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Gardening: Lighting Terminology & Lighting System Comparisons

Lumen: This is the basic unit of light. If you could grab a bunch of light in your arms, the term lumen would describe the amount of light that you have. Since this is the description of the TOTAL amount of light, it would go to follow that if you stuffed that light (the ball that you had in your arms) into a jar, the amount of lumens you have is still the same. Conversely, if you let the ball of light expand to fill the room the amount of lumens is also the same.

Foot Candle: This is the basic unit of light intensity or how much light you shine on a given area. The foot candle is based on how many lumens of light you shine on a given area (measured in square feet). An example would be: If you shine one lumen of light on one square foot - you get one foot candle. If you shine 10 lumens on one square foot - you get 10 foot candles. Light intensity is what really counts for plant growth. This is the term that you need to understand, for we will be talking about it the most.

Watt: The watt is a unit of energy that is commonly applied to electricity. We will be using this term in relation to artificial lighting.

Lumens per Watt: This is relation to artificial lighting. Lumens-per-watt refers to how many lumens of light that a bulb generates per watt of electrical usage. The higher the ratio, the more efficient the lighting system will be.

Reference Points

Outside Daylight: This is the biggy! Direct outside daylight in the summer time is somewhere in the neighborhood of 10,000 foot candles. This is equal to 10,000 lumens per square foot. If you already know a little bit about lighting, you will find this really amazing. If not, as our discussion continues this will eventually hit you as amazing.

Overcast Daylight: 1,000 foot candles.

Open Shade: While standing under a large tall tree, you experience the amount of light referred to as open shade. The light intensity you experience here is somewhere in the neighborhood of 300 foot candles.

Deep Shade: 50 to 100 foot candles.

Average Lit Room: 5 to 10 foot candles.

Full Moonlight: .02 foot candles.

Starlight: .00011 foot candles

Now is this amazing or what? The human eye is extremely sensitive, it can see from daylight all the way down to starlight (one of my hobbies is astronomy and I have found that after your eye dark adapts you can see quite well under the starlight). This is a ratio of 90 million to 1! Even more amazing is the fact that the eye can make the bulk of this adjustment in a fraction of a second. The rest happens in about 20 minutes.

Having brought this to light, you can understand how it is easy to come to the conclusion that an unknowingly unsuitable light source would actually seem bright enough to grow plants under by looking at it.

Lighting Systems

Now we will review the major lighting systems, their efficiency, and examine how they perform in a horticultural situation. If, per chance this discussion gets too technical or boring you can skip to the end of this segment and look at the overall comparison chart to get a general idea of how different lighting systems perform.

Basis for Calculations: In all of the following examples we are going to assume that the efficiency of the lighting system is 75%. In other words, only 75% of the light created by the bulb is reflected onto our example garden. Furthermore, we are going to **greatly simplify** things by assuming that all of the light aimed at our target area actually hits the area - there is no "spillage" so to speak. In practice results will be much different - typically much lower than the stated figures. The idea of this presentation is to communicate the practicality of different lighting systems by placing them on common ground (which really doesn't exist) and comparing them to one another.

Incandescent: Incandescent lighting is your common everyday household light bulb. Their efficiency is in the range of 4 lumens per watt. This means that a 100 watt bulb will generate 400 lumens - TOTAL. (Here's the big leap) Now, if we COULD reflect all of that 400 lumens onto 1 square foot we would get a light intensity of 400 foot candles. It is really not practical that we could design any reflector system that is 100% efficient, so for the purposes of our discussions we will assume 75% reflectance for all of our lighting systems. If we account for the loss in reflectance, we now get 300 foot candles from an incandescent bulb focused on one square foot.

Lets step back here and do a comparison.... 300 F.C. Compared to 10,000? Wow! we aren't even close to daylight.

If we used one 100 watt bulb over a 4 foot by 4 foot garden the light intensity would be 18.75 F.C., Which is totally useless. If we wanted to shoot for 500 F.C. for growing low light plants, we would need 26 - 100 watt bulbs. If we wanted to shoot for 1000 F.C. we would need 53 - 100 watt bulbs over our garden. Aside from the electrical nightmare, we have succeeded in creating an easy-bake-oven instead of an indoor garden. I hope that you see that incandescent light bulbs are truly impractical for horticultural purposes.

Quartz Halogen: Halogens do a lot better at and efficiency of about 20 lumens per watt. Halogens are available in 1000 watt bulbs and since we are trying for as much light as possible, we'll use this for our example. A 1000 watt bulb producing 20 lumens per watt give us 20,000 lumens of total light energy. Our hypothetical light fixture can only reflect 75% of this, so we now have only 15,000 lumens to work with. Our sample garden, 4 foot by 4 foot, has 16 square feet. When we shine our 15,000 lumens onto 16 square feet of growing area we get a light intensity of 937 foot candles. No we're getting into a useable range but, there is one major drawback to halogens.....HEAT. Halogens produce a disproportionate amount of heat in comparison to their light output. Let's look for something better.

