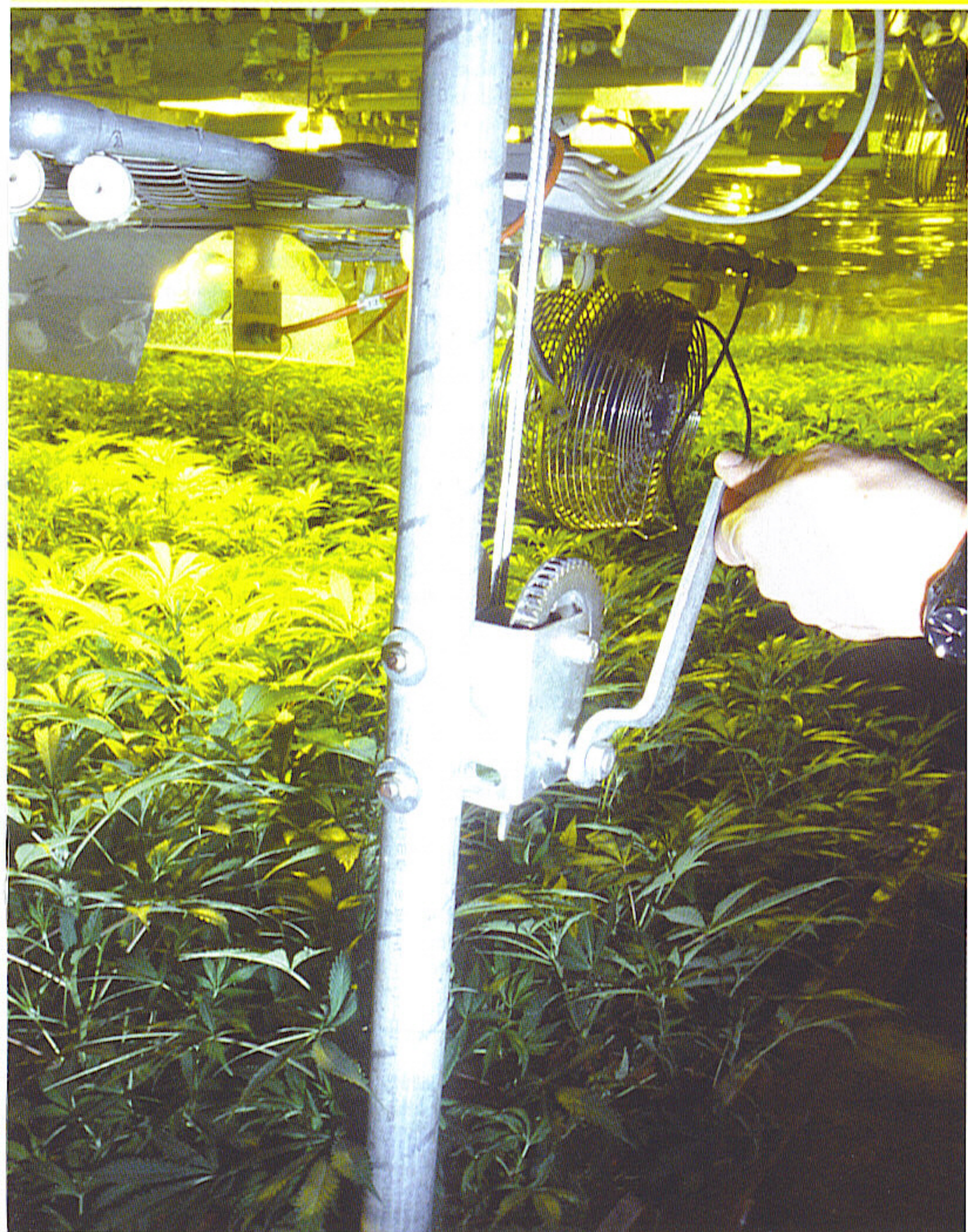
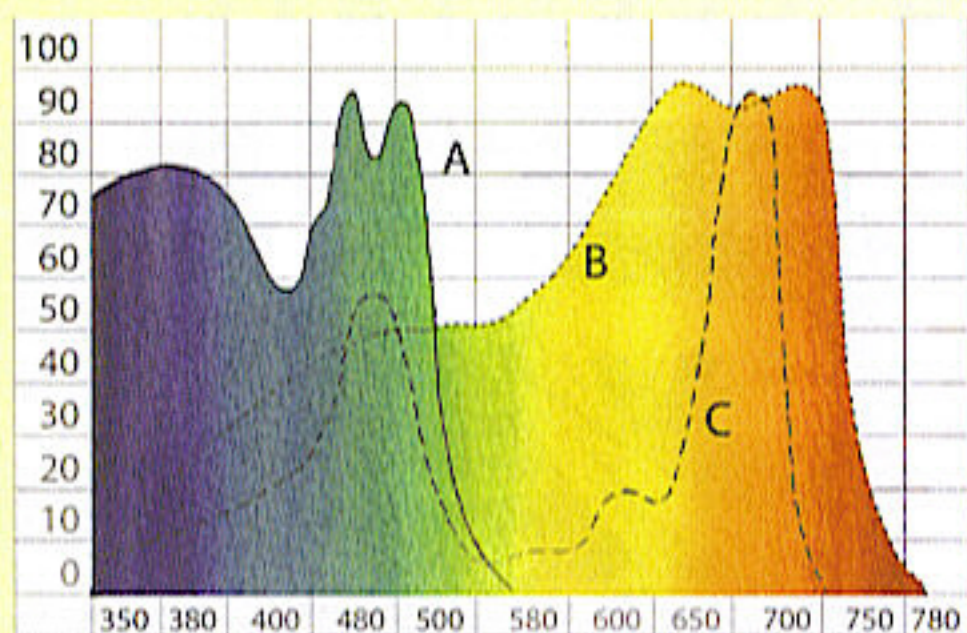


CHAPTER NINE LIGHT, LAMPS & ELECTRICITY

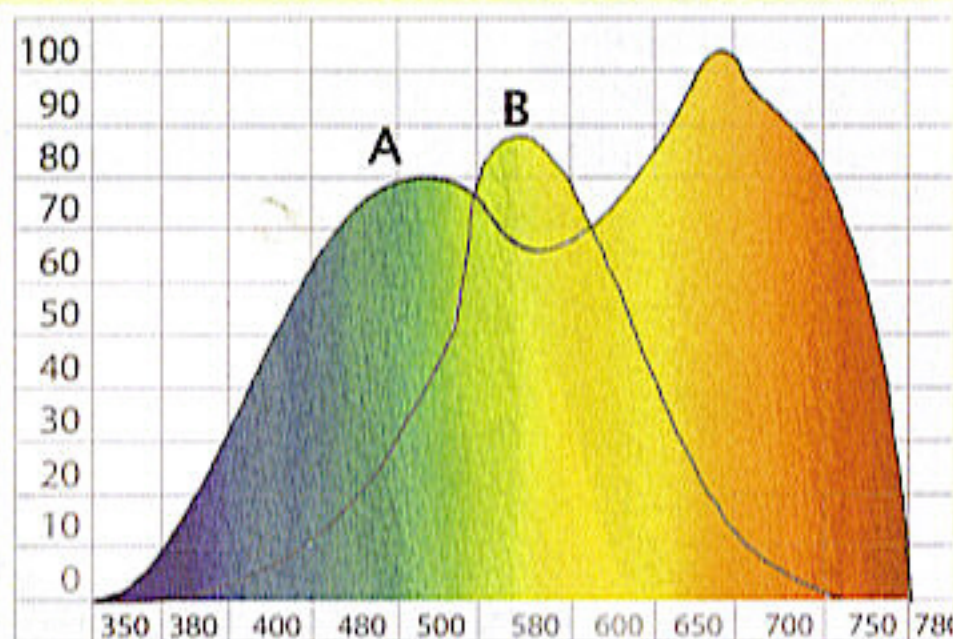


A single handle raises and lowers an entire roomfull of lights!



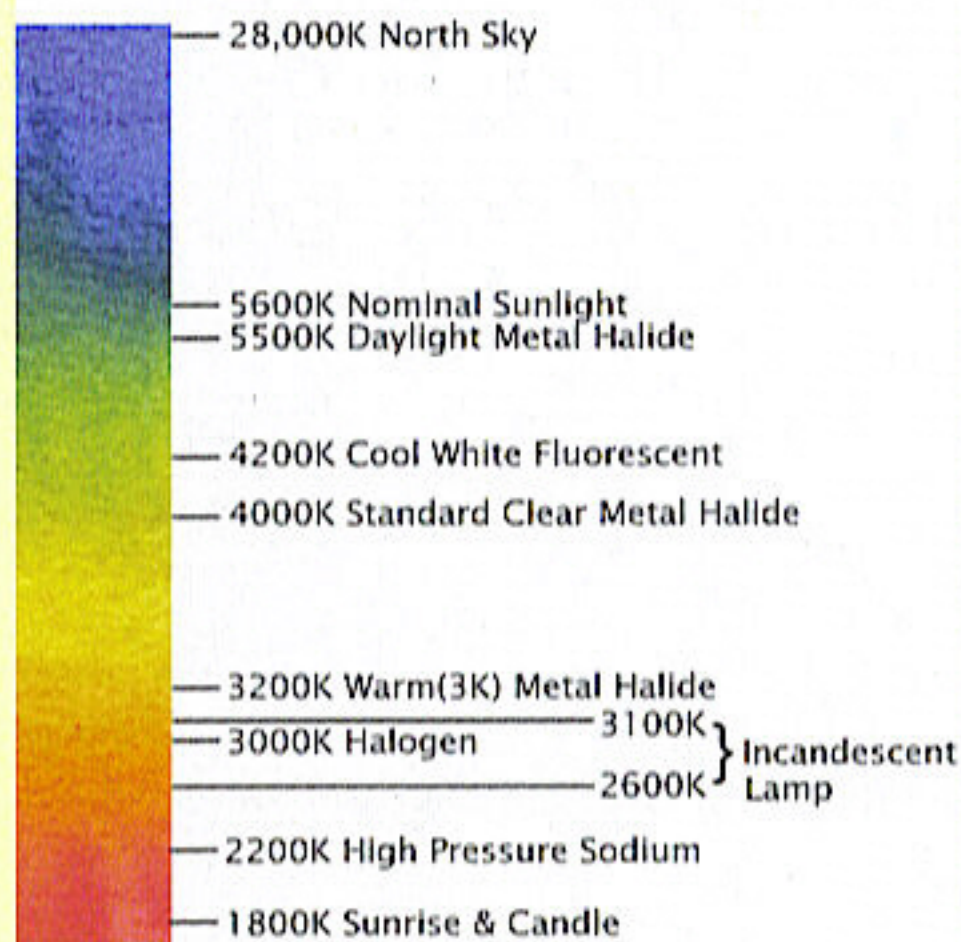
Spectrum of A. Photosynthetic response, B. Light spectrum humans use to see, C. Chlorophyll synthesis

This graph shows the exact level at which A. Phototropic response, B. Photosynthetic response, and C. Chlorophyll synthesis take place.



The single humped line in the center of the graph represents the visible light spectrum humans see. The dual humped line represents the spectrum cannabis needs to grow.

Kelvin Scale



Light, Spectrum, and Photoperiod

Marijuana needs light to grow. The light must have the proper spectrum and intensity to ensure rapid growth. Light is comprised of separate bands of colors. Each color in the spectrum sends the plant a separate signal. Each color in the spectrum promotes a different type of growth.

PAR and Light Spectrum

Plants need and use only certain portions of the light spectrum. The most important colors in the spectrum for maximum chlorophyll production and photosynthetic response are in the blue and red range. The main portion of light used by plants is between 400 and 700 nanometers (nm).^{*} This region is called the Photosynthetically Active Radiation (PAR) zone.^{**}

"PAR watts" is the measure of the actual amount of specific photons a plant needs to grow. Photons are a measure of light energy. Light energy is radiated and assimilated in photons. Photosynthesis is necessary for plants to grow and is activated by the assimilation of photons. Blue photons are worth more PAR watts than red photons, but scientists have difficulty measuring the exact difference.

Each color of light activates different plant functions. Positive tropism, the plant's ability to orient leaves toward light, is controlled by spec-

Bulb Rating	CCT Rating in degrees Kelvin
Warm	3000
Neutral	4000
Cool	6000

Bulb	Kelvin Temp	CRI
Cool White	4150 K	62
Lite White	4150 K	62
Warm White	300 K	52
Deluxe Daylight	8500 K	84
Vitalight	5500 K	96
Noon Sunlight	5300 K	100

trum. Light bulbs deliver only a part of the necessary light marijuana needs to grow. However, they deliver enough! Most of marijuana's light needs can be met by artificial means.

*One nanometer (nm) = one billionth (10^{-9}) of a meter. Light is measured in wavelengths; the wavelengths are measured in nanometers.

**Some scientists still disagree as to the exact PAR zone and make their calculations based on 350 to 750 nanometers. PAR watts measured with this scale will be a little higher.

Measuring Light

Virtually all light is measured in foot-candles, lux, or lumens. Foot-candles and lux measure light visible to the human eye. The human eye sees much less of the light spectrum than plants "see." The eye is most sensitive to light between 525-625 nanometers. The importance of the blue and red portions in the spectrum is diminished greatly when light is measured in foot-can-

dles, lux, or lumens. A foot-candle is a unit of illumination equal to the intensity of one candle at a distance of one foot. The lux scale is similar to that of the foot-candle; one foot-candle is equal to 10.76 lux.

Humans see light differently than plants do. Compare the graphs above to see how the light you see differs from the light a plant uses to grow. Plants use the photosynthetically active response (PAR) portion of the spectrum. Humans use the central portion of the spectrum, while plants are able to use large portions of the spectrum not measured by light meters that record foot-candles, lux, and lumens.

Light is also measured in spectrum with Kelvin temperature which expresses the exact color a bulb emits. Bulbs with a Kelvin temperature from 3000 to 6500 are best for growing marijuana. The PAR section above explains that plants use specific portions of the spectrum—a complete range from blues to reds. Lamps with a spectrum similar to PAR-rated bulbs can use Kelvin temperature of a bulb to ascertain the approximate PAR rating of the lamp. Color spectrum results from a specific mix of different colors. High intensity discharge bulbs are very similar in spectrum. Making these safe assumptions, a rough PAR rating could be extrapolated from a Kelvin temperature rating.

The Color Corrected Temperature (CCT) of a bulb is the peak Kelvin temperature at which the colors in a bulb are stable. We can classify bulbs by their CCT rating which tells us the overall color of the light emitted. It does not tell us the concentration of the combination of colors emitted. Companies use a Color Rendering Index (CRI). The higher the CRI, the better the bulb is for growing.

Light Meters

Most commercial light meters measure light in foot-candles or lux. Both scales measure light to which the human eye reacts to "see." They do not measure photosynthetic response to light in PAR watts.

Light measurements in this book are made in



Although this simple light meter measures light in foot-candles rather than PAR, it still gives an accurate idea of light distribution.

Bulb	Model	Mfrg	MH/HPS	Watts	Initial Lumens	Color Deg. K
Sunmaster	Warm Deluxe	V	MH	1100	133000	385 PAR
AgroSun	AgroSun	V	MH	1000	117000	3250
Multivapor	HO	GE	MH	1000	115000	3800
MultiMetal	Super	I	MH	1000	115000	4200
Metal Halide	Metal Halide	Ph	MH	1000	110000	3700
Solarmax	Veg	V	MH	1000	85000	7200
Super Metalarc	Super	O	MH	1000	115000	3600
Sunmaster	Warm Deluxe	V	MH	1000	117000	315 PAR
Sunmaster	Natural Deluxe	V	MH	1000	117000	315 PAR
Sunmaster	Cool Deluxe	V	MH	1000	80000	315 PAR
Solarmax	Veg / Conversion	V	MH	600	55000	7200
Solarmax	Veg	V	MH	400	32000	7200
Sunmaster	Warm Deluxe	V	MH	400	40000	110 PAR
Sunmaster	Natural Deluxe	V	MH	400	40000	110 PAR
Sunmaster	Cool Deluxe	V	MH	400	32500	110 PAR
Super Metalarc	Super	O	MH	400	40000	4200
Super Metal Halide	Super	Ph	MH	400	4000	4300
AgroSun	AgroSun	V	MH	400	4000	3250
Multivapor	HO	GE	MH	400	40000	4200
Sunmaster	Warm Deluxe	V	MH	250	22000	85 PAR
Sunmaster	Natural Deluxe	V	MH	250	23000	85 PAR
Sunmaster	Cool Deluxe	V	MH	250	21500	85 PAR
Super Metalarc	Super	O	MH	250	23000	4200
Super Metal Halide	Super	Ph	MH	250	23000	4300
Multivapor	HO	GE	MH	250	23000	4200
Hortilux	Super		HPS	1000	145000	2100
Solarmax	Super HPS	V	HPS	1000	147000	2100
Lucalox	HPS	GE	HPS	1000	140000	2100
Sunlux	HPS	I	HPS	1000	140000	2100
Lumalux	HPS	O	HPS	1000	140000	2100
Ceramalux	HPS	Ph	HPS	1000	140000	2100
Solarmax	Super HPS	V	HPS	600	95000	2100
Sunmaster	Super HPS Deluxe	V	HPS	600	85000	358 PAR
Lumalux	Super	O	HPS	600	9000	2200
SonAgro	Plus	Ph	HPS	600	9000	2100
Hortilux	Super	I	HPS	430	58500	2100
Hortilux	Super	I	HPS	400	55000	2100
Solarmax	Super HPS	V	HPS	400	55000	2100
Lucalox	HPS	GE	HPS	400	41000	4000
Sunlux	HPS	I	HPS	400	50000	2100
Lumalux	HPS	O	HPS	400	50000	2100
Ceramalux	HPS	Ph	HPS	400	50000	2100
Hortilux	Super	I	HPS	250	32000	2100
Lucalox	HPS	GE	HPS	250	30000	2100
Sunlux	HPS	I	HPS	250	29000	2100
Lumalux	HPS	O	HPS	250	29000	2100
Ceramalux	HPS	Ph	HPS	250	28500	2100

foot-candles and lux. This information is still valuable, because it records the amount of light spread over a specific surface. The information is then coupled with the PAR rating of different bulbs. Regardless of the lamp, the amount of light emitted is constant. It only makes sense to use the proper reflective hood with a high PAR-rated bulb to grow the best garden.

After all the talk about PAR watts, industry officials are unable to agree on a common scale of measurement. For this reason, we have decided to rely on Kelvin color temperature to measure lamp spectrum.

Photoperiod

The photoperiod is the relationship between the duration of the light period and dark period. Most strains of marijuana will stay in the vegetative growth stage as long as an 18 to 24-hour light and a 6 to 0-hour dark photoperiod are maintained. However, there are exceptions. Eighteen hours of light per day will give marijuana all the light it needs to sustain vegetative growth.

Flowering is most efficiently induced with 12 hours of uninterrupted darkness in a 24-hour photoperiod. When plants are at least two months old—after they have developed sexual characteristics—altering the photoperiod to an even 12 hours, day and night, will induce visible signs of flowering in one to three weeks. Older plants tend to show signs of flowering sooner. Varieties originating in the tropics generally mature later. The 12-hour photoperiod represents the classic equinox and is the optimum daylight-to-dark relationship for flowering in cannabis.

Research has proven that less than 12 hours of light will not induce flowering any faster and reduces flower formation and yield. More than 12 hours of light often prolongs flowering. Some growers have achieved higher yields by inducing flowering via the 12-hour photoperiod, then changing to 13-14 hours of light after two to four weeks. However, flowering is often prolonged. I spoke with growers who increase light by one



This ruderalis cross is blooming in the middle of summer. The photoperiod does not induce flowering in this plant.

hour two to three weeks after flowering is induced. They say the yield increases about 10 percent. Flowering takes about a week longer, and different varieties respond differently.

A relationship exists between photoperiod response and genetics. We can make generalizations about this relationship, because little scientific evidence documents the extent to which specific strains of cannabis are affected by photoperiod. For example, *sativa*-dominant plants that originated in the tropics respond to long days better than *indica*-dominant plants. On the equator, days and nights are almost the same length year-round. Plants tend to bloom when they are chronologically ready, after completing the vegetative growth stage. However, most growers are familiar with the pure *sativa* strain, 'Haze', which flowers slowly for three months or longer, even when given a 12-hour photoperiod. You can start 'Haze' on a 12/12 day/night schedule, but it still must go through the seedling and vegetative stages before spending three months

Give plants 36 hours of total darkness just before inducing flowering with the 12/12 photoperiod. This heavy dose of darkness sends plants an unmistakable signal to flower sooner. Growers using this technique report that plants normally show signs of flowering, such as pistil formation, within two weeks and develop pistils after a week of flowering.

Growers have experimented with giving plants up to 48 hours of total darkness to jump-start flowering and have found that 36 hours—three contiguous 12-hour nights—is most effective.



Half of this 'Haze' plant received light from a street-lamp, causing it to remain in the vegetative growth stage. The other half of the plant received total darkness at night and flowered!

or longer flowering. Plants grow more slowly in 12-hour days than when given 18 hours of light, and inducing flowering takes longer.

Indica-dominant varieties that originated in northern latitudes tend to flower sooner and respond more quickly to a 12-hour photoperiod. Many *indica* varieties will flower under a 14/10 or 13/11 day/night photoperiod. Again, the hours of light necessary to induce flowering in an *indica*-dominant plant is contingent upon the genetics in the strain. More hours of light during flowering can cause some strains to produce bigger plants with reduced flowering time, but some growers have reported looser, leafier buds as a result.

Giving any cannabis variety less than 12 hours of uninterrupted darkness will not make it flower faster. Instead, the plant will take longer to mature, its buds will be smaller, and the overall harvest will be lessened.

Genetically unstable strains could express hermaphroditic tendencies if the photoperiod bounces up and down several times. If you plan to give plants a photoperiod of 13/11 day/night, stick to it. Do not decide you want to change the photoperiod to 15/9. Such variation will stress plants and could produce hermaphrodites.

Some growers experiment with gradually decreasing daylight hours while increasing hours of darkness. They do this to simulate the natural photoperiod outdoors. This practice prolongs flowering and does not increase yield.

The photoperiod signals plants to start flowering; it can also signal them to remain in (or revert to) vegetative growth. Marijuana must have 12 hours of *uninterrupted*, total darkness to flower properly. Dim light during the dark period in the pre-flowering and flowering stages prevents marijuana from blooming. When the 12-hour dark period is interrupted by light,



Turn on a green light bulb to work in the indoor garden at night. Green light will not affect the photoperiod of flowering plants.

plants get confused. The light signals plants, "It's daytime; start vegetative growth." Given this signal of light, plants start vegetative growth, and flowering is retarded or stopped.

Marijuana will not stop flowering if the lights are turned on for a few minutes once or twice during the flowering cycle. If a light is turned on for a few minutes—long enough to disrupt the dark period—on two or three consecutive nights, plants will start to revert to vegetative growth. Less than one half of one foot-candle of light will prevent cannabis from flowering. That is a little more light than reflected by a full moon on a clear night. Well-bred *indica*-dominant plants will revert within three days. *Sativa*-dominant plants take four to five days to revert to vegetative growth. Once they start to re-vegetate, it takes four to six additional weeks to induce flowering!

When light shines on a green object, green pigment in the object absorbs all spectrum colors but green, and the green light is reflected. This is why we see the color green.

The smart way to visit a grow room during the dark period is to illuminate it with a green light. Marijuana does not respond to the green portion of the light spectrum, thus a green bulb is usable in the grow room at night with no ill effects.

Some growers leave the HID on 24 hours a day. Marijuana can efficiently process 16 to 18 hours of light per day, after which it reaches a point of diminishing returns, and the electricity is wasted. (See Chapter Sixteen *Breeding*.)

