the leaves will "burn" do to the intense photochemical reaction of the direct sun with the elevated levels of chlorophyll.

The bonsai enthusiast is well advised to select plants that are well adapted to his indoor environment. He can manipulate the environment to suit his plants, or he can select plants to suit his environment. Little progress will be made struggling to keep unhealthy, mal-adapted plants alive in an unsuitable environment.

There are many lighting systems available that are not discussed in this article such a small metal halide systems and high intensity fluorescent systems. Once the reader understands the basic principles of indoor lighting he can design his own system and calculate the light intensity, set up costs, and operating costs of his system.

Experiment. The successful system with appropriate plant materials will reward your efforts. If your plants are not healthy, change your system or try different plants.

Printed References

Meislik, Jerry FICUS The Exotic Bonsai: All you need to know about ficus is compiled in one source. Also discusses indoor growing and lighting.

Van Patten, George F., New Revised Gardening Indoors   Easy, complete "how to" guide on high-tech indoor gardening.

Online Resources

http://www.bonsaihunk.us Meislik's web site contains Jack Wikle's latest revision of his article explaining his technique for growing bonsai under cool white fluorescent light

http://www.bonsai-bsf.com

http://www.fukubonsai.com

http://www.jimsmithbonsai.com

http://en.wikipedia.org/wiki/Fig

Addendum

I used New Revised Gardening Indoors by George F. Van Patten as my primary source. One of my tables lists lumen per watt ratings for various light sources. Readers should be cautioned to read the label information since values may vary. A rule of thumb is 10 watts per foot for cool white fluorescent tubes, but I have recently seen some 4 foot tubes rated as 60 watts.

Cyril Grumm's fluorescent light placed on homemade wooden stand.