Fluorescent: Since we are trying to be educated gardeners, we will have sought out the extra high output tubes for our garden. These Fluorescent tube generate 2750 lumens per 40 watt tube. That's 68 lumens per watt - now we are getting somewhere. Let's use enough fixtures to cover our 4x4 garden. The fixtures are 4 feet long by six inches wide. This allows us to cram 8 fixtures over our garden - using a total of 640 watts. Each fixture hold 2 tubes, so we have a total of 16 tubes generating 2750 lumens each - that's a total of 44,000 lumens. Subtracting for the loss due to reflectance, we now have 33,000 lumens to cover our garden with. 33,000 divided by 16 square feet equals 2062 foot candles of light intensity, **ASSUMING** the lights are right on top of the plants. When you raise the lights to accommodate for the plants the light intensity drops rapidly. When you double the distance, you cut the light intensity by four times - OUCH. Using an array of 16 - 40 watt tubes you can expect to achieve about 500 foot candles at a distance of 12 inches. With this setup we can grow low to medium light plants without burning them.

Metal Halide: This is what we have been looking for. Metal halide lights have an efficiency range of 80 - 120 lumens per watt. This let's us use a lower input wattage, generates more light and less heat than all of the previous systems. The following table shows the different wattage bulbs, their efficiency, total light output, and the light intensity over a 4 foot x 4 foot garden.

Metal Halide Lighting Comparison			
Wattage	**Lumens / Watt**	**Total Lumens**	**Light Intensity (in foot candles)**
175	80	14,000	650
250	82	20,500	950
400	100	40,000	1875
1000	120	120,000	5600

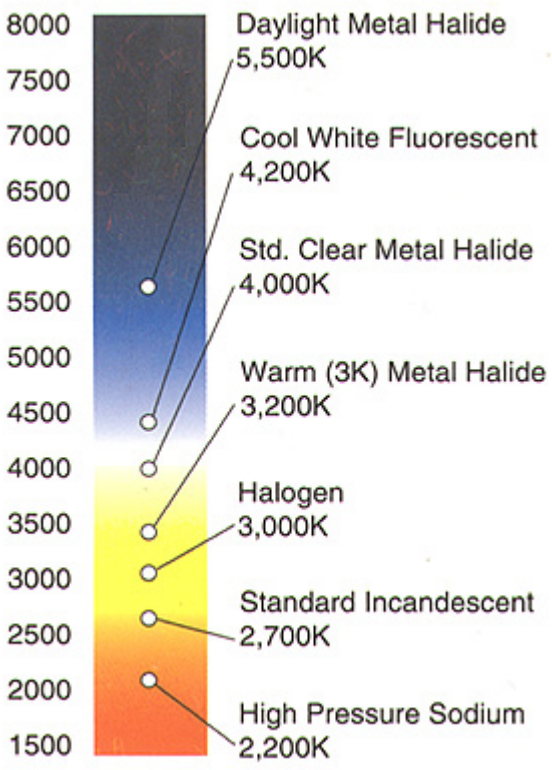
Many people choke over the initial cost of a High Intensity Discharge fixture, but in the long run they are much cheaper. For the same amount of light output M.H. uses 2-20 times less power than other light sources.

Sodium Vapor: The king of efficiency! Sodium vapor lights output from 90-150 lumens per watt. Sodium bulbs put out more light than metal halides but the spectrum is severely shifted towards the red end of the spectrum. The effects of the reddish light are supposed to produce more flowering and fruiting than more balanced lights.

Sodium Vapor Lighting Comparison			
Wattage	**Lumens / Watt**	**Total Lumens**	**Light Intensity (in foot candles)**
150	106	16,000	750
250	110	27,500	1718
400	100	50,000	1875
600	150	90,000	4218
1000	140	140,000	8750

As you can see by the table, sodium vapor wins the light intensity contest hands down.

Spectrum



The diagram above shows the full range of light and where each type of lighting system falls within that range. Artificial lights produce just a slice of the full range. This leads to much discussion and experimentation to determine which, or which combination of lighting is best for a particular crop.

Lets establish a reference point to work from, examine several types of lighting and put this information to practical use.

Reference point: For most of the daylight hours, the outside daylight peak is centered on 5500 degrees Kelvin (refer to the above chart).

Metal Halide: These lights emit a light on the bluish side of the spectrum. They are considered a grow light and it is considered that they produce a more stalky vegetative type of growth in plants. These lights are commonly used throughout all phases of plant growth and produce excellent results.

Agro Sun Halide: Agro Sun is a hybrid halide bulb that generates extra red light for flower and fruit production. This is considered to be the best choice for artificial lighting of plants.

Sodium Vapor: Sodium vapor lighting is way down in the red. There is some indication as well as a lot of marketing hype that the spectrum produced by these lights promote flowering. Personally, I'd like to see a scientific study to verify this.

The bottom line on spectrum: Spectrum is secondary to the over all intensity. Remember, in any artificial lighting situation, we are able to provide only a fraction of natural lighting. Therefore, it is more important to provide intensity than any other lighting factor. For example if you have to choose between a 70 watt sodium vapor and a 400 watt metal halide the only choice is the 400 watt system. The over all performance will be much greater, even if you favor a certain spectrum.