I talked with Dutch and Canadian growers who

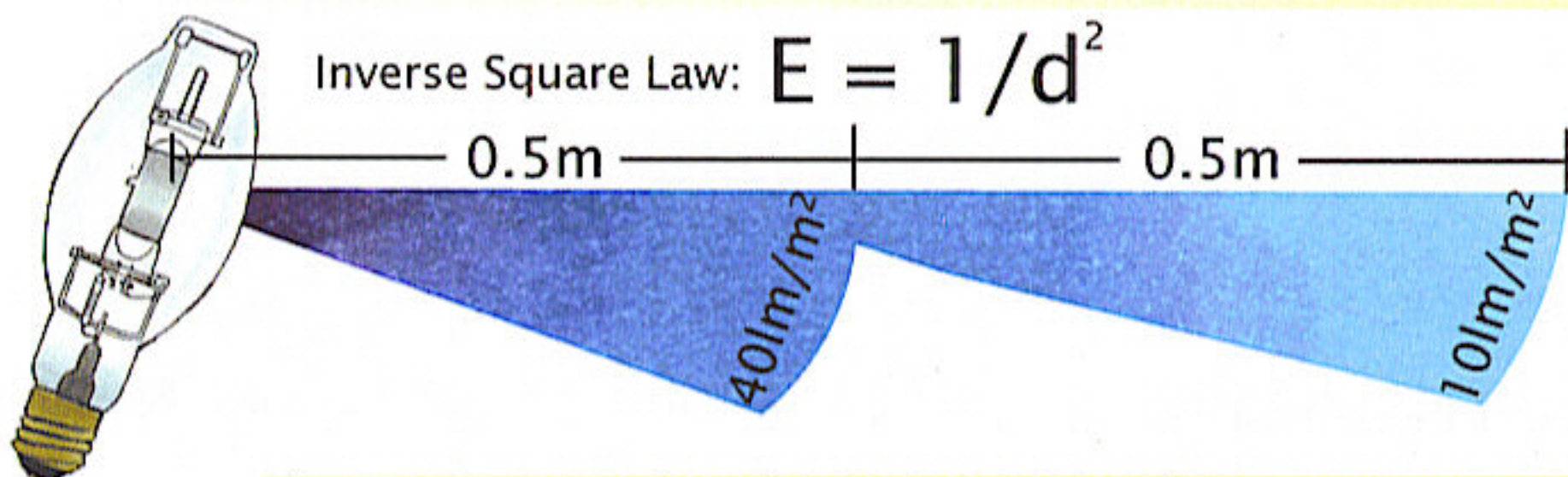


You can put outdoor plants in a closet daily to induce flowering with 12 hours of uninterrupted darkness.

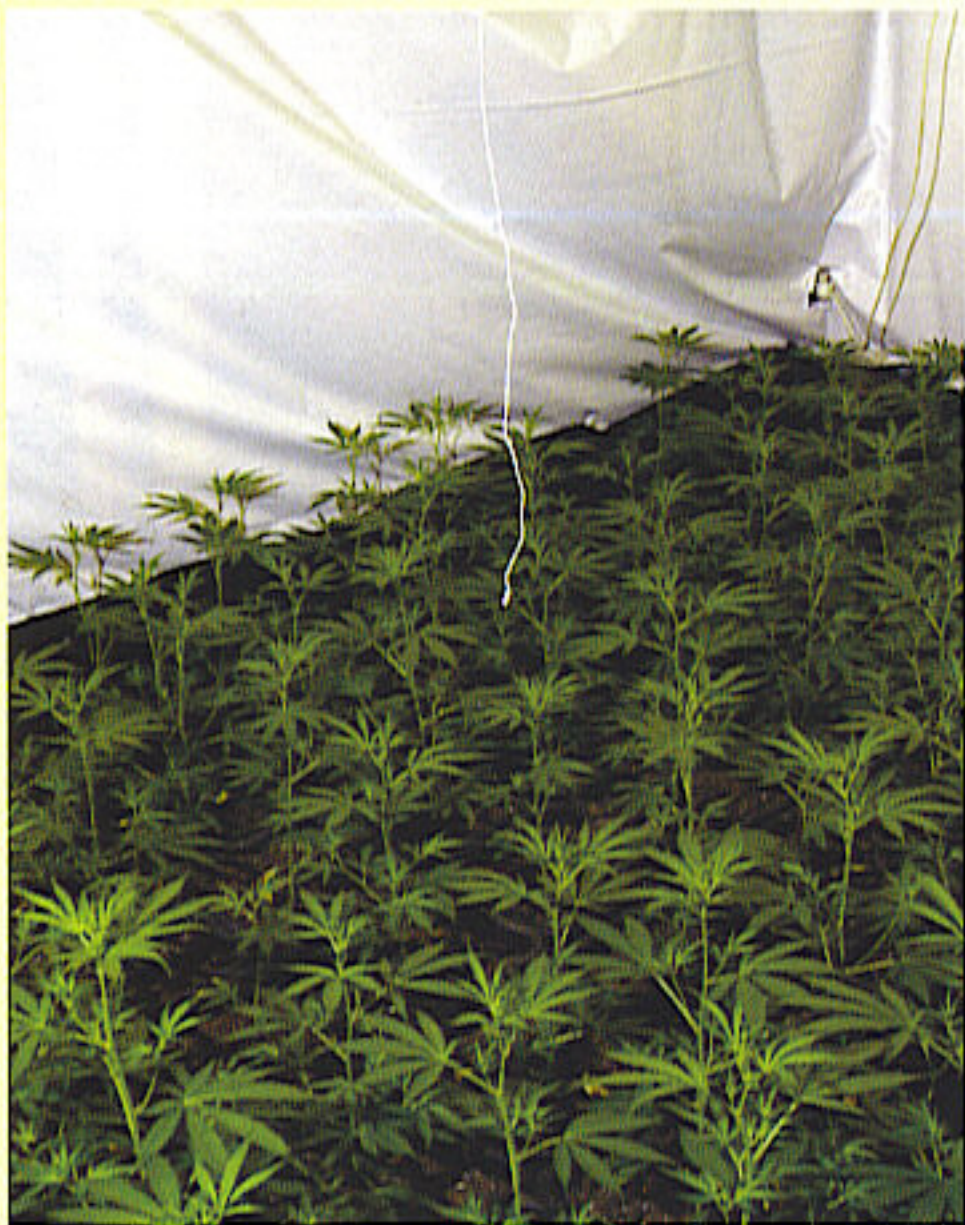
claim their plants flower under a 6-hour dark and 12 hour light photoperiod. This expedited, 18-hour photoperiod regimen is supposed to work, but I'm not sold on it. Growers say that their harvest is undiminished, and that they are getting 25 percent more marijuana in the same time. I have not visited their grow rooms to verify these claims. No electricity is saved by adopting this regimen.

Intensity

High intensity discharge lamps are bright—very, very bright. Growers who properly manage this intense brightness harvest more weed per watt. Intensity is the magnitude of light energy per unit



The Inverse Square Law dictates light intensity in relation to distance.



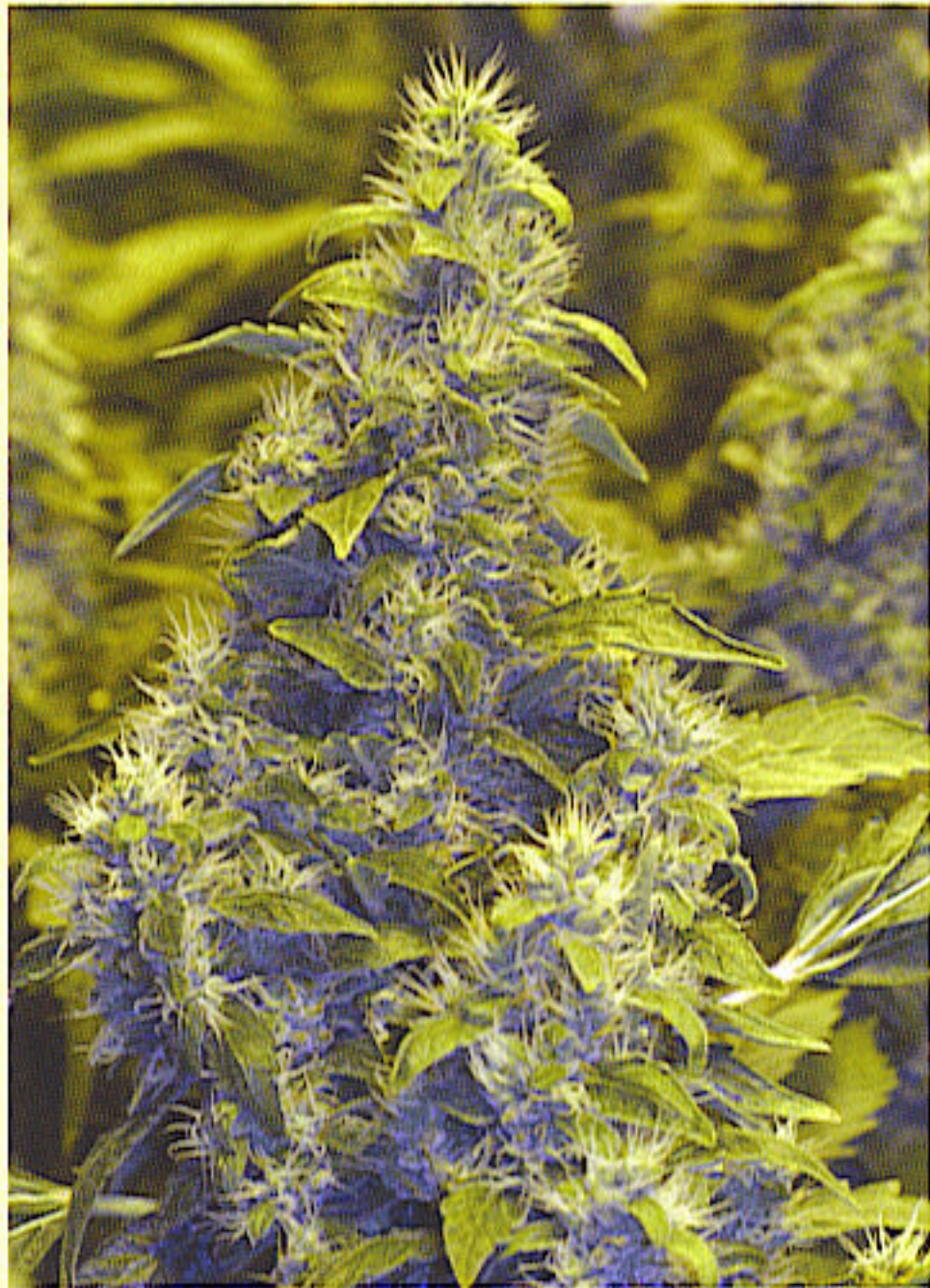
Tie a string 12 to 36 inches long to the HID reflector. Use the string to measure the distance between the bulb and plant canopy.

of area. It is greatest near the bulb and diminishes rapidly as it moves away from the source.

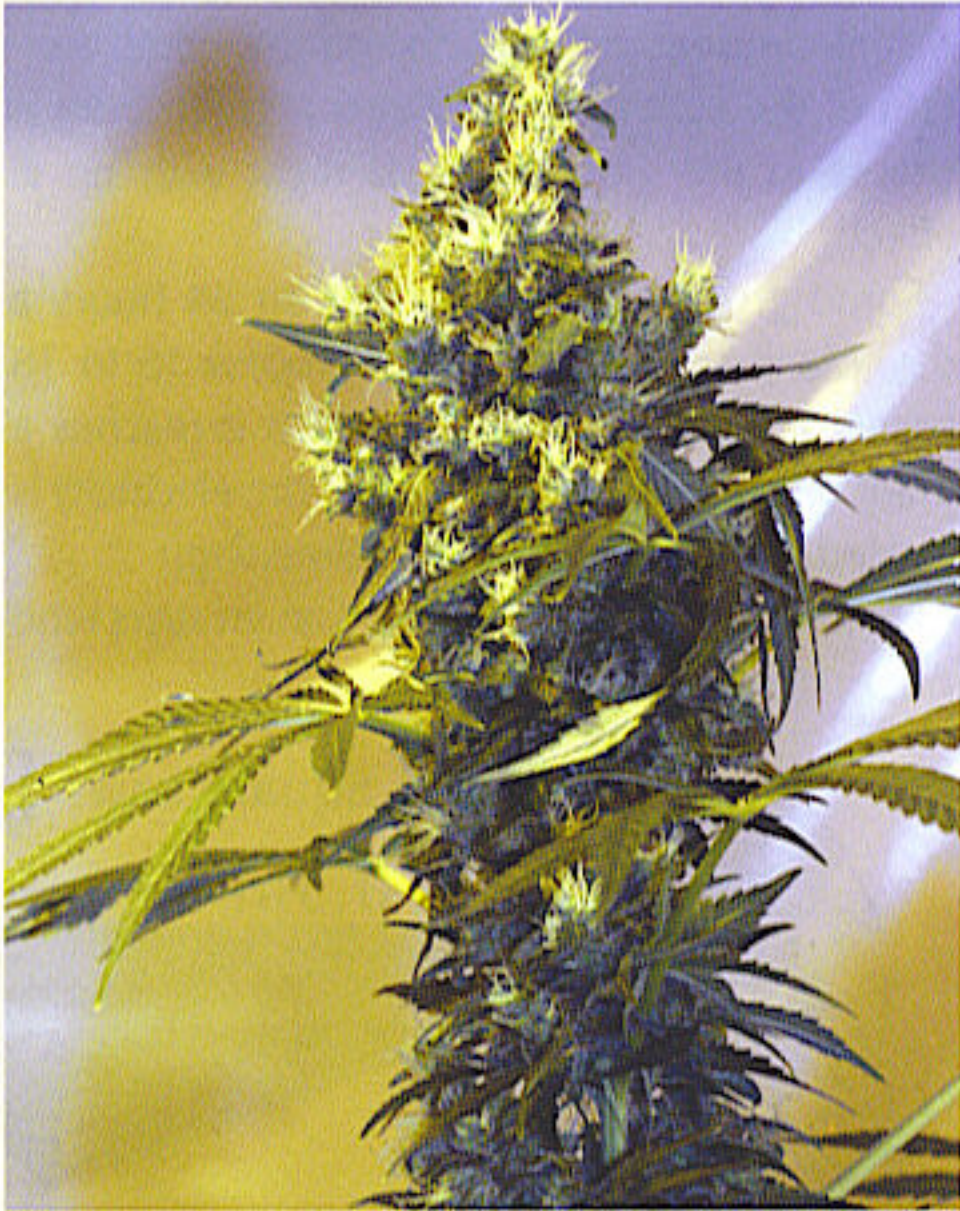
For example, plants that are two feet from a lamp receive one-fourth the amount of light received by plants one foot away! An HID that emits 100,000 lumens produces a paltry 25,000 lumens two feet (60 cm) away. A 1000-watt HID that emits 100,000 initial lumens yields 11,111 lumens three feet (90 cm) away. Couple this



Leaves reach for the light. Strong, well-illuminated plants orient foliage to catch the maximum amount of light possible.



This 'Chronic' cola received plenty of bright PAR watts. It developed super-thick, dense, heavy buds.



Loose buds like this form when they do not receive enough light.

meager sum with a poorly designed reflective hood, and beautiful buds suffer big time! The closer marijuana is to a light source, the more PAR watts it receives and the better it grows, as long as it is not so close that heat from the lamp burns foliage.

The Inverse Square Law

The relationship between light emitted from a point source (bulb) and distance are defined by the inverse square law. This law affirms that the intensity of light changes in inverse proportion to the square of the distance.

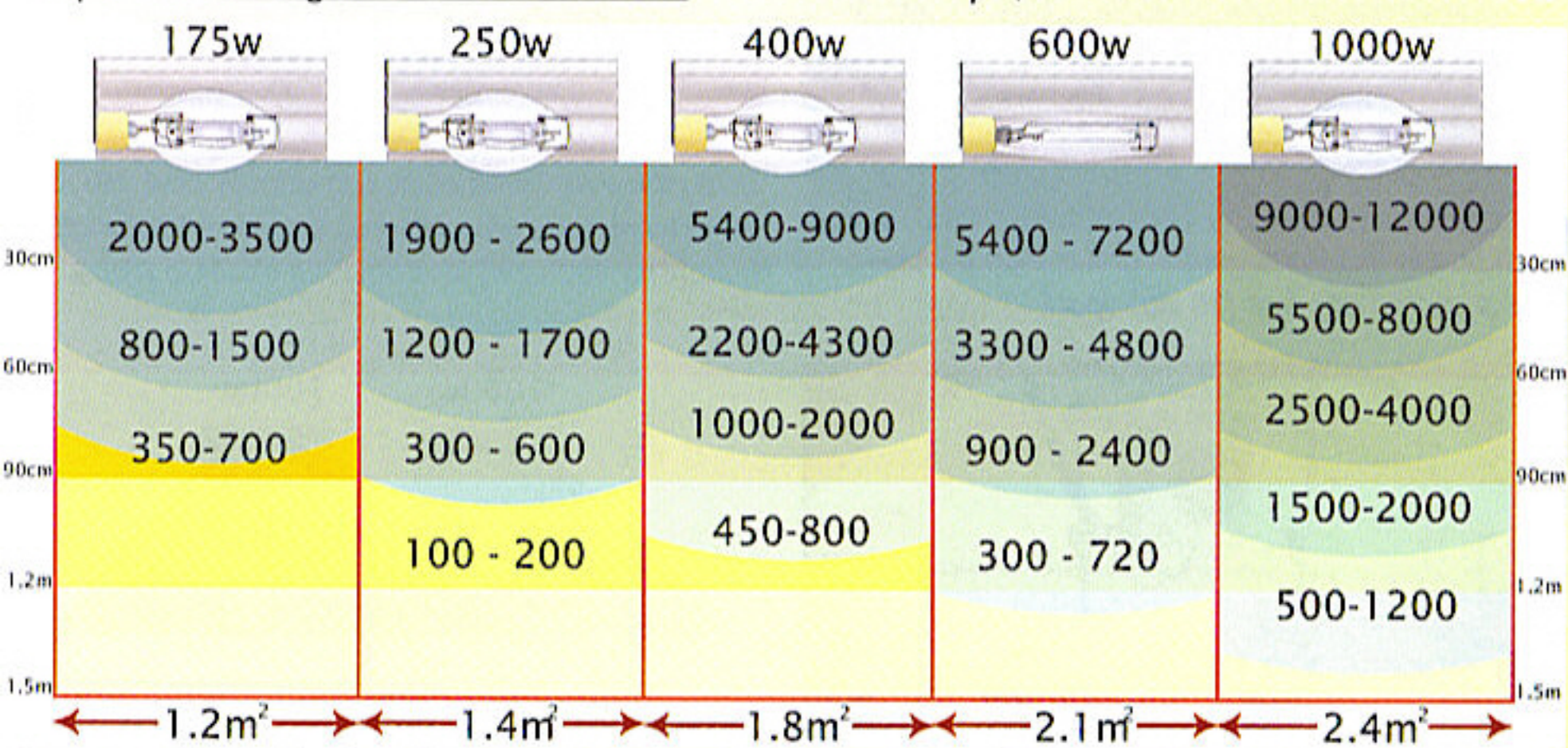
$I = L/D^2$
Intensity = light output/distance²
For example:
= light output/distance²
100,000 = 100,000/1
25,000 = 100,000/4
11,111 = 100,000/9
6250 = 100,000/16

Link to the best light handbook on the Internet
<http://www.intl-light.com/handbook.html>

A 1000-watt standard metal halide emits from 80,000 to 110,000 initial lumens and 65,000 to 88,000 average (mean) lumens. One lumen is equal to the amount of light emitted by one candle that falls on one square foot of surface one foot away. Super halides emit 115,000 initial lumens and 92,000 mean lumens. A 1000-watt HP sodium emits 140,000 initial lumens, and a 600-watt HP sodium emits 90,000; watt for watt, that's seven percent more lumens than the 1000-watt HPS. Lumens emitted are only part of the equation. Lumens received by the plant are much more important.

Lumens received are measured in watts-per-square-foot or in foot-candles (fc). One foot-candle equals the amount of light that falls on one square foot of surface located one foot away from one candle.

Watts-per-square-foot (or m²) is easy to calculate, but is an erroneous way to determine usable light for a garden. It measures how many watts are available from a light source in an area. For example, a 400-watt incandescent bulb



A 175-watt HID yields enough light to grow a 2 × 2-foot garden well. Notice how fast light intensity diminishes more than a foot from the bulb.
A 250-watt HID will illuminate up to a 3-foot square area. Keep the bulb from 12 to 18 inches above plants.
A 400-watt HID delivers plenty of light to illuminate a 4 × 4-foot area well. Hang the lamp from 12 to 24 inches above the canopy of the garden.
A 600-watt HP delivers enough light to illuminate a 4 × 4-foot area well. Hang the lamp from 18 to 24 inches above plants.
A 1000-watt HID delivers enough light to illuminate a 6 × 6-foot area well. Some reflective hoods are designed to throw light over a rectangular area. Large 1000-watt HID's can burn foliage if located closer than 24 inches from plants. Move HID's closer to plants when using a light mover.



Plants are spaced evenly in this bed of contiguous growing medium.



Each bud in this Swiss garden grows from a clone that is spaced one foot (30 cm) apart.

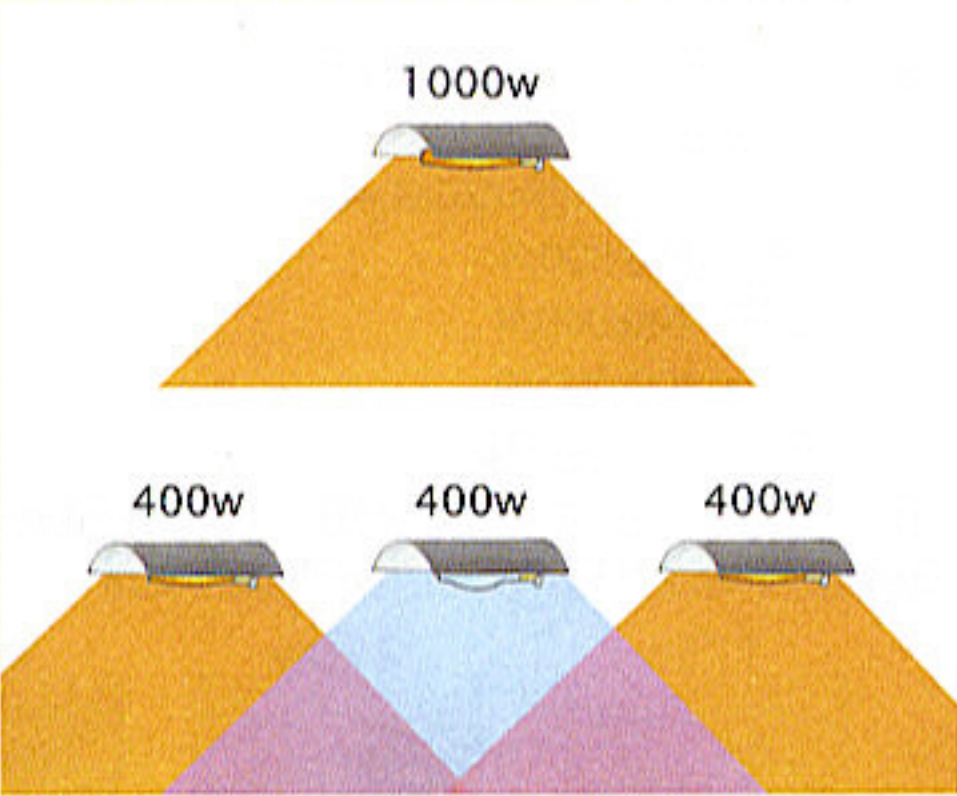


This Adjust-A-Wing spreads light evenly and plants can be placed very close to the bulb without burning.

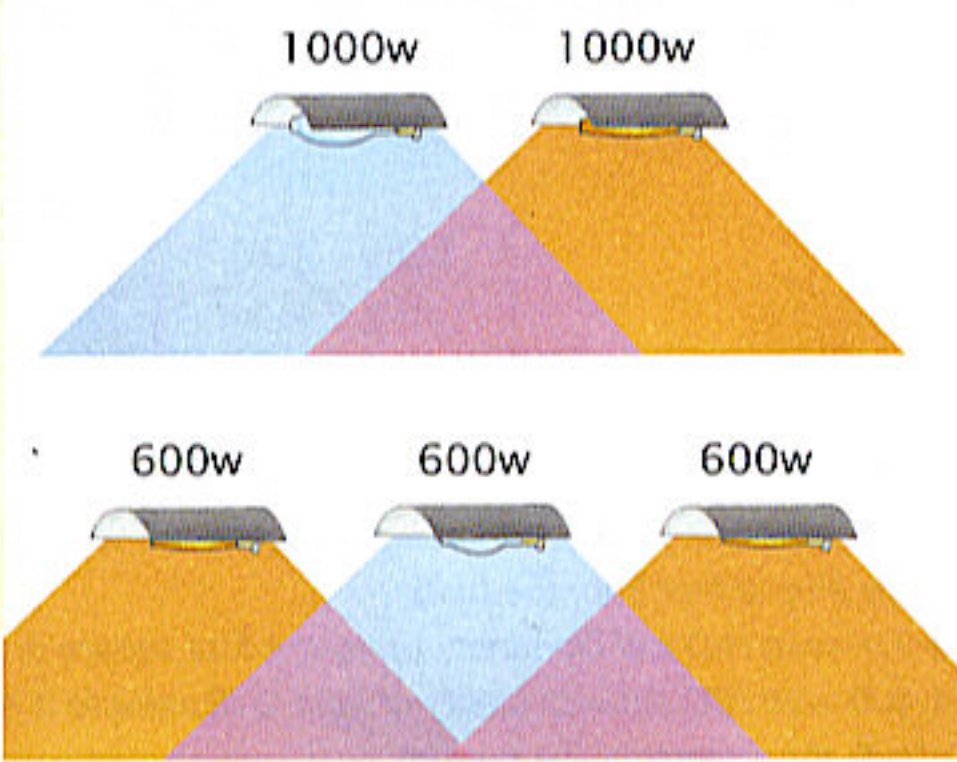
emits the same watts-per-square-foot as a 400-watt metal halide. Mounting height is not considered in watts-per-square-foot; the lamp could be mounted at any height from four to eight feet. Nor does it consider PAR watts or efficiency of the bulb.

The benefits of using lower wattage bulbs include:

- More point sources of light**
- More even distribution of light**
- Able to place bulbs closer to garden**



Using three 400-watt bulbs can actually cover 30 to 40 percent more growing area than one 1000-watt bulb. The 400's can also be hung closer to plants.



Three 600-watt HID's actually deliver more light to plants than two 1000-watt HID's. Smaller HID's provide three points of light and can be located closer to plants.

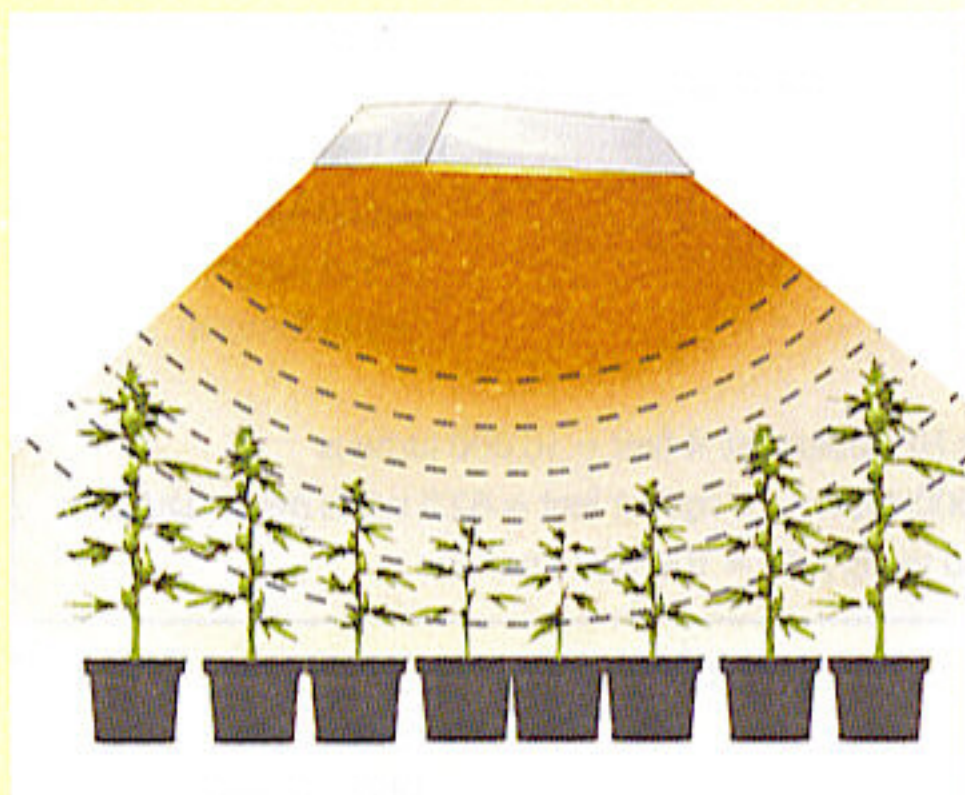
Calculating foot-candles or lux is a more accurate way to estimate the amount of light plants receive, but it still lacks the precision of measuring how much light is used by plants. If you start with a bulb that is rated in PAR watts, using a foot-candle or lux meter will suffice.

To demonstrate how dim light intensity retards plant development, check out an outdoor vegetable garden. Have you ever planted 65-day broccoli that took 100 days to mature? Most gardeners have suffered this fate. Did the plants get full sun all day long? The seed vendor assumes seeds were planted under perfect conditions—full sun and perfect temperature range. Plants that received less PAR light matured slowly and produced less than plants getting full sun all day long. It is the same in an indoor marijuana garden; plants that receive less light grow poorly.

Lamp Spacing

Light intensity virtually doubles for every six inches (15 cm) closer an HID is to the canopy of a garden. When light intensity is low, plants stretch for it. Low light intensity

1000-watt: LPW = 140	
1 foot (30 cm) away	140,000 lumens
2 feet (60 cm) away	35,000 lumens
3 feet (90 cm) away	15,555 lumens
4 feet (120 cm) away	9999 lumens
1000-watt HP sodium @ 4 feet = 10,000 lumens 4 × 4 = 16 square feet, 1000 watts / 16 square feet = 62.5 watts per square foot. 1000 watts / M² = 100 watts per cm²	
1000-watt: LPW = 115	
1 foot (30 cm) away	115,000 lumens
2 feet (60 cm) away	28,750 lumens
3 feet (90 cm) away	12,777 lumens
4 feet (120 cm) away	8214 lumens
1000-watt metal halide @ 3.25 feet = 10,000 lumens 3.25 × 3.25 = 12.25 square feet, 1000 watts / 12.25 = 81.6 watts per square foot. 1000 watts / m² = 10 watts per cm²	
600-watt: LPW = 150	
1 foot (30 cm) away	90,000 lumens
2 feet (60 cm) away	22,500 lumens
3 feet (90 cm) away	9,999 lumens
4 feet (120 cm) away	6428 lumens
600-watt HP sodium @ 3 feet = 10,000 lumens 3 × 3 = 9 square feet, 600 watts / 9 = 66 watts per square foot 600 watts / m² = 6 watts per cm²	
400-watt: LPW = 125	
1 foot (30 cm) away	50,000 lumens
2 feet (60 cm) away	12,500 lumens
3 feet (90 cm) away	5,555 lumens
4 feet (120 cm) away	3571 lumens
400-watt HP sodium @ 2.25 feet = 10,000 lumens 2.25 × 2.25 = 5 square feet, 400 watts / 5 square feet = 80 watts per square foot. 400 watts / m² = 4 watts per cm²	
400-watt: LPW = 100	
1 foot (30 cm) away	40,000 lumens
2 feet (60 cm) away	10,000 lumens
3 feet (90 cm) away	4,444 lumens
4 feet (120 cm) away	2857 lumens
400-watt metal halide @ 2 feet = 10,000 lumens 2 × 2 = 4 square feet, 400 watts / 4 = 100 watts per square foot 400 watts / m² = 4 watts per cm²	



Light intensity is brightest directly under the bulb. To promote even growth, arrange plants under lamps so they receive the same intensity of light.



This gardener is able to rotate and move plants around within the garden beds. Wheels on the bed make it easy to rotate or remove entire beds.



A large bed on casters is easy to maintain.

is often caused by the lamp being too far away from plants. Dim light causes sparse foliage and spindly branches that are further apart on the stem.

Increase yield by giving growing area uniform light distribution. Uneven light distribution causes strong branch tips to grow toward the intense light. Foliage in dimly lit areas is shaded when light distribution is uneven.

Reflective hoods ultimately dictate lamp placement—distance between lamps and above the plants. Nearly all stationary lamps have bright (hot) spots that plants grow toward.

Growers prefer high-wattage lamps—400, 600, 1000, or 1100 watts—because they have lumens-per-watt and their PAR rating is higher than smaller bulbs. Plants receive more light when the lamp is closer to the garden. Even though 400-watt lamps produce fewer lumens-per-watt than a 1000-watt bulb, when properly set up, they actually deliver more usable light to plants. The 600-watt bulb has the highest lumen-per-watt conversion (150 LPW) and can be placed closer to the canopy of the garden than 1000 or 1100-watt bulbs. When the 600-watt bulb is closer to plants, they receive more light.

A 1000-watt HID emits a lot of light. It also radiates a lot of heat. The bulb must be farther away from the plants to avoid burning them. In many cases it is more effective to use smaller wattage bulbs. For example, two 400-watt bulbs can be placed closer to plants than one 1000-watt bulb, and the 400-watt bulbs emit light from two points. The disadvantage is that two 400-watt systems cost more than one 1000-watt system.

Check out the diagrams that show the difference in usable light in different sized growing areas. Growers who use these drawings fine-tune the area with a hand-held light meter.

Look at the simple mathematical examples below to see how much more efficient 400 and 600-watt lamps are than 1000-watt lamps.

For example, a 1000-watt lamp that produces 100,000 lumens at the source produces the following:

The goal is to give plants 10,000 lumens.

If you use three 600-watt HP sodium lamps, you get a total of 270,000 lumens at a cost of \$0.18 per hour (cost per kWh = \$0.10). If you use two 1000-watt HP sodium lamps, you get a total of 280,000 lumens at a cost of \$0.20 per hour.

Use the examples above to see the 1000-watt HP sodium offers more watts per square foot and m^2 to achieve the desired lumen output of 10,000 lumens. However, the bulb also produces a hot spot near the center of the illuminated area. Plants tend to grow into the hot spot and shade other plants.

Although 400-watt lamps have a lower lumen-per-watt conversion, when used properly they may be more efficient than higher wattage bulbs. One 1000-watt halide produces 115,000 initial lumens and a 400-watt halide only 40,000. This means each 400-watt lamp must be located closer to the canopy of the garden to provide a similar amount of light. It also means that several different point sources sustain more even, intense light distribution.

Side Lighting

Side lighting is generally not as efficient as lighting from above. Vertically oriented lamps without reflectors are efficient, but require plants to be oriented around the bulb. To promote growth, light must penetrate the dense foliage of a garden. The lamps are mounted where light intensity is marginal—along the walls—to provide sidelight.

Compact fluorescent lamps are not a good choice for side lighting when using HID lamps. (See *Compact Fluorescent Lamps* below for more information.)

Rotating Plants

Rotating the plants will help ensure even distribution of light. Rotate plants every day or two by moving them one-quarter to one-half turn. Rotating promotes even growth and fully-developed foliage.

Move plants around under the lamp so they receive the most possible light. Move smaller



Tall lanky buds are easy to grow in small containers.



Some clones grow so fast that the harvest is ready before plants shade one another.



You can really pack plants into a garden when they receive a lot of bright light.

plants toward the center and taller plants toward the outside of the garden. Set small plants on a stand to even out the garden profile. Arrange plants in a concave shape (stadium method) under the lamp so all plants receive the same amount of light. Containers with wheels are easier to move.

Take advantage of the different levels of light below the HID. Place seedlings and cuttings requiring low light levels on the perimeter and flowering plants needing higher light levels under bright bulbs.

Plant Spacing

When light shines on a garden, the leaves near the top of plants get more intense light than the leaves at the bottom. The top leaves shade the bottom leaves and absorb light energy, making less light energy available to lower leaves. If the lower leaves do not receive enough light, they will yellow and die. Tall six-foot (1.8 m) plants take longer to grow and have higher overall yields than shorter four-foot (1.2 m) plants, but the yield of primo tops will be about the same. Due to lack of light, the taller plants have large flowers on the top three to four feet (90-120 cm) and spindly buds nearer the bottom. Tall plants tend to develop heavy flower tops whose weight the stem cannot support. These plants need to be tied up. Short plants better support the weight of the tops and have much more flower weight than leaf weight.

At least 99 two-week-old seedlings or clones can be huddled directly under a single 400-watt HID. The young plants will need more space as they grow. If packed too closely together, plants

sense the shortage of space and do not grow to their maximum potential. Leaves from one plant shade another plant's foliage and slow overall plant growth. It is very important to space young plants just far enough apart so their leaves do not touch or touch very little. This will keep shading to a minimum and growth to a maximum. Check and alter the spacing every few days. Eight to sixteen mature females three to four months old will completely fill the space under one 1000-watt HID.

Plants can absorb light only if it falls on their leaves. Plants must be spaced so their leaves do not overlap too much. Yield increases very little when plants are crowded. Plants also stretch for light, which makes less efficient use of intense light.

Best number of plants per square foot or m² is often a matter of experimenting to find the magic number for your garden. In general, each 40-inch-square (m²) space will hold from 16 to 32 plants.

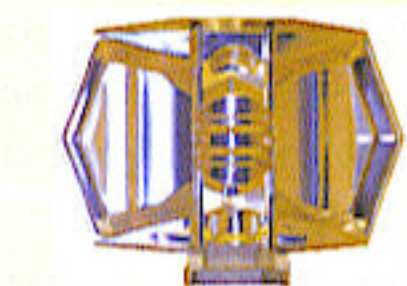
Reflective Hoods

Some reflective hoods reflect light more evenly than others. A reflector that distributes light evenly—with no hot spots—can be placed closer to plants without burning them. These hoods are most efficient, because the lamp is closer and the light more intense. The farther the lamp is from the garden, the less light plants receive. For example, a 1000-watt reflector with a "hot spot" must be placed 36 inches (90 cm) above the garden. A 600-watt lamp with a reflector that distributes light evenly can be placed only 18 inches above the garden. When placed closer,

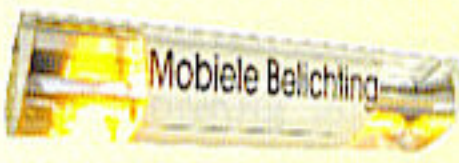
Maximum Light Requirements for Plants			
Growth Stage	Foot-candles	Lux	Hrs. of Light
Seedling	375	4000	16-24
Clone	375	4000	18-24
Vegetative	2500	27,000	18
Flowering	10,000	107,500	12
These guidelines will give plants all the light they need to form dense buds. Less light will often cause looser, less-compact buds to form.			



The ballast box is attached to the reflector in this greenhouse fixture.



The Wide reflector from Hortilux was one of the first European reflectors to use a deflector below the bulb.



Double fixture greenhouse fixture has the ballasts between bulbs.



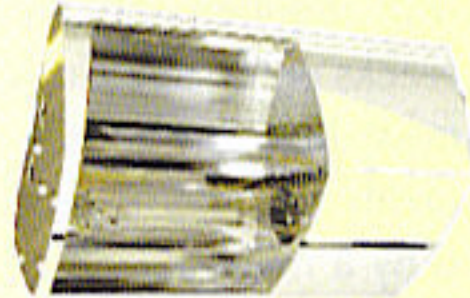
This air-ventilated tube is very inefficient, leaving a "hot spot" below.



Place Hortilux 1000-watt fixture 4 feet (1.2 m) above garden.



You can put the Super Wide reflector very close to plants.



This fixture is designed to be mounted next to a wall. It reflects light down and away from the wall.



This Ecotechnics Diamond reflector from Spain is very efficient.



Hortilux sets the standard with their line of reflectors. The Deep model is to be mounted high in greenhouses.



The Adjust-A-Wing is one of my favorite reflectors because it delivers the most light! The deflector under bulb allows it to be super close to plants.



Parabolic dome reflectors orient bulbs vertically. Although less efficient these hoods work well to grow vegetative plants.



Gavita invented a lamp with the reflector inside the bulb! The reflector is the most efficient I have seen!



The Medium reflector from Hortilux is a favorite in Europe.



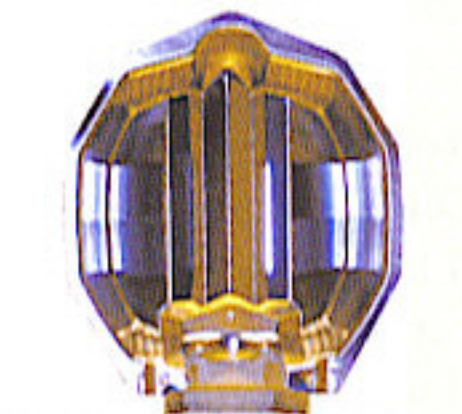
The Hydrofarm reflector is one of the best values in North America. It reflects a lot of light and "breathes" well.



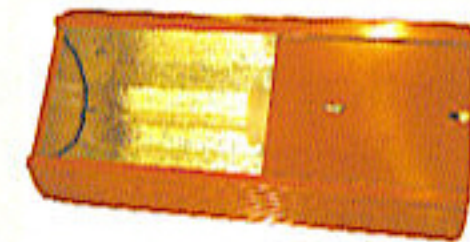
The "cone" reflector is one of the least efficient available. Much reflected light is wasted.



The Butterfly reflector and deflector is one of the most interesting designs I have seen, but I have no idea about efficiency!



Hortilux Midi reflector spreads light well.



The hammered-finish specular interior of this lamp/ballast fixture diffuses light well.



This vertical reflector is covered in plastic. The bulb hangs between plants.



This reflector from Easy Green has holes for forced-air ventilation and can be placed close to plants.

the 600-watt lamp shines as much light on the garden as the 1000-watt bulb!

The proper reflective hood over the lamp and reflective walls can double the growing area. Growers who use the most efficient reflective hoods harvest up to twice as much as those who don't.

Seedlings, cuttings, and plants in the vegetative growth stage need less light than flowering plants, because their growth requirements are different. For the first few weeks of life, seedlings and clones can easily survive beneath fluorescent lights. Vegetative growth requires a little more light, easily supplied by a metal halide or compact fluorescent lamp at the rate indicated in the chart below.

Reflective hoods are made from steel sheet metal, aluminum, even stainless steel. The steel is either cold-rolled or pre-galvanized before a reflective coating is applied. Pre-galvanized steel is more rust resistant than cold-rolled steel. This metal can be polished, textured or painted, with white being the most common paint color. Premium hood manufacturers apply white paint in a powder-coating process. Note: there are different shades of white, and some whites are whiter than others. Flat titanium white is the most reflective color and diffuses light most effectively. Glossy white paint is easy to clean but tends to create hot spots of light. Sheet metal hoods are less expensive than the same size aluminum hood, because of reduced materials expense.



Vertical parabolic dome reflective hoods distribute light evenly over a large area and are perfect for vegetative growth.

The pebble and hammer-tone surfaces offer good light diffusion and more surface area to reflect light. Hot spots are commonplace among highly polished, mirror-like surfaces. Mirror-polished hoods also scratch easily and create uneven lighting.

Horizontal Reflective Hoods

Horizontal reflectors are most efficient for HID systems, and are the best value for growers. A horizontal lamp yields up to 40 percent more light than a lamp burning in a vertical position. Light is emitted from the arc tube. When horizontal, half of this light is directed downward to the plants, so only half of the light needs to be reflected. Horizontal reflectors are inherently more efficient than vertical lamps/reflectors, because half of the light is direct and only half of the light must be reflected.

Horizontal reflective hoods are available in many shapes and sizes. The closer the reflective hood is to the arc tube, the less distance light must travel before being reflected. Less distance traveled means more light reflected.

Horizontal reflective hoods tend to have a hot spot directly under the bulb. To dissipate this hot spot of light and lower the heat it creates, some manufacturers install a light deflector below the bulb. The deflector diffuses the light and heat directly under the bulb. When there is no hot spot, reflective hoods with deflectors can be placed closer to plants.

Horizontally mounted HP sodium lamps use a small reflective hood for greenhouse culture. The hood is mounted a few inches over the horizontal HP sodium bulb. All light is reflected down toward plants, and the small hood creates minimum shadow.

Vertical Reflective Hoods

Reflectors with vertical lamps are less efficient than horizontal ones. Like horizontal bulbs, vertically mounted bulbs emit light from the sides of the arc tube. This light must strike the side of

the hood before it is reflected downward to plants. Reflected light is always less intense than original light. Light travels farther before being reflected in parabolic or cone reflective hoods. Direct light is more intense and more efficient.

Parabolic dome reflectors offer the best value for vertical reflectors. They reflect light relatively evenly, though they throw less overall light than horizontal reflectors. Large parabolic dome hoods distribute light evenly and reflect enough light to sustain vegetative growth. The light spreads out under the hood and is reflected downward to plants. Popular parabolic hoods are inexpensive to manufacture and provide a good light value for the money. Four-foot parabolic hoods are usually manufactured in nine parts. The smaller size facilitates shipping and handling. The customer assembles the hood with small screws and nuts.

Four-foot cone hoods are usually manufactured in four parts. The smaller size facilitates shipping and handling. The customer assembles the pieces with small screws and nuts. Cone-shaped reflectors using a vertical bulb waste light and are very inefficient. Growers who try to save money by purchasing cone-shaped reflectors pay even more in lost efficiency.

For example, say you bought a cone reflective hood for \$20 instead of the top of the line horizontal reflector for \$40. First, let's look at efficiency. The cone hood produces at 60 percent efficiency and the horizontal reflector at 100 percent, or 40 percent more. Each lamp costs \$36 per month to operate 12 hours daily at \$0.10 per kilowatt-hour (kWh). If 100 percent = \$0.10 per kilowatt-hour, then 60 percent efficiency = \$0.06, or a loss of \$0.04 for each kilowatt-hour. With this information we can deduce that $\$36/\$0.04 = 900$ hours. In 900 hours (75 12-hour days) the horizontal reflector has recouped the extra \$20 cost. Not only does the vertical cone yield 40 percent less light, it costs 40 percent more to operate! When this 75-day break-even point is reached, you will be stuck with an inefficient reflective hood that costs more for



Air-cooled fixtures use blowers to direct heat generated by the bulb out ducting.

fewer lumens every second the lamp is using electricity!

Lightweight reflective hoods with open ends dissipate heat quickly. Extra air flows directly through the hood and around the bulb in open-end fixtures to cool the bulb and the fixture. Aluminum dissipates heat more quickly than steel. Train a fan on reflective hoods to speed heat loss.

Artificial light fades as it travels from its source (the bulb). The closer you put the reflector to the bulb, the more intense the light it reflects.

Enclosed hoods with a glass shield covering the bulb operate at higher temperatures. The glass shield is a barrier between plants and the hot bulb. Enclosed hoods must have enough vents; otherwise, heat build-up in the fixture causes bulbs to burn out prematurely. Many of these enclosed fixtures have a special vent fan to evacuate hot air.

Air-Cooled Lamp Fixtures

Several air-cooled lights are available. Some use a reflective hood with a protective glass face and two squirrel cage blowers to move air through the sealed reflective hood cavity. The air is forced to travel around corners, which requires a higher velocity of airflow. Other air-cooled reflectors have no airflow turns, so the air is evacuated quickly and efficiently.



In this experimental system, a hoodless HID travels up and down vertically between tiered tubes of budding females. Growers are trying every possible means to grow more in less space and get the highest yield per watt.



The Cage from THC BC,S in Vancouver, BC is one of the most productive gardens per square foot (m^2).

Water-Cooled Lamp Fixtures

Water-cooled and air-cooled lamp fixtures are somewhat popular in hot climates. These lamps run cooler and can be moved closer to plants. Water-cooled bulbs are difficult for thermal imaging equipment to detect. Air-cooled fixtures are inexpensive to operate and easy to set up. Keep outer jacket clean and avoid scratching.

Growers decrease bulb heat by 80 percent with a properly set up water-cooled bulb. The water and outer jacket account for a ten percent lumen loss. Growers make up for the loss by moving bulbs closer to plants. On an average day, a 1000-watt bulb uses about 100 gallons of water to keep cool, if the water runs to waste. To recirculate the water requires a big, big reservoir. The water in the reservoir that serves a recirculating cooling system must also be cooled. Reservoir coolers can easily cost \$1000.

No Reflective Hood

One option is to remove the reflective hood. With no hood, the lamp burns cooler and emits only direct light.

Reflective Hood Study

I constructed a black room, everything black inside, to measure the amount of light reflective



Plants grow in vertical slabs and are irrigated from above in this recirculating garden.

hoods yield. The room was 10 × 10-foot square (3 m²). The floor was covered with black tar paper. Less than three percent light could be reflected from the black surfaces—there was no extra light in this room. Measurements were made every 12 inches (30 cm) on a matrix marked on the floor. The walls had one-foot increments marked.

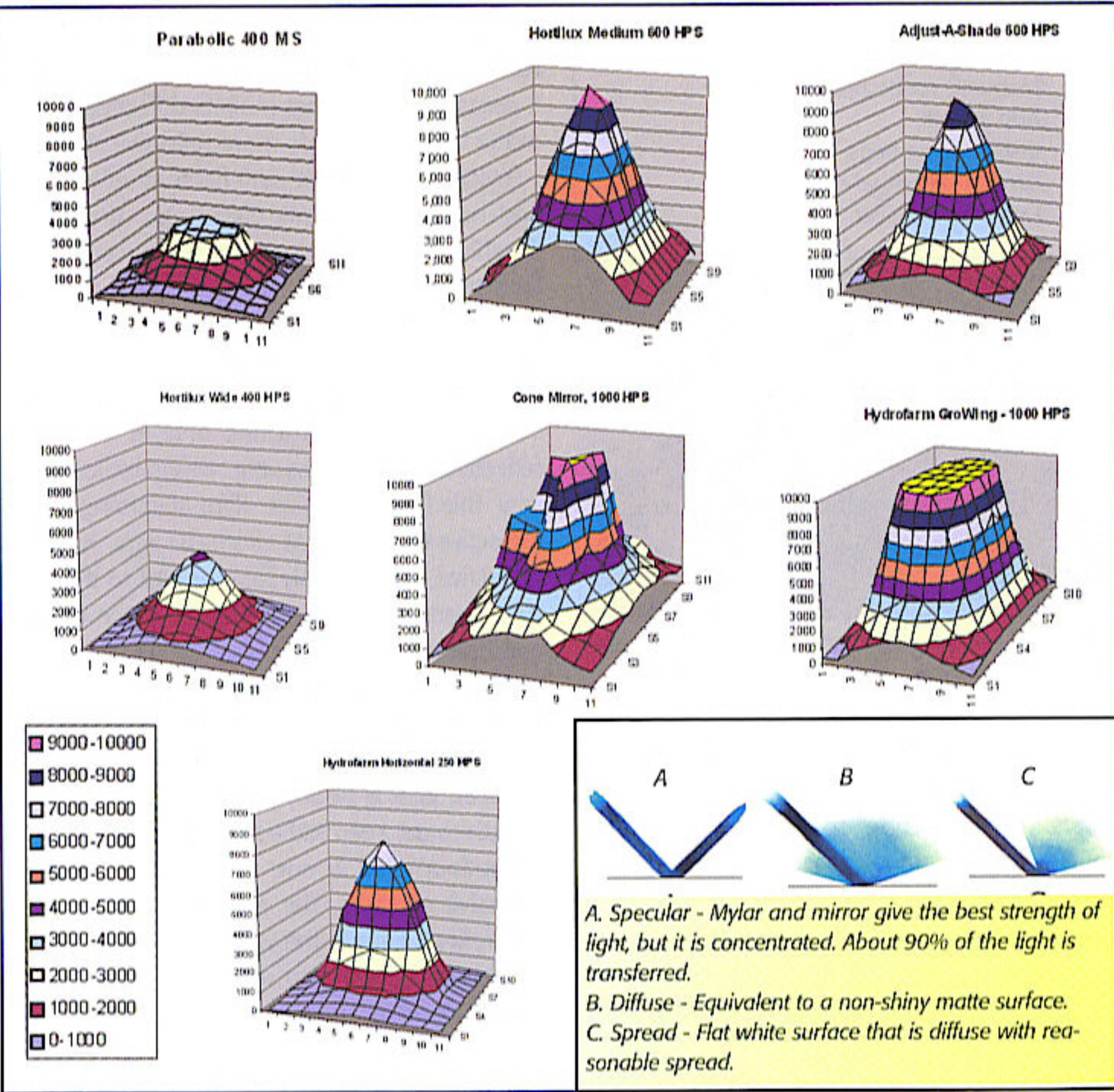
I tested five different lamps: a 1000-watt clear super metal halide, a 1000-watt HP sodium, a 600-watt HP sodium, a 400-watt super metal halide, and a 400-watt HP sodium. I positioned the bulb exactly three feet from the floor. Every lamp was warmed up for 15 minutes before taking measurements.

The foot-candle readings on the floor were taken every 12 inches (30 cm) and the results posted to a spreadsheet program. I used a simple spreadsheet graph program to present the graphic results.

The studies show a huge difference between reflective hoods. Some companies do not test their hoods before putting them on the market. To protect yourself and your plants, set up tests like the ones I did here to find out which reflector is the best for your needs.

When a reflector distributes light evenly, the lamp can be placed closer to plants.

In general, the larger the wattage of the bulb,



Reflective Chart

Material	Percent Reflected
Foylon	94-95
Reflective Mylar	90-95
Flat white paint	85-93
Semi-gloss white	75-80
Flat yellow	70-80
Aluminum foil	70-75
Black	less than 10

How to add light without using more electricity.

Any unused light is wasted. There are several ways to get the most out of your light without adding more watts, including:

- Use several 400 or 600-watt lamps instead of 1000's.
- Manually rotate plants regularly.
- Add a shelf.
- Install rolling beds.
- Grow a perpetual crop.
- Use a light mover.

sources of light, which evens out distribution.

A heat vent outlet around the bulb helps dissipate heat into the atmosphere. Excessive heat around the bulb causes premature burnout.

The studies show the light distribution of several types of light reflectors. The graphs clearly show that horizontal reflectors deliver many more lumens than vertical setups.

Check out the "Light Measurement Handbook" available free on the Internet. The 64-page technical book answers endless light questions. Download the book in a few minutes, photos and all: www.Intl-Light.com/handbook/.

Reflective Light

Flat white contains little or no light-absorbing pigment, so it absorbs almost no light and reflects almost all light. Do not use glossy white. It contains varnish that inhibits reflective light. A matte texture provides more reflective surface.

Foylon is a reflective material that reflects light and heat in an evenly dispersed pattern. It is durable, and it reflects about 95 percent of the light that hits it. The material is plied with rip-stop fiber and is thick enough to act as an insulator. It's also heat and flame resistant. For more information on Foylon, see www.greenair.com.

Reflective Mylar provides one of the most reflective surfaces possible. Mylar looks like a very thin mirror. Unlike light-absorbing paint, Reflective Mylar reflects almost all light. To install Reflective Mylar, simply tape or tack to the wall. To prevent rips or tears, place a piece of tape over the spot where the staple, nail or tack will be inserted. Although expensive, Mylar is preferred by many growers. The trick is to position it flat against the wall. When loosely affixed to surfaces, light is poorly reflected. To increase its effectiveness, keep Reflective Mylar clean.

Aluminum foil is one of the worst possible reflective surfaces. The foil always crinkles up and reflects light in the wrong directions-actually wasting light. It also reflects more ultraviolet rays than other surfaces, which are harmful to chloroplasts in leaves.

Mirrors also reflect light, but much less than



Move small plants to shelves around the perimeter of the grow room. Remember, plants grow wherever light shines!

the more efficient it is. Since light intensity diminishes so quickly, bulbs must be close to plants. Consequently, more lamps or point sources of light are necessary for even distribution of bright light.

Operating costs for three 600-watt HPS lamps are lower than for two 1000-watt HPS lamps. The 600-watt lamps produce more lumens for the same amount of money, plus they can be closer to plants. There are also three point

Mylar. Light must first pass through the glass in the mirror, before it is reflected back through the same glass. Light is lost when passing through the glass.

More Free Growing Light

Even though the lumens-per-watt conversion is lower with 400-watt bulbs than 1000-watt bulbs, hanging ten 400-watt lamps over the same area that four 1000-watt lamps cover, provides more even distribution of light and minimizes shading. Three 600-watt lamps that produce 270,000 lumens from three point sources, instead of two 1000-watt HP sodiums yielding 280,000 lumens from two points, lower total light output by 10,000 lumens, but increases the number of sources of light. Lamps can be placed closer to plants, increasing efficiency even more.

Manually rotating plants helps them fill out better, promoting more even development. The longer plants are in the flowering growth stage, the more light they need. During the first three to four weeks of flowering, plants process a little less light than the last three to four weeks. Plants flowering during the last three to four weeks are placed directly under the bulb where light is the brightest. Plants that have just entered the flow-

ering room can stay on the perimeter until the more mature plants are moved out. This simple trick can easily increase harvests by five to ten percent.

When plants get big, it can become laborious to rotate them. Difficult jobs often go undone. Save the strain and use a light mover, or put the containers on wheels.

Add a shallow shelf around the perimeter of the garden to use light that is eaten by the walls. This sidelight is often very bright and very much wasted. Use brackets to put up a four to six-inch-wide shelf around the perimeter of the garden. The shelf can be built on a slight angle and lined with plastic to form a runoff canal. Pack small plants in six-inch pots along the shelf. Rotate them so they develop evenly. These plants can either flower on the short shelf or when moved under the light.

Installing rolling beds will remove all but one walkway from the garden. Greenhouse growers learned long ago to save space. We can use the same information to increase usable grow space in a grow room. Gardens with elevated growing beds often waste light on walkways. To make use of more growing area place two, two-inch (6 cm) pipes or wooden dowels below the grow-



Reliable linear light movers offer an exceptional value to indoor growers. Light intensity increases exponentially when bulbs are moved closer to the garden using a light mover.



A single light mover transports all four 1000-watt HP sodium lamps over this rockwool garden of flowering females.

ing bed. The pipe allows the beds to be rolled back and forth, so only one walkway is open at a time. This simple trick usually increases growing space by about 25 percent.

Growing a perpetual crop and flowering only a

Benefits of a light mover:

Bulbs can be placed closer to the canopy of the garden.

Increases bright light to more plants.

Delivers light from different angles providing even lighting.

Increases intense light coverage 25 percent or more.

Light is closer to plants.

Economical use of light.

portion of the garden allows for more plants in a smaller area and a higher overall yield. More plants receive intense light, and no light is wasted in such a garden.

Light Movers

Replicate the movement of the sun through the sky with a motorized light mover. A light mover is a device that moves lamps back and forth or in circles across the ceiling of a grow room. The linear or circular path distributes light evenly. Use a light mover to get lights closer to plants. Keep plants at least 12 inches away from a lamp on a light mover. The closer a lamp is to plants without burning them, the more light plants get!

Light movers make bright light distribution more even. Uniform light distribution makes cannabis grow evenly. Budding branches tend to grow toward and around stationary HID's. These extra-tall spikes of buds shade other foliage. More plants receive more intense light with a lamp moving overhead. This is not a substitute

Watch out for the following:

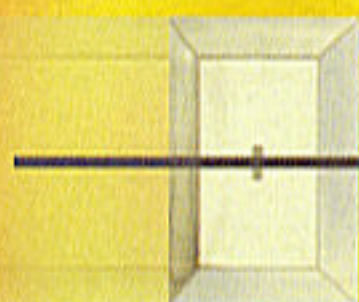
Stretched or leggy plants.

Weak or yellowing plants.

Foliage burned directly under the bulb.

Uneven lighting.

Light mover binding or getting hung up.



This is the approximate coverage of a linear light mover. Note the brightest light is close to the reflector.

for more lumens from an additional lamp. It is a more efficient way to use each HID, especially 1000-watt lamps. A lamp that is directly overhead casts more direct, intense light to a greater number of plants.

Slower-moving light movers are generally more reliable. Fast-moving light movers can cause lightweight reflectors to wobble or list.

Light from a stationary bulb always shines with the same intensity in the same spot. If upper foliage shades lower leaves, growth slows and is uneven. Light, received by plants from several directions, shines more intensely on more foliage. The light energy is being processed by more foliage and promotes even growth. In nature, as the sun arcs overhead, the entire plant gets full benefit of the light. Most varieties of cannabis grow into a classic Christmas tree shape. This is the most efficient configuration for the plant's growth. Light reaches the center of the plant as well as all outside parts.

Commercial light movers supply more intense light to more plants for less money. Growers report that light movers make it possible to use fewer lamps to get the same yield. Light movers increase intense light coverage by 25 to 35 percent. According to some growers, three lamps mounted on motorized light mover(s) will do the job of four lamps.

Motorized light movers keep an even garden profile. The HID draws about 9.2 amperes (A). If this lamp is on a 15 or 20 ampere circuit, you can easily add a light mover that draws one more ampere to the circuit with no risk of overload.

Linear systems move in a straight line simulating the sun's path through the heavens. A linear system increases intense light to plants in a linear oval. The area covered by a light mover depends on the length of the track and the number of lamps. The systems use a track that affixes to the ceiling. The lamp moves back and forth across the ceiling, guided by the track. The lamp is fastened to the mover with an adjustable chain or cord. These units vary in length and the speed at which the lamp travels. Some are designed for one lamp, while others are able to

Setting up a Light Mover Step-by-Step

Step One: Choose the right place.

Step Two: Affix board to the ceiling. Mount light mover track on board. Attach Sun Twist units to a board that is screwed into ceiling joists.

Step Three: Run electrical cord via timer to light mover.

Step Four: Attach supporting electrical wires with cable ties alongside track. You may want to install eyebolts alongside the light track.

Step Five: Reduce vibrations by backing the mounting board with a vibration-absorbing material.

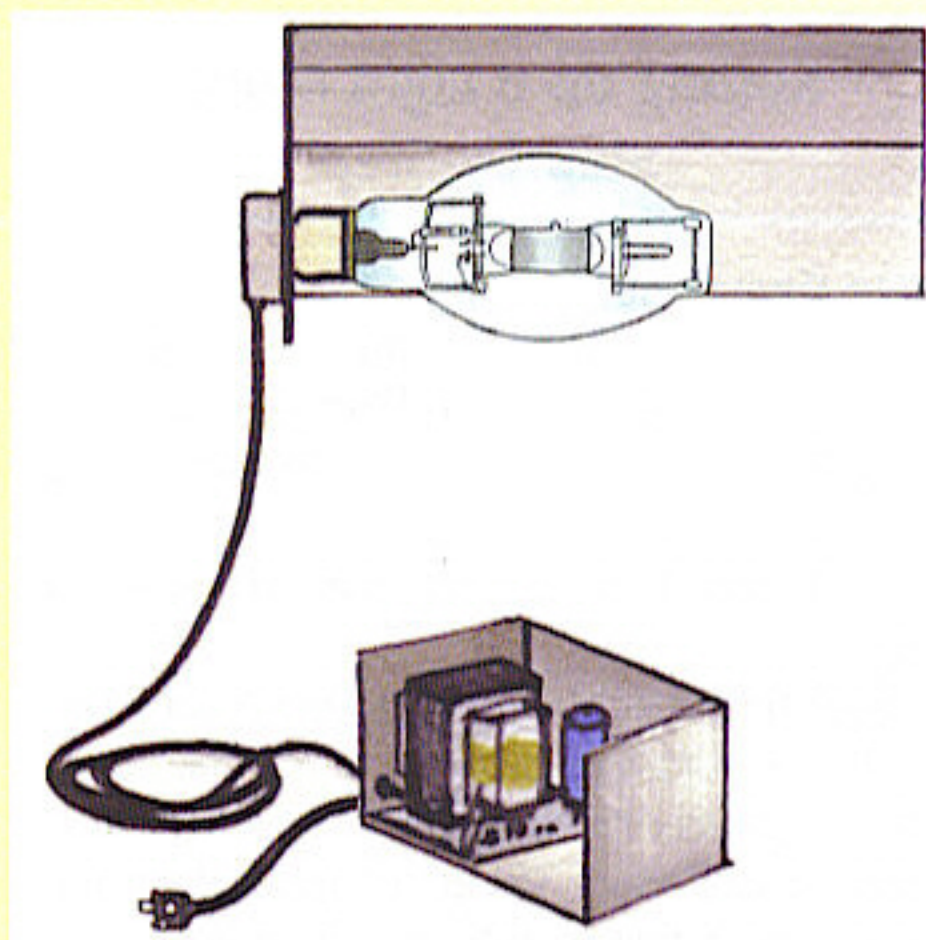


Affix a sturdy board to the ceiling. Mount a light mover on the board with joist below. Run electrical cord via timer to light mover.

move six lamps efficiently. A six-foot linear light mover increases optimum coverage of light from 36 to 72 square feet (3.3 to 6.5 m²).

Young clones and seedlings might stretch and become leggy if the lamp travels too far away. Start using the light movers after the plants are 12 inches (30 cm) tall and have several sets of leaves.

Planter boxes or containers on wheels offer a good alternative to light movers. Containers are rotated daily; wheels make this job a snap. Light reaches every corner of the garden without having to move the lamp. This method has a similar effect as moving the lamp overhead, but is more work because all plants have to be moved, rather than only one or two lamps.



A simple cutaway drawing of a metal halide reveals the transformer and capacitor in a protective metal box. The bulb and hood are attached to the ballast with 14/3-wire and a mogul socket.

High Intensity Discharge (HID) Lights

Growers use HID lamps to replace natural sunlight indoors and grow outstanding cannabis. High intensity discharge lamps out-perform all other lamps in their lumens-per-watt efficiency, spectral balance, and brilliance. The spectrum and brilliance of HID's help growers replicate growth responses induced in cannabis by natural sunlight. Compare charts on HID spectral emission with the chart on photosynthetic response, chlorophyll synthesis, and positive tropism.

The HID lamp family contains mercury vapor, metal halide, High Pressure (HP) sodium, and conversion bulbs. Metal halide, HP sodium, and conversion lamps have a spectrum similar to actual sunshine and can be used to grow marijuana. Mercury vapor lamps were the first HID's on the market. Obsolete mercury vapor lamps are inefficient electrically and produce a poor spectrum for plant growth. Now most all mercury vapor lamps have been retrofitted with more efficient HID's.

Researchers have created a few better bulbs with a higher PAR rating, but there is no new technology in sight. The latest glass covers of the

bulbs have become slightly better at letting light through, but there have been very few major technical advances in these bulbs for the last 20 years.

Popular HID wattages include 150, 175, 250, 400, 430, 600, 1000, and 1100. A 1500-watt metal halide is also available but is not practical for growing. The 1500-watt lamp is designed for stadium lighting and generates too much heat and light to be used efficiently indoors. Smaller 150-250-watt bulbs are popular for small gardens measuring up to three feet square. Brighter 400-1100 lamps are favorites for larger gardens. The 400 and 600-watt bulbs are most popular among European growers. North American growers favor 600 and 1000-watt bulbs. Super efficient 1100-watt metal halides were introduced in 2000.

Incandescent bulbs are the least efficient; 600-watt HP sodium lamps are the most efficient. The brightest bulbs measured in lumens-per-watt are the metal halide and HP sodium bulbs.

Originally developed in the 1970s, metal halides and HP sodium bulbs were characterized by one main technical limitation—the larger the bulb, the higher the lumens-per-watt conversion. For example, watt for watt, a 1000-watt HP sodium produces about 12 percent more light than a 400-watt HPS and about 25 percent more light than a 150-watt HPS. Scientists overcame this barrier when they developed the 600-watt HP sodium. Watt for watt, a 600-watt HPS produces seven percent more light than the 1000-watt HPS. The "pulse start" metal halides are also brighter and much more efficient than their predecessors.

High intensity discharge lamps produce light by passing electricity through vaporized gas enclosed in a clear ceramic arc tube under very high pressure. The dose, or combination of chemicals, sealed in the arc tube determines the color spectrum produced. The mix of chemicals in the arc tube allows metal halide lamps to yield the broadest and most diverse spectrum of light. The spectrum of HP sodium lamps is somewhat limited because of the narrower

band of chemicals used to dose the arc tube. The arc tube is contained within a larger glass bulb. Most of the ultraviolet (UV) rays produced in the arc tube are filtered by the outer bulb. Never look at the arc tube if the outer bulb breaks. Turn off the lamp immediately. Some bulbs have a phosphor coating inside the bulb. This coating makes them produce a little different spectrum and fewer lumens.

General Electric, Iwasaki, Lumenarc, Osram/Sylvania, Philips, and Venture (SunMaster) manufacture HID bulbs. These companies construct many bulbs with the exact same technical statistics. According to some gardeners, certain brands of bulbs are better than others because of where they are manufactured. They usually came to this conclusion because they purchased two different brands of (1000-watt) bulbs and had better luck using one brand. What these gardeners don't know is that many of the manufacturers buy and use the same components, often manufactured by competitors!

Pulse-start metal halides commonly use 240 volts and harbor the starter in the ballast box, not in the arc tube. These systems employ physically smaller reactor ballasts that keep original line voltage within ten percent of the voltage in the arc tube.

Reflective walls increase light in the growing area. Less intense light on the perimeter of gardens is wasted unless it is reflected back onto foliage. Up to 95 percent of this light can be reflected back toward plants. For example, if 500 foot-candles of light is escaping from the edge of the garden and it is reflected at the rate of 50 percent, then 250 foot-candles will be available on the edge of the garden.

Reflective walls should be 12 inches (30 cm) or less from the plants for optimum reflection. Ideally, take walls to the plants. The easiest way to install mobile walls is to hang the lamp near the corner of a room. Use the two corner walls to reflect light. Move the two outside walls close to plants to reflect light. Make the mobile walls from lightweight plywood, Styrofoam, or white

Visqueen plastic.

Using white Visqueen plastic to "white out" a room is quick and causes no damage to the room. Visqueen plastic is inexpensive, removable, and reusable. It can be used to fabricate walls and partition rooms. Waterproof Visqueen also protects the walls and floor from water damage. Lightweight Visqueen is easy to cut with scissors or a knife and can be stapled, nailed, or taped.

To make the white walls opaque, hang black Visqueen on the outside. The dead air space between the two layers of Visqueen also increases insulation.

The only disadvantages of white Visqueen plastic are that it is not as reflective as flat white paint, it may get brittle after a few years of use under an HID lamp, and it can be difficult to find at retail outlets.

Using flat white paint is one of the simplest, least expensive, most efficient ways to create optimum reflection. Artists' titanium white paint is more expensive, but more reflective. While easy to clean, semi-gloss white is not quite as reflective as flat white. Regardless of the type of white used, a non-toxic, fungus-inhibiting agent should be added when the paint is mixed. A gallon of good flat white paint costs less than \$25. One or two gallons should be enough to "white out" the average grow room. But do not paint the floor white—the reflection is detrimental to tender leaf undersides. Use a primer coat to prevent bleed-through of dark colors or stains or if walls are rough and unpainted. Install the vent fans before painting. Fumes are unpleasant and can cause health problems. Painting is labor-intensive and messy, but it's worth the trouble.

About Ballasts

A ballast regulates specific starting requirements and line voltage for specific HID lamps. Wattages from 150-1100 use old-fashioned coil transformer-type ballasts. Smaller wattages—below 100—use energy-efficient electronic ballasts. Electronic ballasts run cool and quiet. Scientists continue to develop electronic ballasts

for larger wattage HID's, but the failure rate is still very high. It is very important to buy the proper ballast for your HID. Smart growers buy the entire HID system—ballast, lamp, socket, connecting wiring, and timer—at the same time from a reputable supplier to ensure the ballast and lamp go together.

Be careful when purchasing ballasts that are made in China or Asia, in general. Many of these ballasts are poorly made and do not meet local safety standards. Do not be tricked by misleading sales phrases such as "all components UL or CSA approved." Of course, each of the components could be UL or CSA approved, but when the components are used together to operate a lamp, they are not UL or CSA approved. Furthermore, chances are that if components are approved, they are not approved for the specific application. Cheap transformers, capacitors, and starters are cheap because they are of inferior quality.

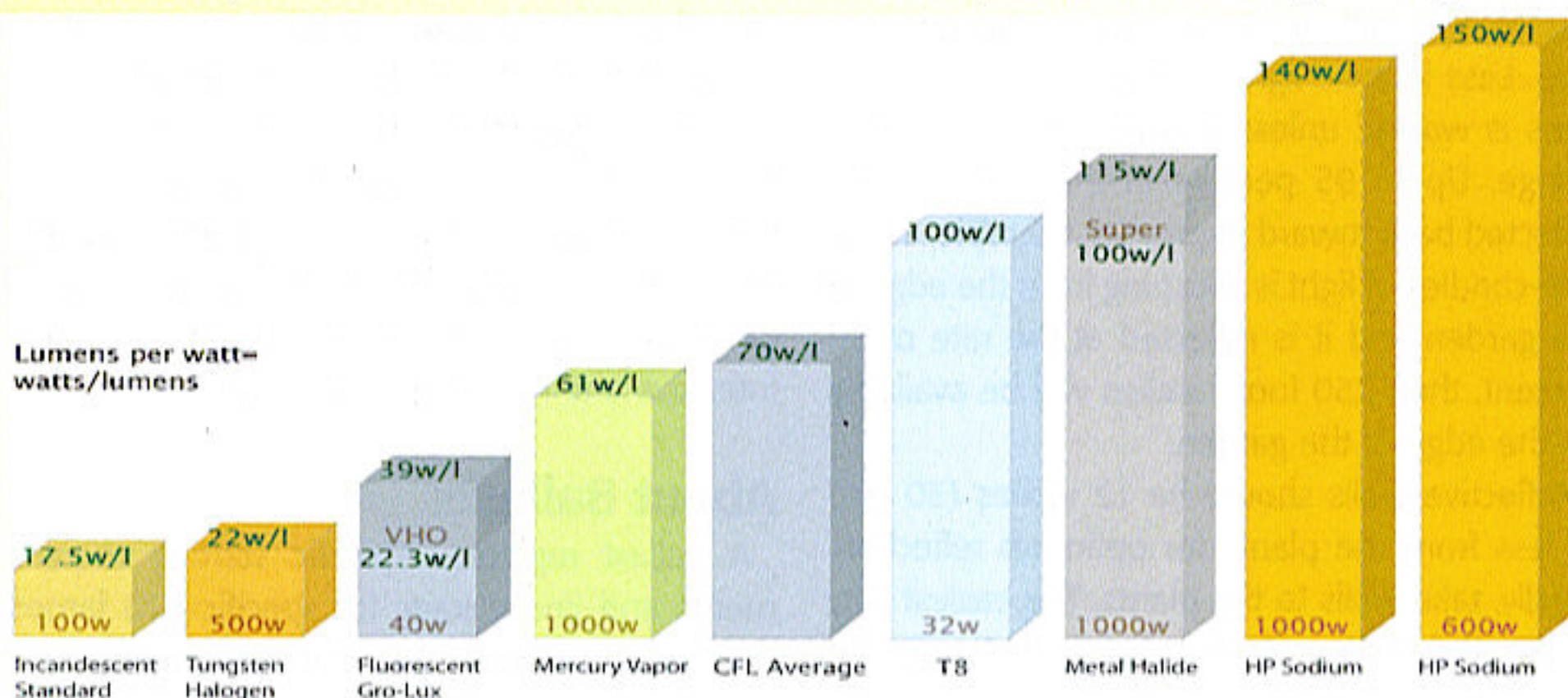
Do not try to mix and match ballasts and lamps. Just because a lamp fits a socket attached to a ballast, does not mean it will work properly in it. If you use the wrong ballast, capacitor, or starter with a lamp, the lamp will not produce the rated amount of light, and it will burn out sooner. The wrong lamp plugged into the wrong ballast adds up to a burnout!

The "core," or transformer, consists of metal plates stuck together by resin and wound with copper wire. The capacitor can is on the right under the connecting wires.

More economical ballast kits contain a transformer core, capacitor (HPS and some metal halides), starter, containing box, and, sometimes, wire. You can purchase components separately from an electrical supply store, but it's a bigger hassle than it's worth. If unfamiliar with electrical component assembly and reading wiring diagrams, purchase the assembled ballast in a package containing the lamp and hood from one of the many HID distributors.

Do not buy used parts from a junkyard or try to use a ballast if unsure of its capacity. Just because a bulb fits a socket attached to a ballast, does not mean that it is the proper system. One of the most miserable gardens I have ever seen was grown with mercury vapor streetlights and makeshift reflective hoods. The grower was low on money, so he pilfered all the street lamps, ballast and all, in front of his house.

Even though HID's have specific ballasting requirements, the ballasts have a good deal in common. The most common characteristics ballasts share are noise and heat. This noise could drive some people to great fits of paranoia! Ballasts operate at 90-150°F (32-60°C). Touch a



The above bar graph shows the lumens-per-watt conversion of different lamps. Notice that except for the 600-watt HPS, the lumens-per-watt conversion factor increases with higher wattage bulbs. The lumens-per-watt formula is used to measure the lamps' efficiency—the amount of lumens produced for the quantity of watts (electricity) consumed.

"strike anywhere" kitchen match to the side to check if it is too hot. If the match lights, the ballast is too hot and should be taken into the shop for assessment. A ballast that runs too hot is noisy and could cause problems or burn out. Heat is the number one ballast destroyer. Many ballasts are manufactured with a protective metal box. This outer shell safely contains the core, capacitor (starter), and wiring. If you build another box around a ballast to dampen noise, make sure there is plenty of air circulation. If the ballast runs too hot, it will be less efficient, burn out prematurely, and maybe even start a fire!

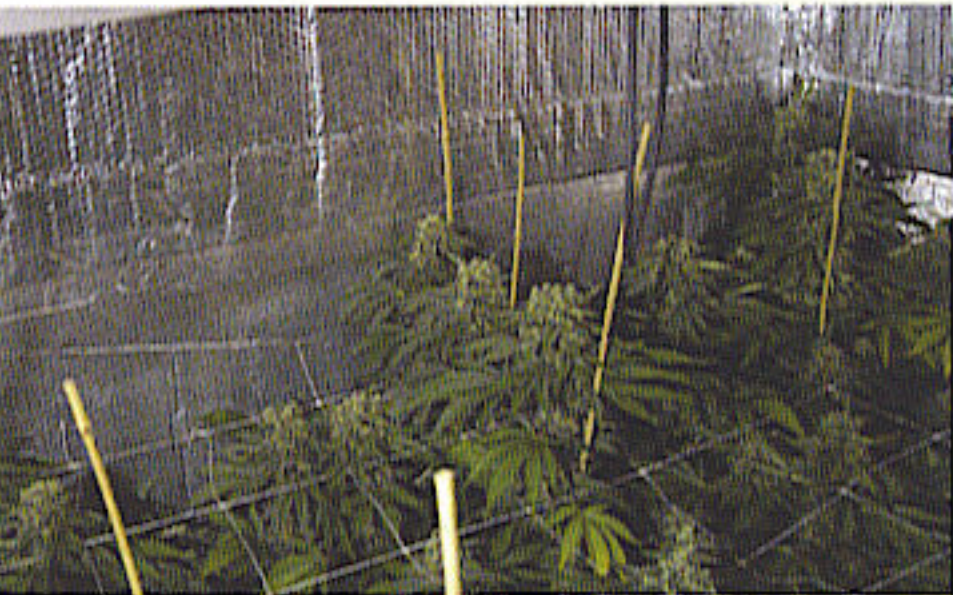
More expensive ballasts are equipped with ventilation fans to maintain cool operating temperatures. Air vents allow a ballast to run cooler. The vents should protect the internal parts and prevent water from splashing in.

Some industrial ballasts are sealed in fiberglass or similar material to make them weatherproof. These ballasts are not recommended. They were designed for outdoor use where heat buildup is not a problem. Indoors, the protection of the sealed unit from weather is unnecessary and creates excessive heat and inefficient operation.

A handle will make the ballast easy to move. A



Plastic Visqueen is easy to clean, and it covers walls completely.



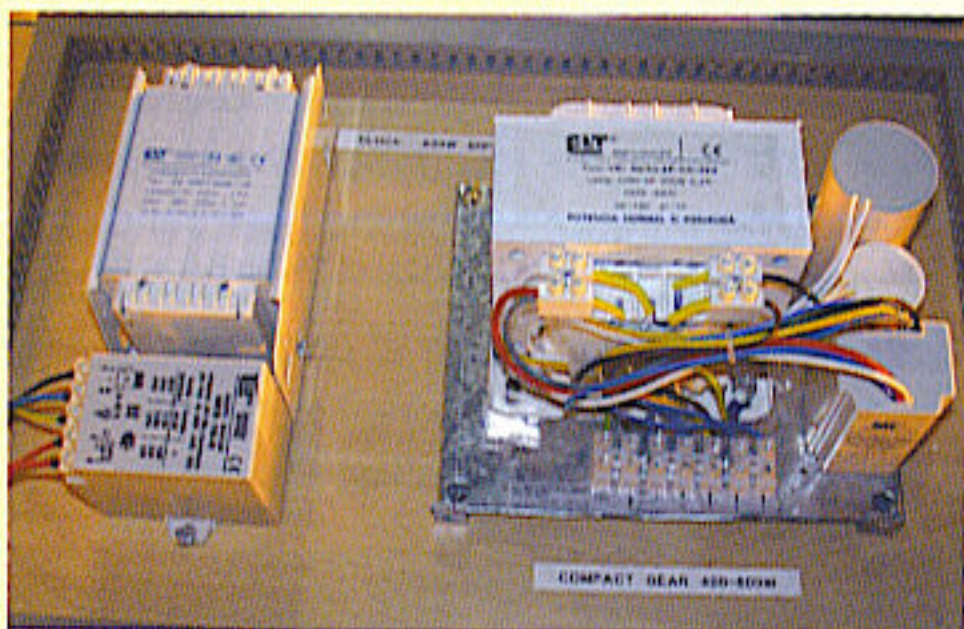
Reflective walls are easy to set up.



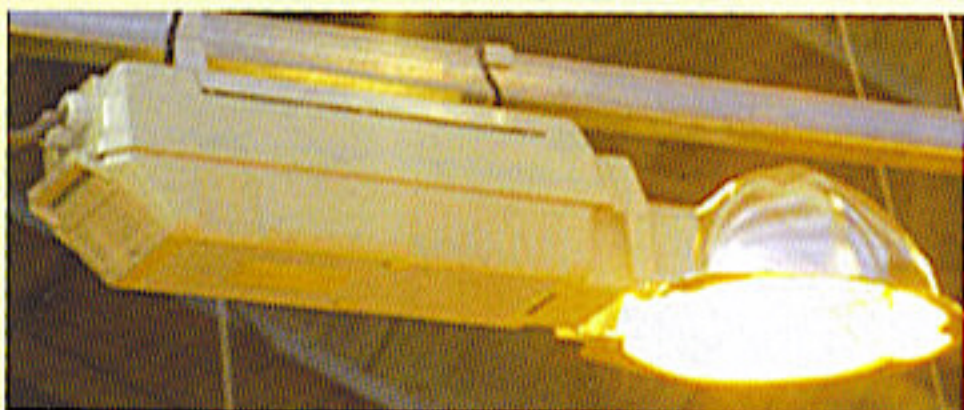
Movable reflective walls are easy to remove for maintenance, and they give the maximum reflection.



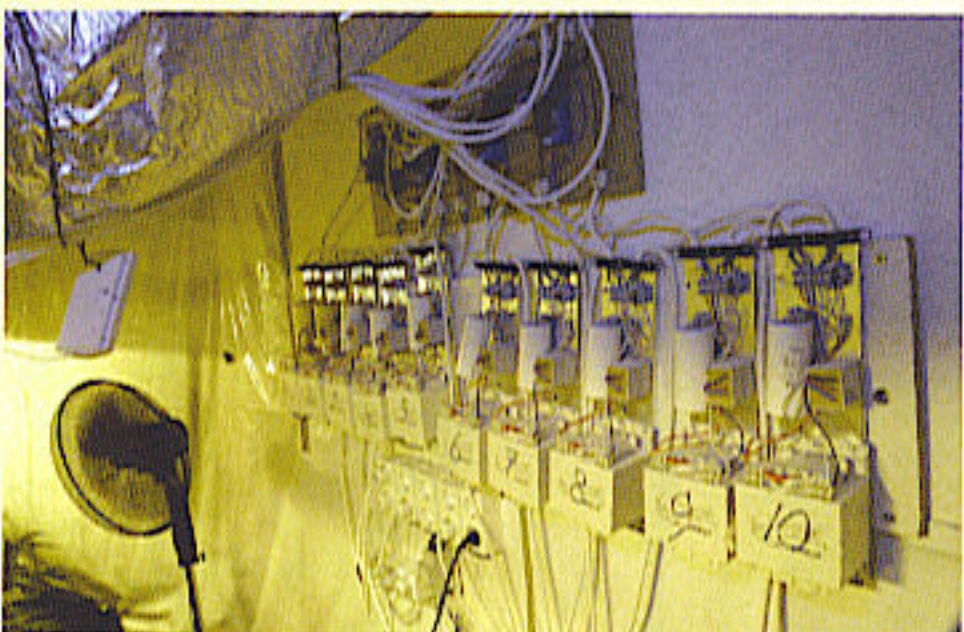
Insulated greenhouse mobile blankets also make great grow room partitions.



Ballast designs are more simple now than ever before. Above, you see two new European ballast designs.



The ballast is attached to the bulb and reflective hood in this greenhouse fixture.



Attach ballasts to the wall on a plank for easy inspection and troubleshooting.



Place ballasts up on shelves so they stay out of the way and out of the splash-range of water.

small 400-watt halide ballast weighs about 30 pounds (14 kg), and a large 1000-watt HP sodium ballast tips the scales at about 55 pounds (25 kg). This small, heavy box is very awkward to move without a handle.

Most ballasts sold by HID stores are "single tap" and set up for 120-volt household current in North America or 240-volts in Europe, Australia, and New Zealand. North American ballasts run at 60 cycles per minute, while European, Australian, and New Zealand models run at 50 cycles per minute. A ballast from Europe, Australia, or New Zealand will not work properly at 60 cycles per minute. Some "multi-tap" or "quad-tap" ballasts are ready for 120 or 240-volt service. Single-tap ballasts accommodate only one voltage, usually 120. Multi-tap ballasts accommodate either 120 or 240-volt service.

It is generally easiest to use the regular 120-volt systems, because their outlets are more common. The 240-volt systems are normally used in Europe, Australia, and New Zealand or in North America when several lamps are already taking up space on other 120-volt circuits. Changing a "multi-tap" ballast from 120 volts to 240 volts is a simple matter of moving the wire from the 120-volt tap to the 240-volt tap. "Single-tap" ballasts cannot change operating voltages. Consult the wiring diagram found on each transformer for specific instructions. There is no difference in the electricity consumed by using either 120 or 240-volt systems. The 120-volt system draws about 9.6 amperes, and an HID on a 240-volt current draws about 4.3 amperes. Both use the same amount of electricity. Work out the details yourself using the chart below.

The ballast has a lot of electricity flowing through it. Do not touch the ballast when operating. Do not place the ballast directly on a damp floor or any floor that might get wet and conduct electricity. Always place it up off the floor, and protect it from possible moisture. The ballast should be suspended in the air or on a shelf attached to the wall. It does not have to be

very high off the ground, just far enough to keep it dry.

Place the ballast on a soft foam pad to absorb vibrations and lower decibel sound output. Loose components inside the ballast can be tightened to further deaden noise caused by vibrations. Train a fan on ballasts to cool them. Cooler ballasts are more efficient, and bulbs burn brighter.

Ballasts can be attached to the light fixture remote. The remote ballast offers the most versatility and is the best choice for most indoor grow shows. A remote ballast is easy to move. Help control heat by placing it on or near the floor to radiate heat in a cool portion of the grow room, or move the ballast outside the garden to cool the room. Attached ballasts are fixed to the hood; they require more overhead space, are very heavy, and tend to create more heat around the lamp.

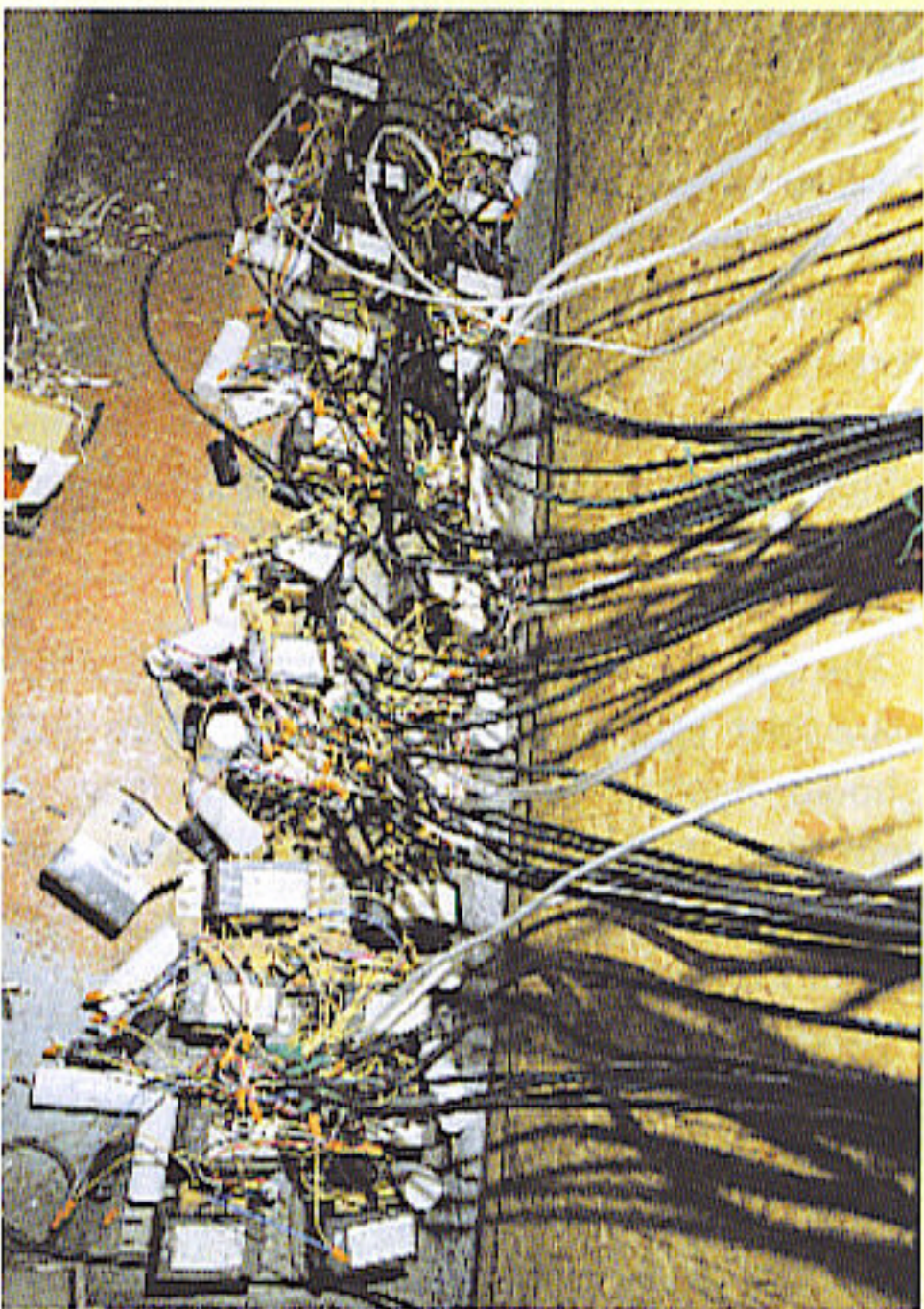
Ballasts may be manufactured with an attached timer. These units are very convenient, but the timer should be constructed of heavy-duty heat-resistant materials. If it is lightweight plastic, it could easily melt under the heat of the ballast.

Ballasts with a switch allow growers to use the same ballast with two different sets of lights. This wonderful invention is perfect for running two flowering grow rooms. The lights go on for 12 hours in one grow room while they are off in a second room. When the lights turn off in the first room, the same ballasts hooked to another set of lights in the second room are turned on. This setup is very popular in Canada.

There are also ballasts to run both metal halide and HP sodium systems. These dual-purpose ballasts are not a good idea. They will work, but they generally over-drive the metal halide bulb causing it to burn out prematurely after accelerated lumen output loss. I do not recommend these types of ballasts. If you have a limited budget and can only afford one transformer, use conversion bulbs to change spectrum. (See *Conversion Bulbs*)



This grower lost the crop! He also almost lost his life! Pay attention to electrical connections, ampere ratings for wire, breaker switches, and connectors.



Stoners have a way of making simple things complex.

About HID Bulbs

Many new HID bulbs have been developed in the last few years. The most notable have been the 430-watt HP sodium, pulse start metal halides, the AgroSun, SunMaster PAR bulbs, and the 1100-watt metal halide. These HID bulbs are also available with many different outer envelopes, so bulbs can fit into more confining reflective hoods.

High intensity discharge bulbs are rated by wattage and by the size of the outer envelope or bulb.

High intensity discharge bulbs come in different shapes and sizes. Below each bulb are the numbers industry uses to define their shape and size.

In general, HID bulbs are designed to be tough and durable. New bulbs are tougher than used bulbs. Once the bulb has been used a few hours, the arc tube blackens, and the internal parts become somewhat brittle. After a bulb has been used several hundred hours, a good bump will substantially shorten its life and lessen its luminescence.

Never remove a warm lamp. Heat expands the metal mogul base within the socket. A hot bulb is more difficult to remove, and it must be forced. Special electrical grease is available to lubricate sockets (Vaseline works too). Lightly smear a dash of the lubricant around the mogul socket base to facilitate bulb insertion and extraction.

The outer arc tube contains practically all of the ultraviolet light produced by HID's. If an HID should happen to break when inserting or removing, unplug the ballast immediately and avoid contact with metal parts to prevent electrical shock.

Always keep the bulb clean. Wait for it to cool before wiping it off with a clean cloth every two to four weeks. Dirt will lower lumen output substantially. Bulbs get covered with insect spray and salty water vapor residues. This dirt dulls lamp brilliance just as clouds dull natural sunlight.

Hands off bulbs! Touching bulbs leaves them with your hand's oily residue. The residue weakens the bulb when it is baked onto it. Most

growers clean bulbs with Windex or rubbing alcohol and use a clean cloth to remove filth and grime, but Hortilux Lighting advises cleaning bulbs with a clean cloth only.

Lumen output diminishes over time. As the bulb loses brilliance, it generates less heat and can be moved closer to the garden. This is not an excuse to use old bulbs; it is always better to use newer bulbs. However, it is a way to get a few more months out of an otherwise worthless bulb.

Write down the day, month, and year you start using a bulb so you can better calculate when to replace it for best results. Replace metal halides after 12 months of operation and HP sodium bulbs after 18 months. Many growers replace them sooner. Always keep a spare bulb in its original box available to replace old bulbs. You can go blind staring at a dim bulb trying to decide when to replace it. Remember, your pupils open and close to compensate for different light levels! One way to determine when to replace a bulb is to examine the arc tube. When the arc tube is very cloudy or very blackened, it is most likely time to replace it.

Bulb Disposal

1. Place the bulb in a dry container, and then place it in the trash.
2. Lamps contain materials that are harmful to the skin. Avoid contact, and use protective clothing.
3. Do not place the bulb in a fire.

Metal Halide Systems

The metal halide HID lamp is the most efficient source of artificial white light available to growers today. It comes in 175, 250, 400, 1000, 1100, and 1500-watt sizes. They may be either clear or phosphor coated, and all require a special ballast. The smaller 175 or 250-watt halides are very popular for closet grow rooms. The 400, 1000 and 1100-watt bulbs are very popular with most indoor growers. The 1500-watt halide is avoided due to its relatively short 2000 to 3000 hour life and incredible heat output. American growers

Ohms Power Law:

$$\text{Volts} \times \text{Amperes} = \text{Watts}$$

$$115 \text{ volts} \times 9 \text{ amperes} = 1035 \text{ watts}$$

$$240 \text{ volts} \times 4 \text{ amperes} = 960 \text{ watts}$$

generally prefer the larger 1000-watt lamps, and Europeans almost exclusively favor 400-watt metal halide lamps.

The main metal halide manufacturers include General Electric (Multivapor), Osram/Sylvania (Metalarc) and Westinghouse (Metal Halide), Iwasaki (Eye), Venture (SunMaster), and Philips (Son Agro). Each manufacturer makes a super halide which fits and operates in standard halide ballasts and fixtures. Super metal halides produce about 15 percent more lumens than standard halides. Super halides cost a few dollars more than standards but are well worth the money.

SunMaster, a division of Venture Lighting, has developed new horticultural metal halide bulbs. The new bulbs are brighter and provide a spectrum better suited to plant growth. Growers prefer the Warm Deluxe bulbs. Check out their web site: www.sunmastergrowlamps.com.

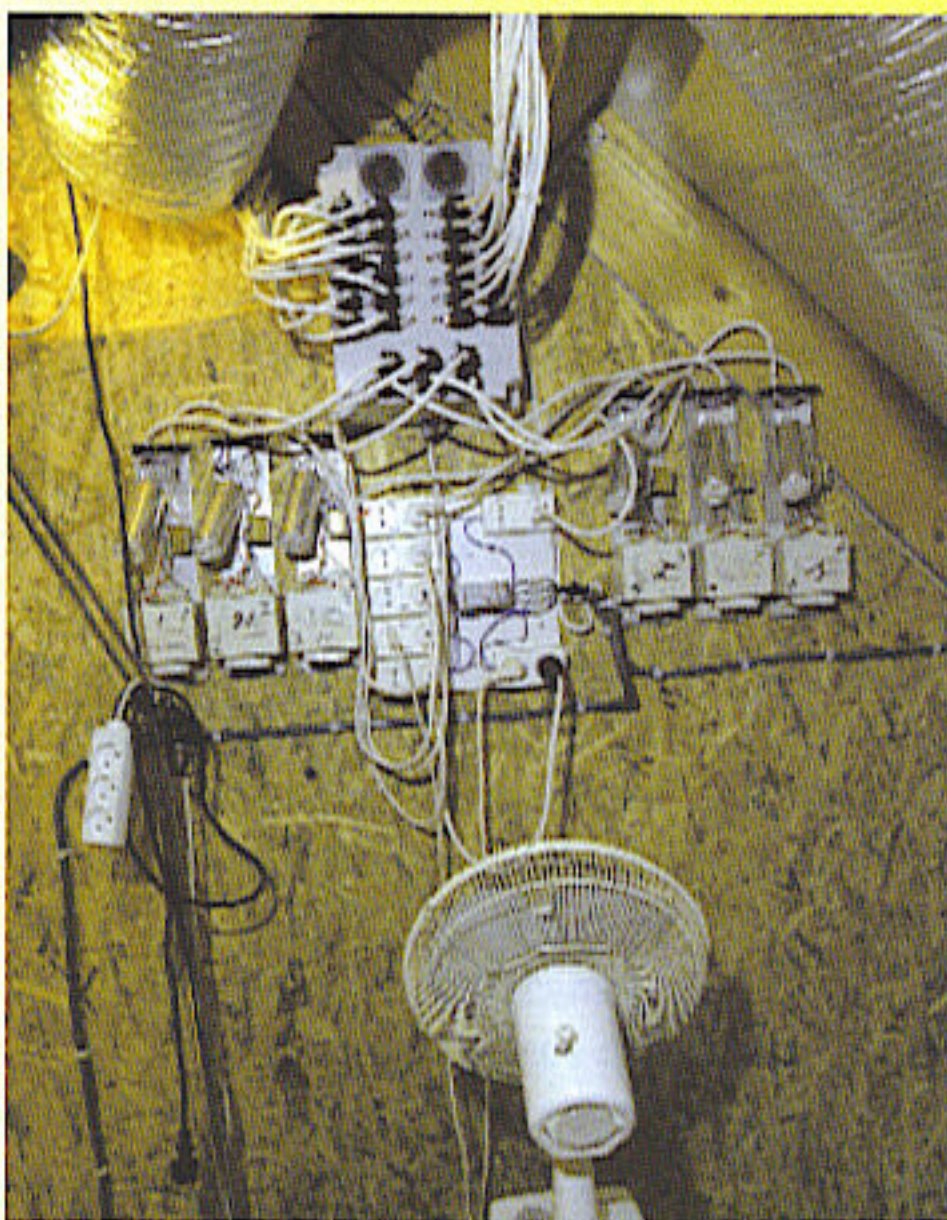
Clear halides are most commonly used by indoor growers. Clear super metal halides supply the bright lumens for plant growth. Clear halides work well for seedling, vegetative, and flower growth.

Phosphor coated 1000-watt halides give off a more diffused light and are easy on the eyes, emitting less ultraviolet light than the clear halides. They produce the same initial lumens and about 4000 fewer lumens than the standard halide and have a slightly different color spectrum. Phosphor-coated halides have more yellow, less blue and ultraviolet light. Phosphor-coated bulbs used to be popular among growers, but this trend has waned over the last ten years because they are not as bright as clear bulbs.

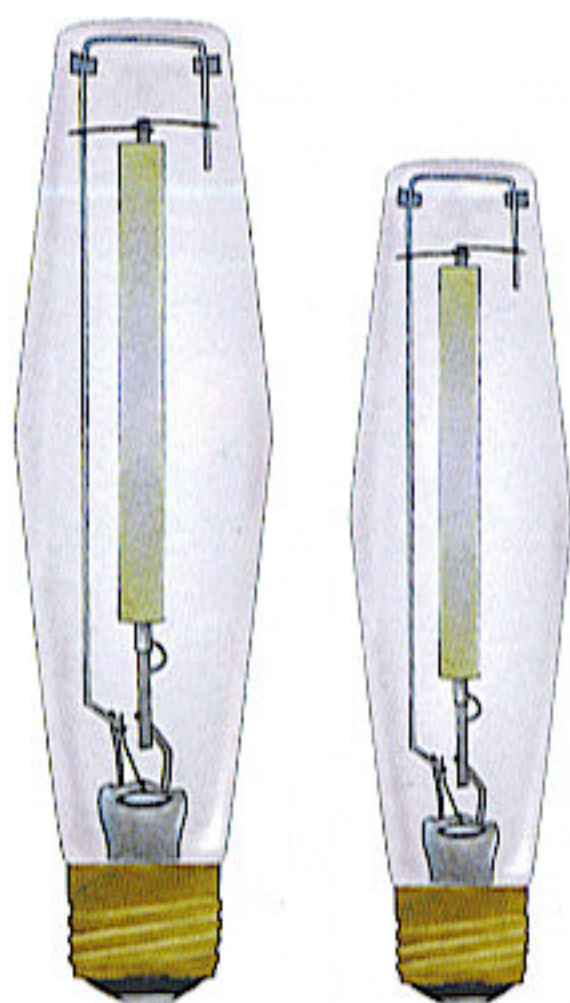
The 1000-watt super clear halides are the most common halides used to grow marijuana in North America. Compare energy distribution charts and lumen output of all lamps to decide which lamp offers the most light for your garden. Typically, a home grower starts with one super metal halide.



BC growers run flowering rooms 24 hours a day with half as many ballasts. This box is made for three transformers, capacitors, and starters to run six 1000-watt HP sodiums. Three lamps run for 12 hours; the other three lamps run for the next 12 hours.



The switch on the top of this photo from Blues Brothers is running twelve 600-watt lamps in a zigzag pattern. A fan is trained on the ballasts and switch to keep them cool.



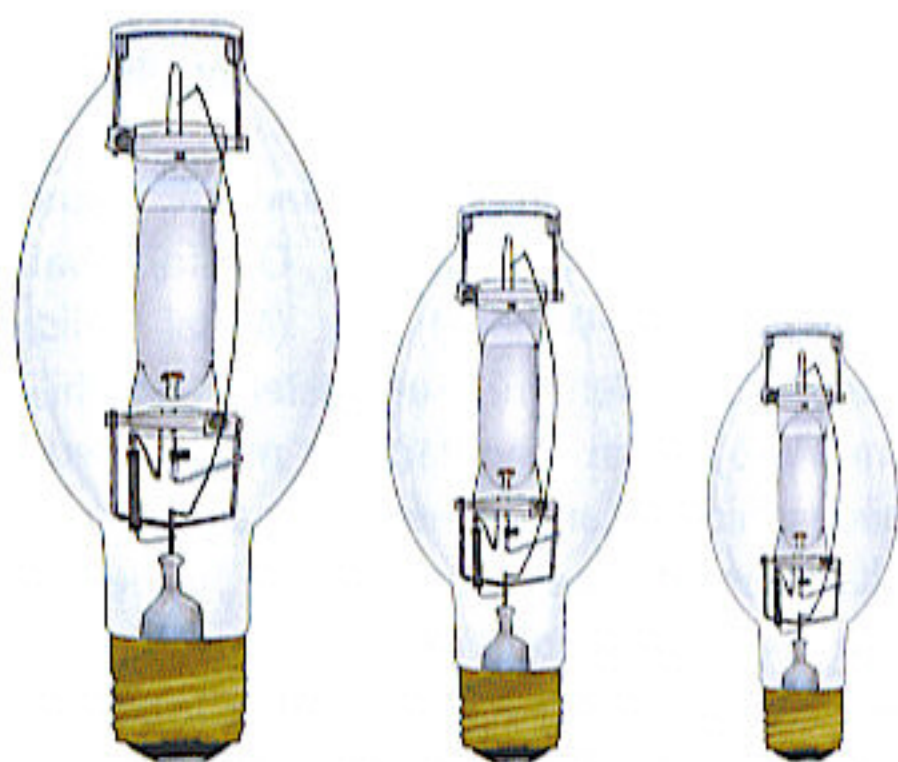
High Pressure Sodium Bulbs

Construction and Operation

Metal halide lamps produce light by passing or arcing electricity through vaporized argon gas, mercury, thorium iodide, sodium iodide, and scandium iodide within the quartz arc tube. After they are in their proper concentrations in the arc tube, the characteristic bright white light is emitted. This process takes about three to five minutes. The metal halide arc system is very complex and requires a seasoning period of 100 hours operation for all of its components to stabilize. If a power surge occurs and the lamp goes out or is turned off, it will take five to fifteen minutes for the gases inside the arc tube to cool before restarting.

The outer bulb functions as a protective jacket that contains the arc tube and starting mechanism, keeping them in a constant environment as well as absorbing ultraviolet radiation. Protective glasses that filter out ultraviolet rays are a good idea if you spend much time in the grow room, or if you are prone to staring at the HID!

When the lamp is started, incredible voltage is necessary for the initial ionization process to take place. Turning the lamp on and off more than once a day causes unnecessary stress on the HID system and will shorten its life. It is best to start



Metal Halide Bulbs

the lamp only once a day, and always use a timer.

The metal halides operate most efficiently in a vertical ± 15 -degree position (see diagram above). When operated in positions other than ± 15 -degrees of vertical, lamp wattage, lumen output, and life decrease; the arc bends, creating non-uniform heating of the arc tube wall, resulting in less efficient operation and shorter life. There are special lamps made to operate in the horizontal or any other position other than ± 15 degrees (see diagram above). These bulbs have "HOR" stamped on the crown or base which refers to horizontal.

Lumen Maintenance and Life

The average life of a halide is about 12,000 hours, almost two years of daily operation at 18 hours per day. Many will last even longer. The lamp reaches the end of its life when it fails to start or come up to full brilliance. This is usually caused by deterioration of lamp electrodes over time, loss of transmission of the arc tube from blackening, or shifts in the chemical balance of the metals in the arc tube. Do not wait until the bulb is burned out before changing it. An old bulb is inefficient and costly. Replace bulbs every 10-12 months or 5000 hours. Electrode deterioration is greatest during start-up. Bulbs are cheap! Throw another one in, and you will be happy!

The halide may produce a stroboscopic (flashing) effect. The light will appear bright, then dim, bright, dim, etc. This flashing is the result of the arc being extinguished 120 times every second. Illumination usually remains constant, but it may pulsate a little. This is normal and nothing to worry about.

Metal Halide Ballasts

Read "About Ballasts." The ballast for a 1000-watt halide will operate standard, clear, and phosphor-coated and super, clear, and phosphor-coated halides on a 120 or 240-volt current. Different ballasts are required for each lamp wattage; 150, 250, 400, 1000, 1100, and 1500. The ballast for each wattage will operate all halides (super or standard, clear or phosphor coated) of the same wattage. Each ballast must be specifically designed for the 150, 250, 400, 1000, 1100, or 1500-watt halides, because their starting and operating requirements are unique.

Metal Halide Bulbs

Universal metal halide bulbs designed to operate in any position, vertical or horizontal, supply up to ten percent less light and often have a shorter life.

SunMaster Warm Deluxe Grow Lamps emit balanced light similar to a 3000 Kelvin source. The enhanced orange-red component promotes flowering, stem elongation, and germination while a rich blue content assures healthy vegetative growth.

Venture manufactures the AgroSun for Hydrofarm. It is an enhanced metal halide bulb with more yellow/orange in the spectrum. To find out more about this lamp, hit the site www.growlights.com.

High Pressure Sodium Systems

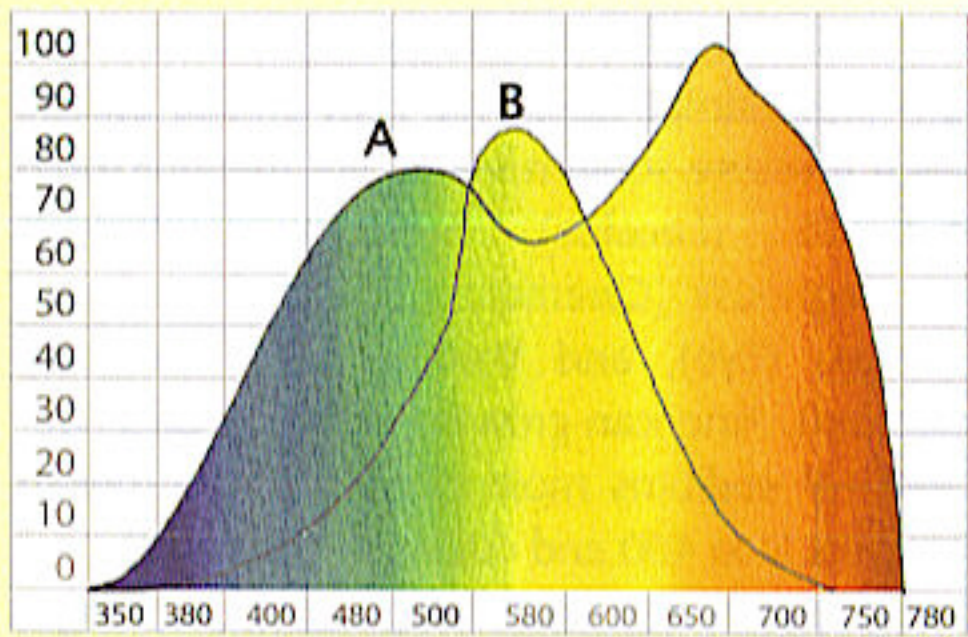
The most impressive fact about the 600-watt high-pressure sodium lamp is that it produces 90,000 initial lumens. The HP sodium is also the most efficient HID lamp available. It comes in 35, 50, 70, 100, 150, 200, 250, 310, 400, 600, and 1000 wattages. Nearly all of the HP sodium

bulbs used in grow rooms are clear. All HP sodium vapor lamps have their own unique ballast. High pressure sodium lamps are manufactured by: GE (Lucalox), Sylvania (Lumalux), Westinghouse (Ceramalux), Philips (Son Agro), Iwasaki (Eye), and Venture (High Pressure Sodium). American growers use 1000 and 600-watt HP sodiums most often, while European growers love 400 and 600-watt HPS lamps.

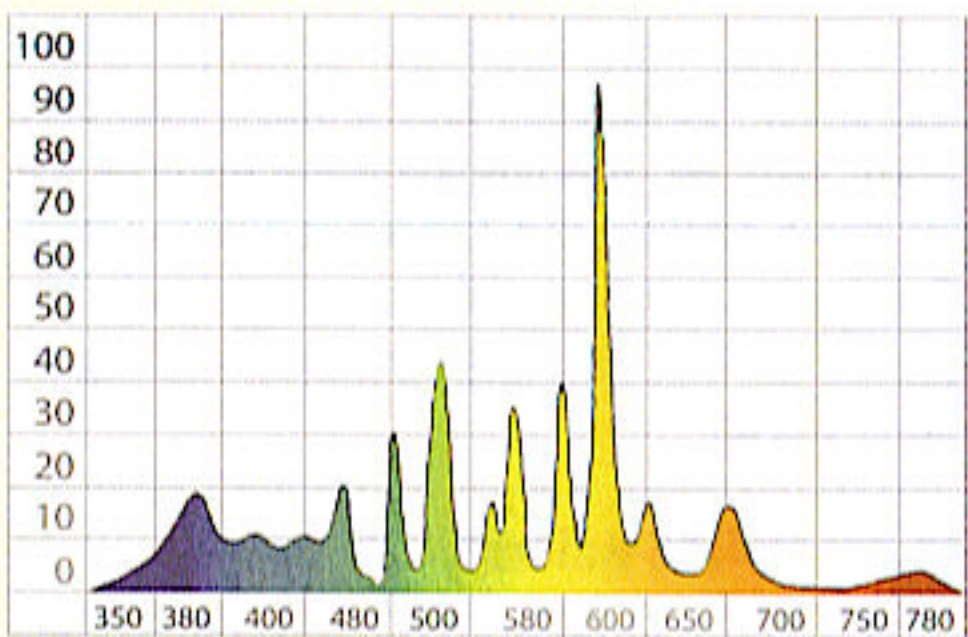
High pressure sodium lamps emit an orange-tinged glow that could be compared to the harvest sun. The color spectrum is highest in the yellow, orange, and red end. For many years, scientists believed this spectrum promoted flower production. However, with the new PAR technology, scientists are rethinking old theories. Marijuana's light needs change when flowering; it no longer needs to produce so many vegetative cells. Vegetative growth slows and eventually stops during blooming. All the plant's energy and attention is focused on flower production so it can complete its annual life cycle. Light from the red end of the spectrum stimulates floral hormones within the plant, promoting flower production. According to some growers, flower volume and weight increase when using HP sodium lights. Other compelling evidence shows the SunMaster halides to be superior. Growers using a 10 × 10-foot (3 m²) room often retain the 1000-watt halide and add a 1000-watt sodium during flowering. Flowering plants need more light to produce tight, full buds. Adding an HP sodium lamp not only doubles available light, it increases the red end of the spectrum. This 1:1 ratio (1 halide and 1 HP sodium) is a popular combination for flowering.

Operation and Construction

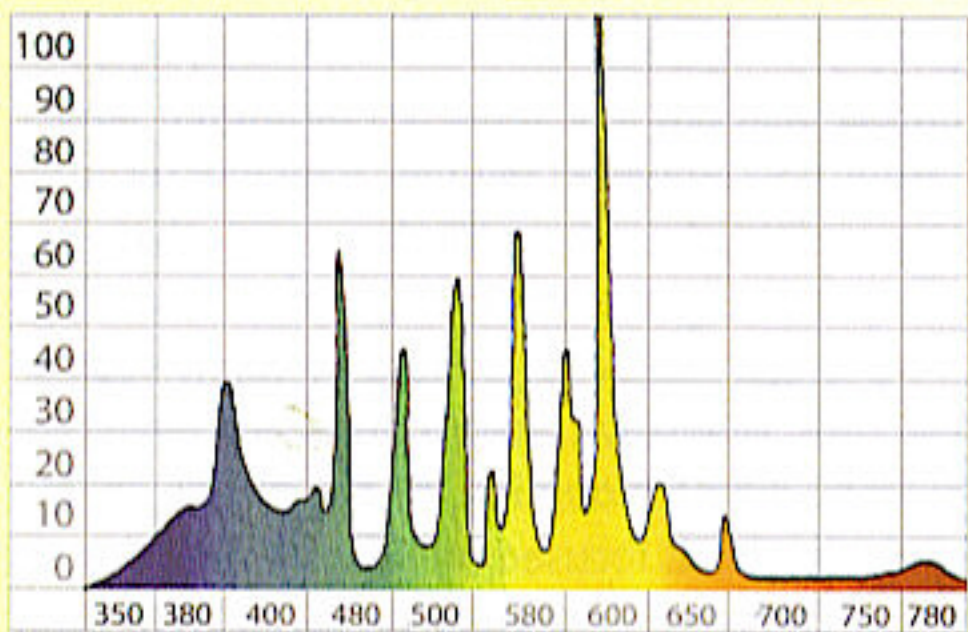
High pressure sodium lamps produce light by passing electricity through vaporized sodium and mercury within an arc tube. The HP sodium lamp is totally different from the metal halide in its physical, electrical, and color spectrum 'characteristics.' An electronic starter works with the magnetic component of the ballast to supply a short, high-voltage pulse. This electrical pulse



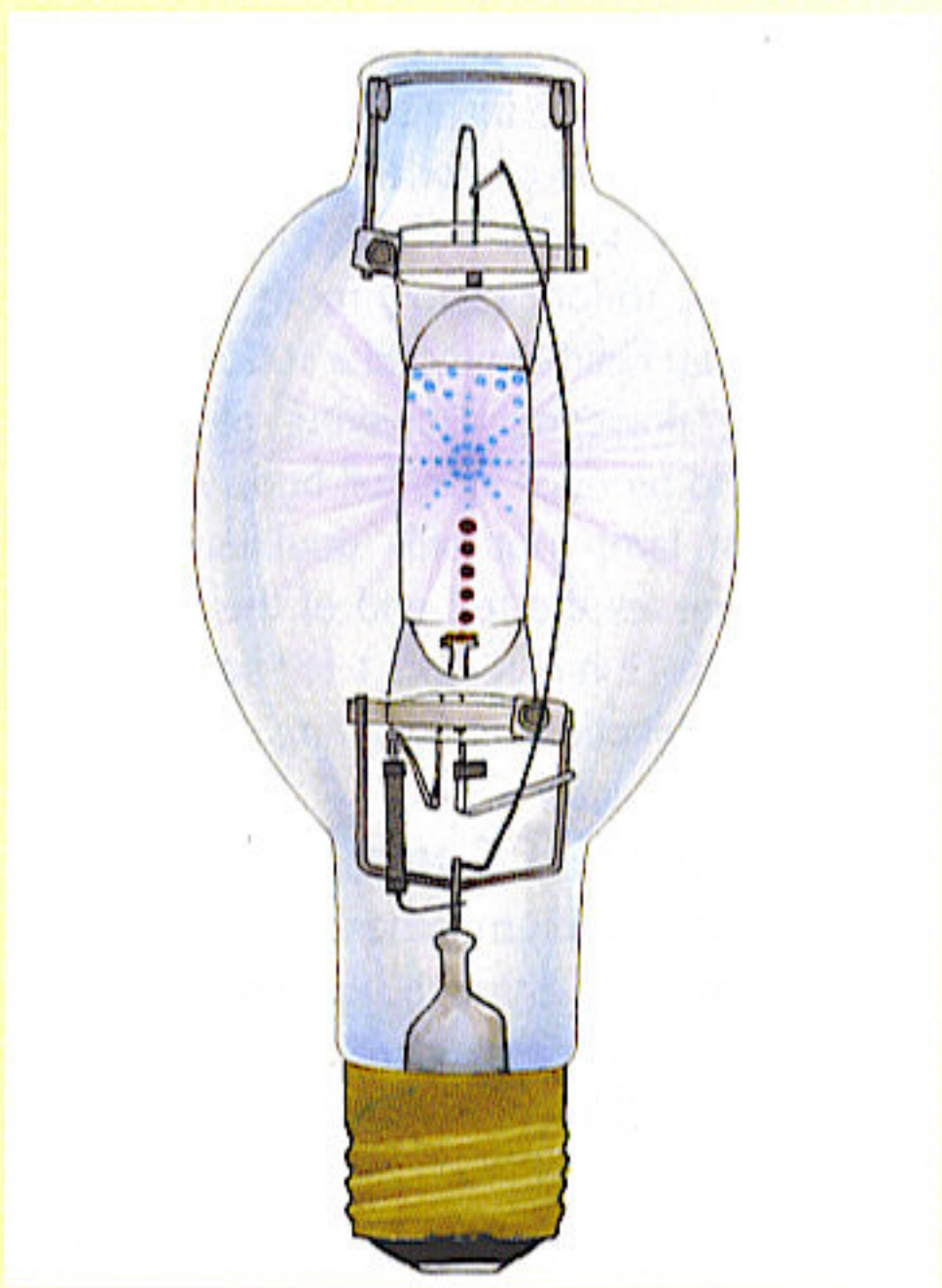
Cool Deluxe SunMaster



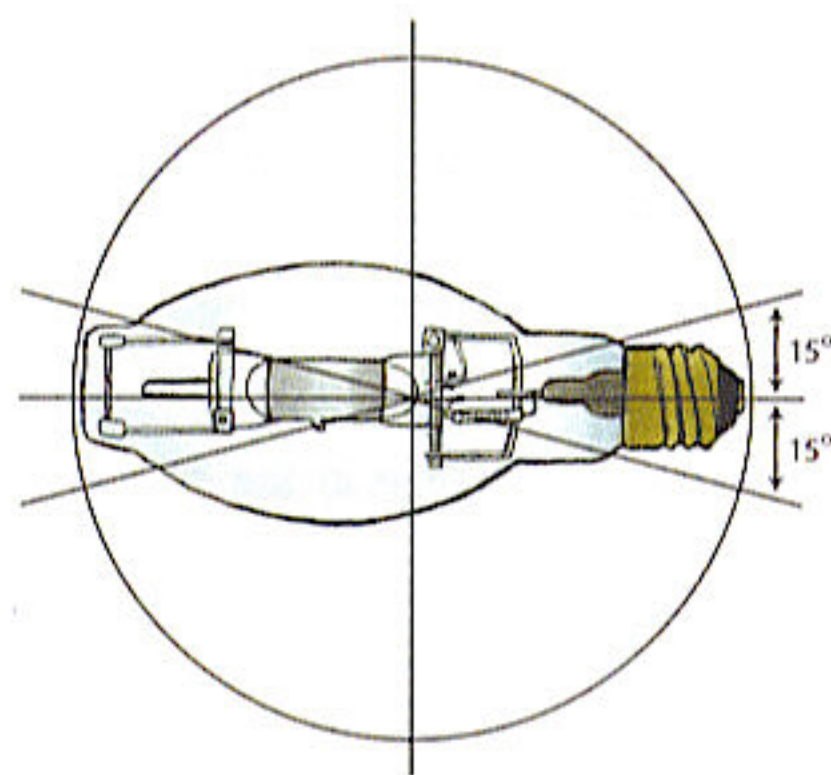
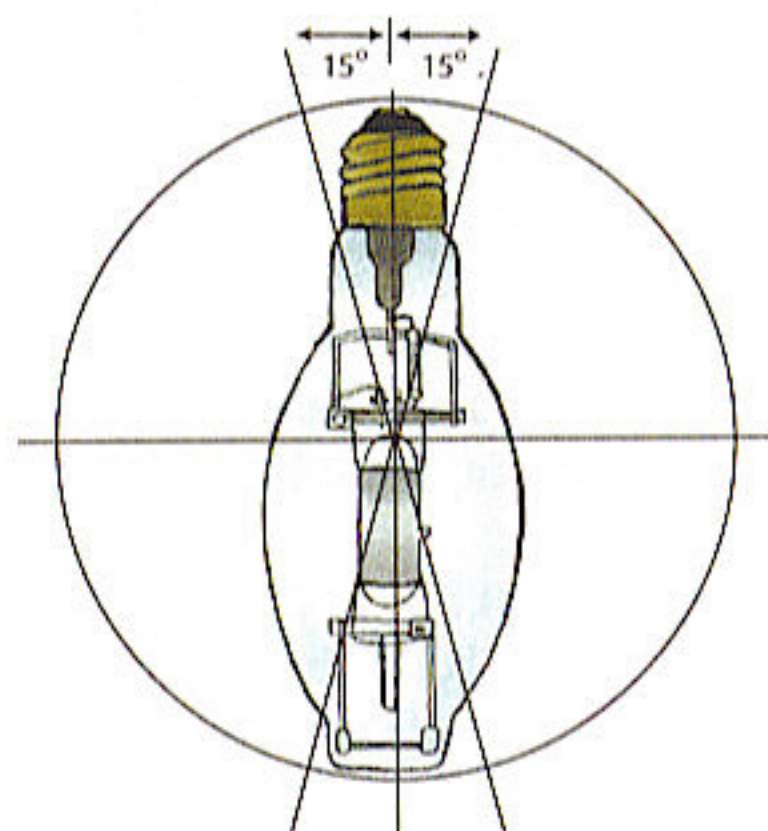
Warm Deluxe Sunmaster



Neutral Deluxe SunMaster



Metal Halide bulb showing reaction.



Base Up (BU) and Base Down (BD) metal halide lamps must be vertical to operate properly. Horizontal (H) lamps must orient the arc tube horizontally to burn brightest.

vaporizes the xenon gas and initiates the starting process that takes three to four minutes. Electricity passes, or arcs, between the two main electrodes. If the lamp is turned off, or power surge occurs and the lamp goes out, the gases in the tube will usually need to cool three to fifteen minutes before restarting is possible.

Similar to the metal halide, the HP sodium has a two-bulb construction, with an outer protective bulb and inner arc tube. The outer bulb, or jacket, protects the arc tube from damage and contains a vacuum, reducing heat loss from the arc tube. The sodium, mercury, and xenon gas are contained within the arc tube and have a constant operating temperature. The lamp may be operated in any position (360 degrees). However, most prefer to hang the lamp overhead in a horizontal operating position.

Life and Lumen Maintenance

High pressure sodium lamps have the longest life and best lumen maintenance of all HID's. Eventually, the sodium bleeds out through the arc tube. Over a long period of daily use, the sodium to mercury ratio changes, causing the voltage in the arc to rise. Finally, the arc tube's operating voltage will rise higher than the ballast is able to sustain. At this point, the lamp will start, warm-up to full intensity, and go out. This sequence is then repeated over and over, signaling the end of the lamp's life. The life of a 1000-watt HP sodium lamp will be about 24,000 hours, or five years, operating at 12 hours per day. Replace HPS bulbs after 18 to 24 months to keep the garden bright.

Sodium Ballasts

Read "About Ballasts." A special ballast is specifically required for each wattage of HP sodium lamp. Each wattage lamp has unique operating voltages and currents during start-up and operation. These voltages and currents do not correspond to similar wattages of other HID lamps. Sodium ballasts contain a transformer that is larger than that of a metal halide, a capacitor, and an igniter or starter. Purchase complete

HID systems rather than a component kit.

HP Sodium Bulbs

High pressure sodium bulbs are used for industrial, residential, and horticultural lighting. The bulbs are inexpensive and readily available. Discount building stores often carry 250 and 400-watt lamps. All HP sodium lamps will grow cannabis. Even though they are brighter, the spectrum contains little blue and more yellow/orange. Lack of color balance makes plants stretch between internodes, but does not necessarily diminish overall harvest.

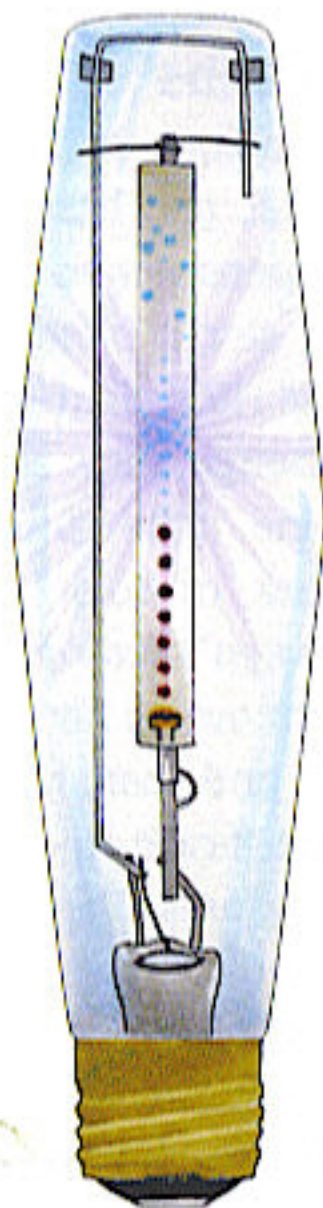
Philips designed and manufactures the 430-watt Son Agro specifically to augment natural sunlight and grow plants. The bulb produces a little more blue light in the spectrum. Adding a touch more blue light helps prevent most plants from becoming leggy. The other enhanced performance HP sodium bulb is the Hortilux by Eye (Iwasaki).

The 600-watt HP sodium increased the lumens-per-watt (LPW) efficiency of high intensity bulbs by seven percent. The 600-watt HP sodium is the most efficient lamp on the market. The 430-watt Son Agro HP sodium bulbs have more blue in the spectrum and run a little hotter than their 400-watt counterpart. The Son Agro bulbs are the choice of European growers.

Conversion Bulbs

Conversion, or retrofit, bulbs increase flexibility. One type of conversion bulb allows you to utilize a metal halide (or mercury vapor) system with a bulb that emits light similar to an HP sodium bulb. The bulb looks like a blend between a metal halide and an HP sodium. While the outer bulb looks like a metal halide, the inner arc tube is similar to that of an HP sodium. A small igniter is located at the base of the bulb. Other conversion bulbs retrofit HP sodium systems to convert them into virtual metal halide systems.

Conversion bulbs are manufactured in 150, 215, 360, 400, 880, 940, and 1000-watt sizes. You do not need an adaptor or any additional equipment. Simply screw the bulb into a compatible ballast of comparable wattage.



HPS + Reaction

Conversion bulbs operate at a lower wattage and are not as bright as HP sodium bulbs. Although conversion bulbs have less blue, they are up to 25 percent brighter than metal halide systems and their lumens-per-watt conversion is better than that of super metal halides. The 940-watt conversion bulb has a lumens-per-watt rating of 138. Similar to the HP sodium lamp, the conversion bulb has a life expectancy of up to 24,000 hours. Unlike most high-pressure sodium lamps which flicker on and off near the end of their lives, conversion bulbs go off and remain off at the end of their lives.

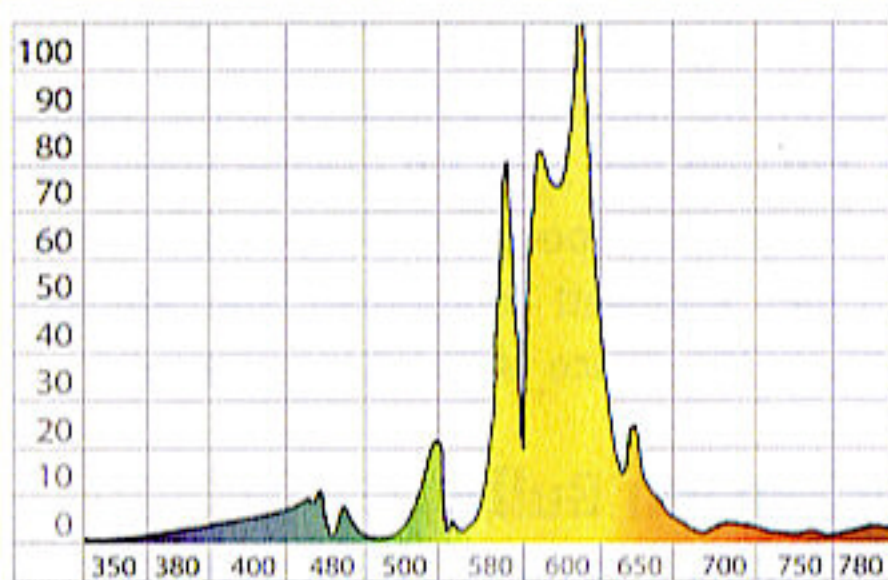
Although conversion bulbs are not inexpensive, they are certainly less expensive than an entire HP sodium system. For gardeners who own a metal halide system, or who deem metal halide the most appropriate investment for their lighting needs, conversion bulbs offer a welcome alternative for bright light. In the United States, CEW Lighting distributes Iwasaki lights. Look for their Sunlux Super Ace and Sunlux Ultra Ace lamps.

Venture, Iwasaki, and Sunlight Supply manufacture bulbs for conversion in the opposite direction, from high-pressure sodium to metal halide. Venture's White-Lux and Iwasaki's White Ace are metal halide lamps which will operate in an HP sodium system. The 250, 400, 1000-watt conversion bulbs can be used in compatible HPS systems with no alterations or additional equipment. If you own a high-pressure sodium system but need the added blue light which metal halide bulbs produce, these conversion bulbs will suit your needs.

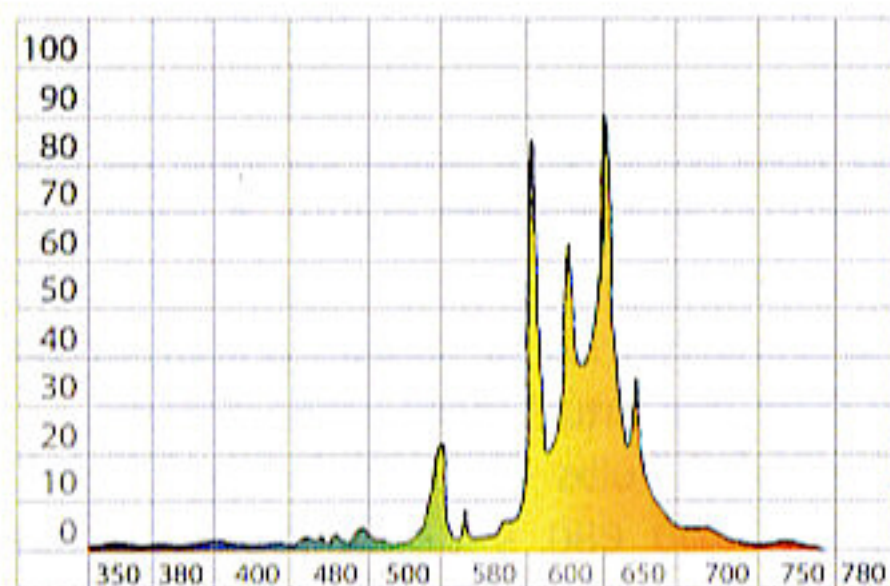
Many gardeners have great success using conversion bulbs. If you have a metal halide system but want the extra red and yellow light of an HP sodium lamp to promote flowering, simply buy a conversion bulb. Instead of investing in both a metal halide and an HP sodium system, you can rely on a metal halide system and use conversion bulbs when necessary, or vice versa.

HP Sodium to Metal Halide

The Sunlux Super Ace and Ultra Ace (Iwasaki)



Spectrum HPS Super



Color spectrum of Son Agro bulb

and Retrolux (Philips) produce an HP sodium spectrum with a metal halide system. These bulbs make it possible to use a metal halide ballast and get the same spectrum as an HP sodium lamp. Lumens-per-watt efficiency is traded for the convenience of using these bulbs. A 1000-watt HP sodium bulb produces 140,000 initial lumens. A MH to HPS conversion bulb produces 130,000 initial lumens. If you only want one lamp, a conversion bulb is a fair choice.

Metal Halide to HP Sodium

The White Ace (Iwasaki) and White Lux (Venture) are conversion bulbs. They have a metal halide spectrum and are used in an HPS system. The bulb converts from HPS to MH and produces 110,000 initial metal halide lumens.

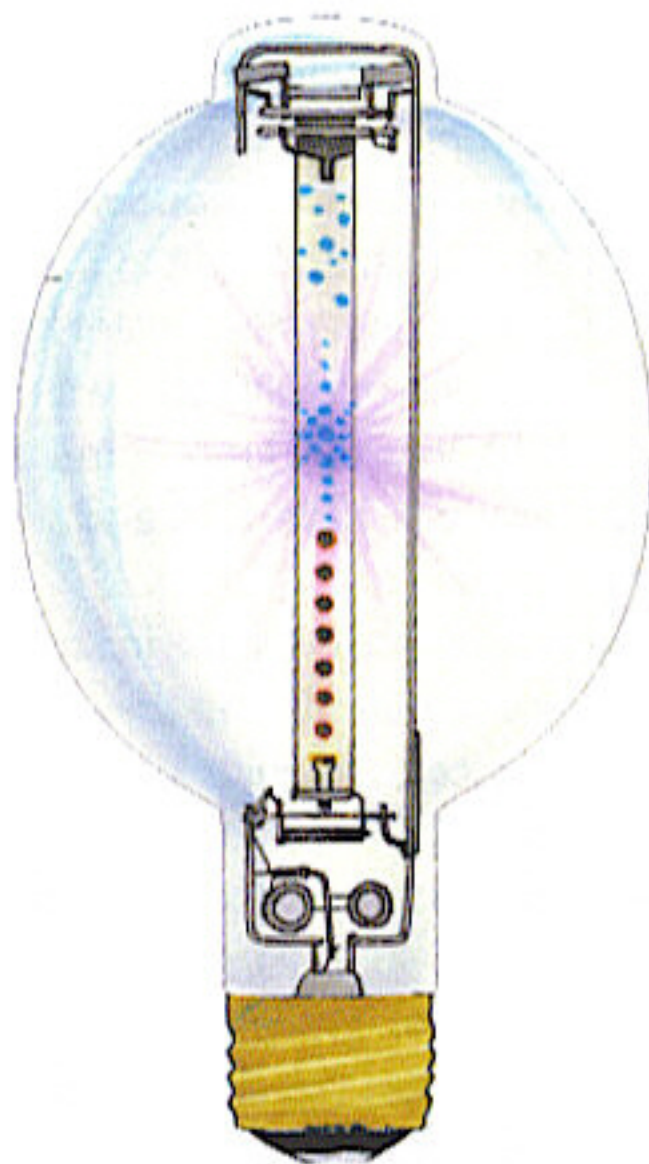
Mercury Vapor Lamps

The mercury vapor lamp is the oldest and best-known member of the HID family. The HID principle was first used with the mercury vapor lamp around the turn of the 20th century, but it was not until the mid 1930s that the mercury vapor lamp was really employed commercially.

Mercury vapor lamps produce only 60 lumens-per-watt. A comparison of the spectral energy distribution of the mercury vapor and the photosynthetic response chart will show this is a poor lamp for horticulture. It is expensive to operate and produces a spectrum with a low PAR value.

Lamps are available in sizes from 40 to 1000-watts. Bulbs have fair lumen maintenance and a relatively long life. Most wattages last up to three years at 18 hours of daily operation.

Bulbs usually require separate ballasts, however there are a few low wattage bulbs with self-contained ballasts. Uninformed growers occasionally try to scrounge mercury vapor ballasts from junk yards and use them in place of the proper halide or HP sodium ballast. Trying to modify these ballasts for use with other HID's will cause problems.



Conversion bulbs make it possible to have both metal halide and HP sodium spectrums at the expense of electrical efficiency.

Fluorescent Lamps

Fluorescent lamps have gone through major changes in recent years. New bulbs produce more light. Most growers use fluorescents to grow clones and small vegetative plants and maintain mother plants. Some growers even use them to flower a crop. Fluorescents are available in many different spectrums, some almost identical to natural sunlight.

Fluorescent lamps are long glass tubes that come in a wide variety of lengths, from one to twelve feet. The two- and four-foot tubes are the easiest to handle and most readily available. Two four-foot fluorescent bulbs in a shop light fixture cost from \$20 to \$30.

Fluorescent lamps work very well for root cuttings. They supply cool, diffused light in the proper color spectrum to promote root growth. Use any "daylight spectrum" fluorescent lamp to root cuttings. Fluorescents produce much less light than HID's and must be very close (two to four inches) to the plants for best results.

Using fluorescents along with HID's is awk-

ward and problematic. When using them in conjunction with HID's, fluorescents must be very close to plants to provide enough intense light to do any good. Fixtures may also shade plants from HID light and generally get in the way.

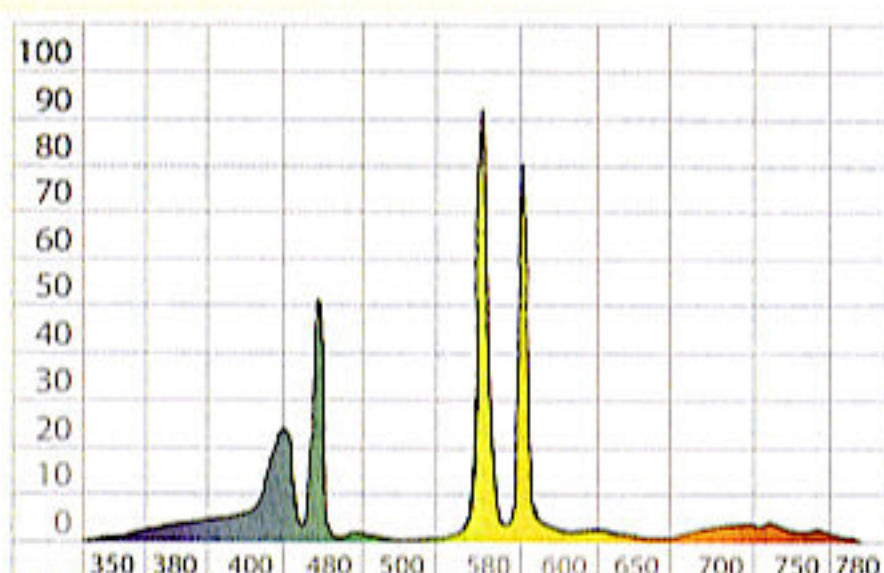
Plants will flower under fluorescent lights. The buds will be small and light, but, with enough fluorescent light, you can grow a mature crop. The grow show will have to literally be lined with fluorescents.

Fluorescent tubes are available in so many different wattages or outputs that they are hard to track! All fluorescents require specific ballasts. The old standard (T12) tubes use about 10 watts per linear foot. A two-foot tube uses about 20 watts, four-foot: 40 watts, etc. The most common bulbs used for growing are available in lengths from 15 inches (38 cm) to four feet (120 cm). Lamps are available in very low to more than 50 watts. Circular fluorescent tubes are also available but used by few growers.

Power twist, or groove type, lamps offer additional lumens in the same amount of linear space. The deep wide grooves give more glass surface area and more light output. Several companies market variations of power twist fluorescents.

Black light fluorescent lamps emit ultraviolet (UV) rays through a dark filter glass bulb, but they are not used to grow cannabis. Ultraviolet light is supposed to promote more resin formation on buds. However, all known experiments that add artificial UV light in a controlled environment have proven that it does not make any difference.

Most of the major lighting manufacturers—GE, Osram/Sylvania, and Philips—make fluorescent lamps in a variety of spectrums. The most common are Warm White, White, Cool White, Full Spectrum, and Daylight. See chart for Kelvin temperatures. Sylvania has the GroLux and the Wide Spectrum GroLux. The Standard GroLux is the lamp to use for starting clones or seedlings. It is designed for use as the only source of light, having the full spectrum necessary for photosynthesis and chlorophyll production. The Wide



Mercury Vapor Spectrum

Full Spectrum?

The term full-spectrum was coined in the 1960s by photo-biologist Dr. John Ott to describe electric light sources that simulate the visible and UV spectrum of natural light. Today there are many fluorescent lamps advertised as "full-spectrum." All fluorescent bulbs marketed as "full-spectrum" grow lights are tri-phosphor-coated. Until photo-biologist Dr John Ott began producing and selling the first "color-corrected" bulbs, all fluorescent lamps were halo-phosphor or deluxe halo-phosphor blends, which did not render the reds well. Tri-phosphor-coated lamps emit the visible light spectrum in spectrums from 2700 K to 6400 K. They simulate colors by mixing the three colors associated with the three cone types in our eyes "specially formulated to replicate all the wavelengths in the visible spectrum."

The term "full-spectrum" has been successful to help sell overpriced lights. Now the market is rampant with hype about the lights. Resellers purchase tri-phosphor bulbs from manufacturers and market them as "Grow Lites." Major lamp manufacturers do not sell tri-phosphor-coated lights as "full-spectrum."

Spectrum GroLux is designed to supplement natural light and covers the blue to far-red regions. Westinghouse has the AgroLight that produces a very similar spectrum to the sun. Warm White and Cool White bulbs used together make excellent lamps to root clones.

Type/model	Kelvin Temperature
Warm White	2700 K
White	3000 K
Neutral	3500 K
Cool White	4100 K
Full Spectrum	5000 K
Daylight	6500 K

Fluorescent bulbs are further classified by diameter and come in the sizes T12 (1.5 inch [5 cm]), T8 (1 inch [3 cm]), T5 (0.625 inch [1.5 cm]) and CFL (see section below "Compact Fluorescent Lamps"). The T12 uses old-fashioned magnetic ballasts. The T8 and the T5 (technically CFL's) use electronic ballasts. Growers prefer slimmer T8 and T5 bulbs with electronic ballasts because they run cooler, electricity cycles faster, and lights do not flicker.

The average lumen output of a 40-watt T12 is 2800 lumens, about 68 lumens per watt.

A 32-watt T8 bulb yields 100 lumens per watt and cranks out 100 average lumens.

A 54-watt T5 throws 5000 average lumens, which means it produces 92 lumens per watt.

Construction and Operation

Fluorescent lamps create light by passing electricity through gaseous vapor under low pressure.

Like the HID family, fluorescents require an appropriate fixture containing a small ballast to regulate electricity and household electrical current. The fixture is usually integrated into the reflective hood. There are several types of fixtures. The most common fluorescent bulbs used for growing are hooked to sockets with bi-pin connectors. If purchasing new tubes, make sure the bulb fits the fixture. The fixture may contain one, two, or four tubes.

A ballast radiates almost all heat produced by the system. The ballast is located far enough away from fluorescent tubes that plants can actually touch them without being burned.

Ballasts will normally last 10-12 years. Used fluorescent fixtures are generally acceptable. The end of a magnetic ballast's life is usually accom-

panied by smoke and a miserable chemical odor. Electronic ballasts simply stop. When the ballast burns out, remove it and buy a new one to replace it. Be very careful if the ballast has brown slime or sludge on or around it. This sludge could contain carcinogenic PCB's. If the ballast contains the sludge, dispose of it in an approved location. Most modern fluorescents are self-starting, but older fluorescents require a special starter. This starter may be integrated into the body of the fixture and hidden from view, or be a small metal tube (about 1 inch [3 cm] in diameter and 0.5-inch long [1 cm]), located at the end of the fixture on the underside. The latter starters are replaceable, while the former require a trip to the electrical store.

If your fluorescent fixture does not work, and you are not well versed in fluorescent troubleshooting, take it to the nearest electric store and ask for advice. Make sure they test each component and tell you why it should be replaced. It might be less expensive to buy another fixture.

The tubular glass bulb is coated on the inside with phosphor. The mix of phosphorescent chemicals in the coating and the gases contained within determine the spectrum of colors emitted by the lamp. Electricity arcs between the two electrodes located at each end of the tube, stimulating the phosphor to emit light energy. The light emission is strongest near the center of the tube and somewhat less at the ends. If rooting just a few cuttings, place them under the center of the fixture for best results.

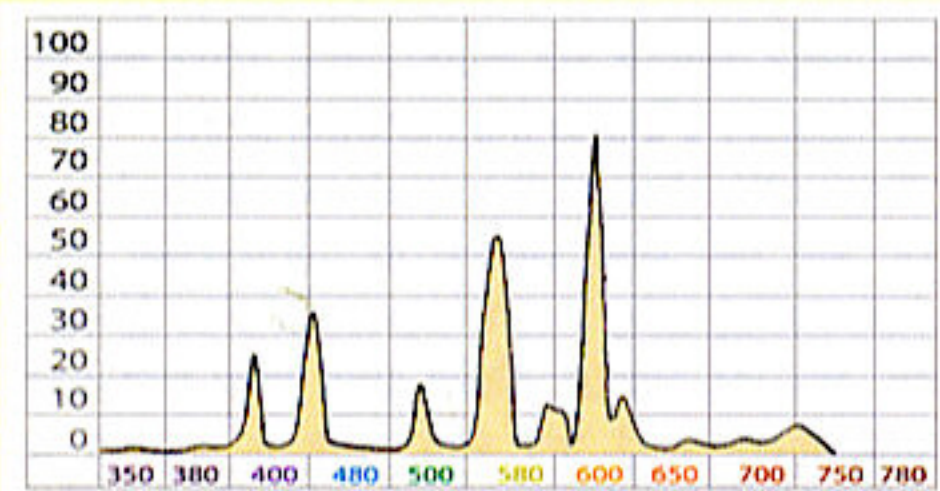
Once the fluorescent is turned on, it will take a few seconds for the bulb to warm-up before an arc can be struck through the tube. Fluorescents blacken with age, losing intensity. Replace bulbs when they reach 70 percent of their stated service life listed on the package or label. A flickering light is about to burn out and should be replaced. Life expectancy ranges from 9000 hours (15 months at 18 hours daily operation).

Compact Fluorescent Lamps

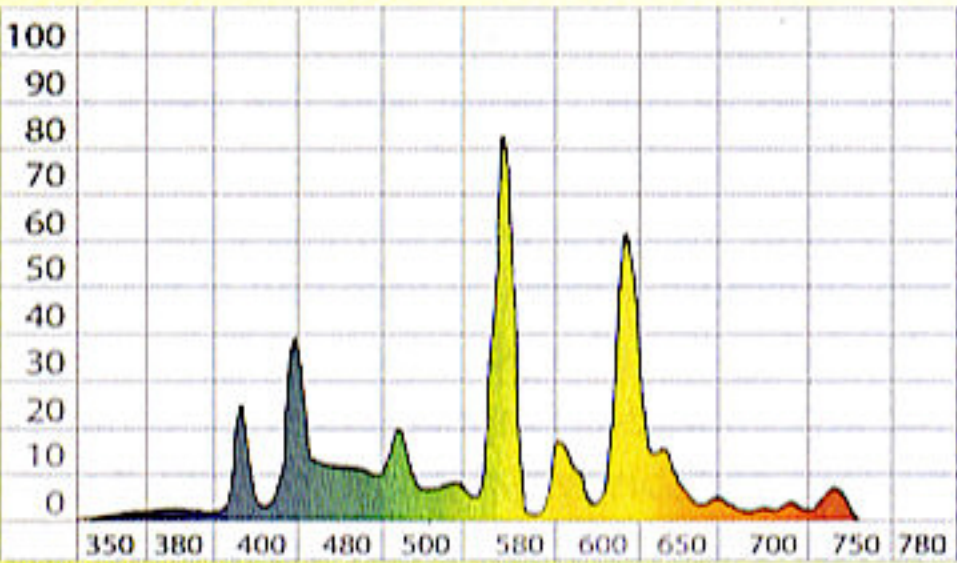
Available since the early 1990s, compact fluo-



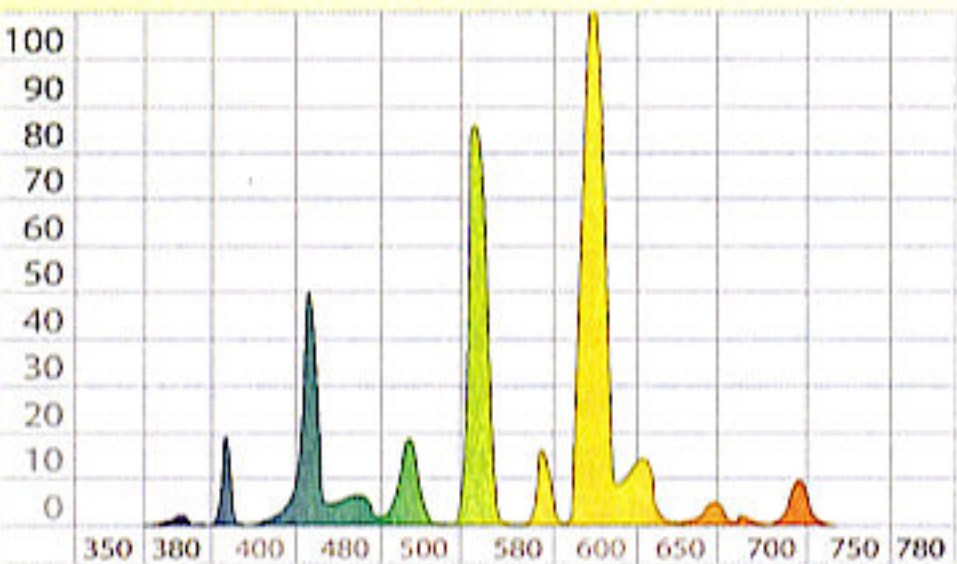
Fluorescent lamps are great for rooting cuttings. Some people even use them to grow cannabis. Buds that flower under fluorescents lack density and weight.



Warm white (2700 K) fluorescent spectrum



Daylight (6400 K) fluorescent spectrum



Cool white (4100 K) fluorescent spectrum

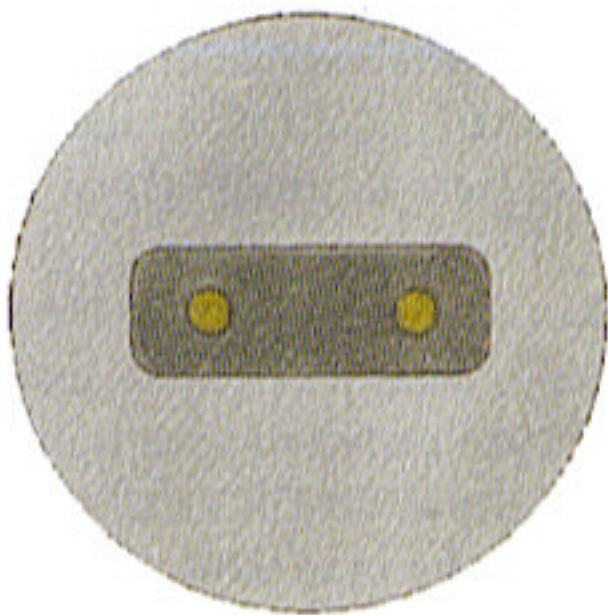
rescent lamps (CFL) are finally available in larger wattages. The larger CFL's are having a major impact on small indoor grow shows. CFL's are similar to long-tube fluorescents but boast increased power, smaller size, and an electronic ballast that ensures longevity and precise spectrum rendition. Although not as bright as HID's they are available in Cool White and Warm White spectrums and generate little heat. Compact fluorescent lamps are perfect for growers with a limited budget and a small space. They run cooler than HID's and require minimal ventilation.

When CFL's were first introduced, wattages were too small, and bulbs did not emit enough light to grow cannabis. New large-wattage CFL's are much brighter than smaller, low-wattage CFL's. Several years ago, European companies started selling 55-watt CFL's and Home Depot began to sell a 65-watt CF flood light for \$30. Soon afterward 95, 125, and 200-watt CF lamps made in China became available in North America and Europe. The new lamps changed the way growers looked at CFL's. The new CFL's provide enough light to grow cannabis from seed to harvest.

Compact fluorescent lamps used to grow cannabis are available in two basic styles and shapes. Modular CFL's have independent bulbs and ballasts that can be replaced separately. The bulb is shaped like a long "U" with a two- or four-pin fixture (these lamps are designated "1U"). The 20-inch (50 cm) long "1U" 55-watt, dual-pin base bulbs are common in Europe. Normally, two 55-watt lamps are placed in a reflective hood. Shorter U-shaped bulbs are common in North America, the United Kingdom, Europe, Australia, and New Zealand.

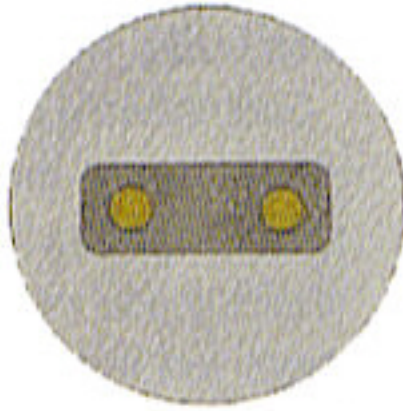
The second type consists of miniaturized fluorescent tubes packaged with an attached (electronic) ballast. The short lamps consist of several U-shaped tubes (designated 4U, 5U, 6U, etc., for the number of U-shaped tubes) that measure from eight to twelve inches (20-30 cm) not including the two- to four-inch (5-10 cm) attached ballast and threaded base. Smaller wattages fit into household incandescent light

T-12



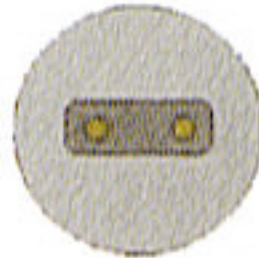
1.5 in 3.8 cm

T-8



1 in 2.5cm

T-5



625 in 1.6cm

bulb sockets. Larger 95, 125, 150, and 200-watt bulbs require a larger mogul socket. Common wattages used for growing cannabis include 55, 60, 65, 85, 95, 120, 125, 150, and 200.

This end view of different sized fluorescent lamps shows their diameters.

Watts	Initial Lumens
26	1800
55	3500
60	4000
65	4500
85	6000
95	7600
12	9000
125	9500
150	12,000
200	15,000

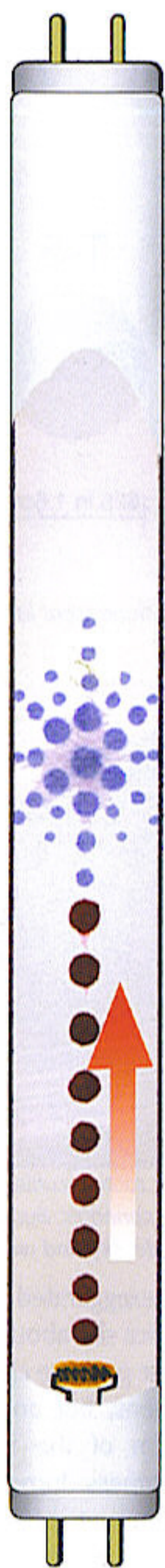
Lighting and specialty stores sell CF lamps, but often charge more than discount warehouse stores. Look for deals at Home Depot and other similar discount stores. Check the Internet, for example, www.lightsite.net is an outstanding site that also has a retail store locator. Philips is producing some of the higher wattage lamps. Their PL-H bulb is a 4U bulb available in 60, 85, and 120 wattages with Kelvin ratings from 3000 to 4100.

Beware of manufacturer and reseller web sites making outrageous claims about CFL perform-



Fluorescent lamps are great for rooting cuttings. Some people even use them to grow cannabis. Buds that flower under fluorescents lack density and weight.

ance. The most common exaggerated claim is found at the Lights of America site about the 65-watt Florex security light. The package claims the lamp produces 6825 lumens, but an asterisk directs you to the bottom of the box and explains these are "brightness lumens" not "photometric lumens." A look at their website www.lightsofamerica.com claims the 65 watt Florex produces 4550 lumens. We tested them and we can agree with 4500 lumens.



The arc tube of a fluorescent lamp is long, emitting light along its entire length.

Furthermore, manufacturers commonly compare the output of CFL's with incandescent lamps. But the comparison is misleading. They claim the 65 watt CFL is equivalent to a 500 watt incandescent. A 65 watt CFL produces the same number of lumens as a 500 watt incandescent bulb. Given this information many people assume that a 65 watt lamp produces as much light as all 500 watt bulbs. Not true.

Cool White CFL's have a kelvin (K) temperature of 4100, with more blue in the spectrum, which lessens internodal branching space in plants. Cool White CFL's are perfect to grow short, stout seedling and vegetative plants. Warm White CFL's (2700 K) have more red in the spectrum and can be used alone but are best used in conjunction with Cool White lamps to avoid internodal stretching during flowering. A 95- to 120-watt lamp will illuminate a space of about two square feet.

Light from CFL's fades fast and must be placed close to the plants. The bulb produces very little heat and can be mounted about two inches (5 cm) away from foliage to achieve the best results.

Short U-shaped bulbs are most efficient when vertically oriented. When mounted horizontally under a reflective hood, much light is reflected back and forth between the bulb's outer envelope and the hood, which markedly lowers efficiency. Heat also builds up from the ballast. Both conditions lessen efficiency.

Save electricity in the grow house and replace incandescent bulbs with compact fluorescents. Compact fluorescents use about 75 percent less energy than incandescent lamps, and emit 90 percent less heat for the same amount of light. If you replace ten 100-watt incandescent bulbs, you will save 750 watts of electricity!

Construction and Operation

Compact fluorescent lamps create light by passing electricity through gaseous vapor under low pressure. Compact fluorescent bulbs are coated inside with tri-phosphor which further expands light emission. CFL's must warm up about five minutes so the chemicals become stable before they come to full brightness. Like all fluorescents, CFL's require an appropriate fixture containing a small electronic ballast to regulate electricity and household electrical current. Ballasts are either attached to the lamp (self-ballasted) or integrated into the reflective hood. Smaller self-ballasted lamps screw into a household incandescent bulb socket. Larger bulbs screw into a mogul socket. Each 1-U bulb is hooked to sockets with bi-pin connectors.

Compact fluorescent lamps will normally last 10-20,000 hours (18-36 months at 18 hours daily use). The life of a CF ballast is from 50,000 to 60,000 hours (seven to nine years at 18 hours

daily use). Lamps with attached ballast burn out three to six times faster than the ballast. When the lamp's life is over, the lamp and the attached ballast are both thrown away, which means you are throwing away a perfectly good ballast! My preference is to use the long CFL's that are not attached to a ballast.

Compact fluorescent lamps can also be used to supplement the reddish-yellow spectrum from HP sodium lamps. However, the outer case covering the attached ballast is susceptible to deterioration from UV light. When used in conjunction with other HID lamps that produce UV rays, the ballast case deteriorates more quickly. Attached ballasts are not designed for humid grow room applications. Couple this weakness to humidity with a bit of UV light, and bulbs burn out more quickly.

The end of ballast life is signaled when it stops. When the ballast burns out, remove and replace it.

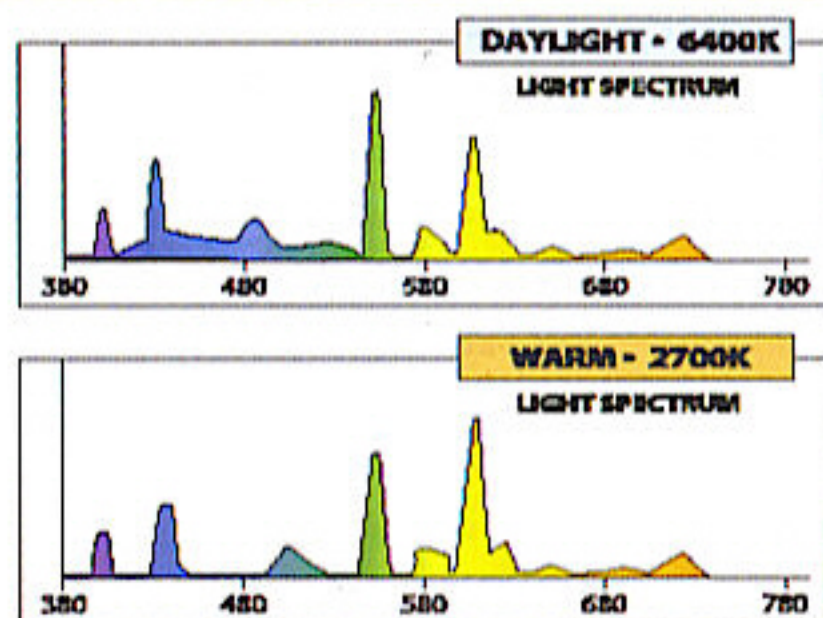
Although CFL's are not considered hazardous waste, they still contain a little mercury and should be disposed of properly to avoid contaminating the environment. Place CFL bulbs in a sealed plastic bag and dispose the same way you do batteries, oil-based paint, motor oil, etc. at your local Household Hazardous Waste (HHW) Collection Site.

Other Lamps

Several other lamps deserve a mention, however, they grow marijuana poorly. Incandescent lamps are inefficient, tungsten halogen lamps are bright but inefficient, and low-pressure sodium lamps are efficient but have a limited spectrum.

Incandescent Lamps

Incandescent lamps were invented by Thomas Edison. Light is produced by sending electricity through the filament, a super fine wire inside the bulb. The filament resists the flow of electricity, heating it to incandescence, causing it to glow and emit light. The incandescent bulbs work on ordinary home current and require no ballast. They come in a wide range of wattages and con-



CFL light spectrums are perfect for growing plants, even cannabis!

structions.

Most incandescent lamps have a spectrum in the far-red end, but there are some incandescent grow lamps that have an enhanced blue spectrum. They are expensive to operate and produce few lumens-per-watt. They are most efficiently used as a source of rooting medium heat for clones rooting under cool fluorescents.

Tungsten Halogen Lamps

The tungsten halogen lamp is a poor grow light. It was originally called Iodine Quartz lamp. The outer tube is made of heat-resistant quartz. The main gas inside the quartz tube was iodine, one of the five halogens. Today, Bromine is used most often in the lamps. Similar to incandescent lamps, they use a tungsten wire filament and a sealed bulb and are very expensive to operate. Their lumens-per-watt output is very low. They run on a household current and require no ballast. Tungsten bulbs are as inefficient to operate as are the incandescent lamps. Their color spectrum is in the far-red end with 10-15 percent in the visible spectrum.

LP Sodium Lamps

Low Pressure (LP) sodium lamps are monochromatic. Do not use these lamps to grow cannabis. They produce light in a very narrow portion of the spectrum, at 589 nanometers, and emit a yellow glow. They are available in wattages from 55 to 180. Their lumens-per-watt conversion is the highest of all lamps on the

market today. Their main use in industry has been for security or warehouse light.

Lamps require specific ballasts and fixtures according to wattage. The fixture for a 180-watt lamp is just a little larger than a fixture for two 40-watt, four-foot (120 cm) fluorescent tubes.

After visiting hundreds and hundreds of grow rooms over the last 20 years, I have seen only one LP sodium lamp in use.

About Electricity

You don't need to understand the basics of electricity to grow indoors or in a greenhouse, but understanding the basics will save you money, time, and possibly the shock of your life.

Before you touch anything electrical, please remember to work backwards when installing electrical components or doing wiring. Start at the bulb, and work towards the plug-in. Always plug in the cord last!

Ampere (amp): is the measure of electricity in motion. Electricity can be looked at in absolute terms of measurement just as water can. A gallon is an absolute measure of a portion of water; a coulomb is an absolute measure of a portion of electricity. Water in motion is measured in gallons per second, and electricity in motion is measured in coulombs per second. When an electrical current flows at one coulomb per second, we say it has one ampere.

Overload Chart

Rating	Available	Overload
15	13	14
20	16	17
25	20	21
30	24	25
40	32	33

Connect only one 1000-watt HID to a 15, 20, or 25 ampere 120-volt (North American) circuit.

Connect two 1000-watt HID's to a 15 ampere 240-volt (European) circuit.

Breaker Switch: ON/OFF safety switch that will turn the electricity OFF when the circuit is overloaded. Look for breaker switches in the breaker panel or breaker box.

Circuit: the circular path that electricity travels. If this path is interrupted, the power will go off. If this circuit is given a chance, it will travel a circular route through your body!

Conductor: something that is able to carry electricity easily. Copper, steel, water, and your body are good electrical conductors.

Fuse: Electrical safety device consisting of a fusible metal that melts and interrupts the circuit when overloaded. Never replace fuses with pennies or aluminum foil! They will not melt and interrupt the circuit when overloaded. This is an easy way to start a fire.

Ground: means to connect electricity to the ground or earth for safety. If a circuit is properly grounded and the electricity travels somewhere it is not supposed to, it will go via the ground wire into the ground (earth) and be rendered harmless. Electricity will travel the path of least resistance. This path must be along the ground wire.

The ground is formed by a wire (usually green, brown, or bare copper) that runs parallel to the circuit and is attached to a metal ground stake. Metal water and sewer pipes also serve as excellent conductors for the ground. Water pipes conduct electricity well and are all in good contact with the ground. The entire system, pipes, copper wire, and metal ground stake conduct any misplaced electricity safely into the ground.

The ground wire is the third wire with the big round prong. The ground runs through the ballast all the way to the hood. High intensity discharge systems must have a ground that runs a

Type/model	Kelvin Temperature
Warm White	2700 K
White	3000 K
Neutral	3500 K
Cool White	4100 K
Full Spectrum	5000 K
Daylight	6500 K

Chapter NINE

LIGHT, LAMPS & ELECTRICITY

continual path from the socket through the ballast to the main fuse box, then to the house ground.

GFI: Ground Fault Interrupt outlets are required anywhere water is used in a home or business. Install GFI outlets in grow rooms to provide an instant, safe electrical shut-off when necessary.

Hertz: Irregular fluctuations or cycles in electricity within a conductor (wire). In the United States, electricity runs at 60 hertz (Hz), or cycles, per second.

Ohm's Power Law: A law that expresses the strength of an electric current: volts $\times$ amperes = watts.

Short Circuit: A short or unintentional circuit formed when conductors (wires) cross. A short circuit will normally blow fuses and turn off breaker switches.

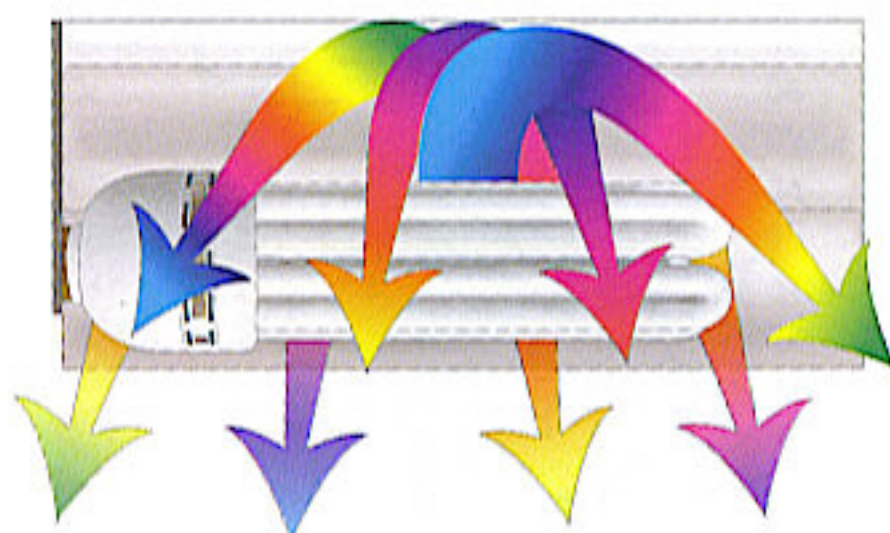
Volts: Electricity is under pressure or electrical potential. This pressure is measured in volts. Most home wiring is under the pressure of approximately 120 or 240 volts.

Watts: are a measure of work. Watts measure the amount of electricity flowing in a wire. When amperes, (units of electricity per second) are multiplied by volts (pressure), we get watts. 1000 watts = 1 kilowatt.

A halide lamp that draws about 9.2 amperes $\times$ 120 volts = 1104 watts. Remember Ohm's



Each of the 20-inch (50-cm) bulbs uses 55 watts of electricity.

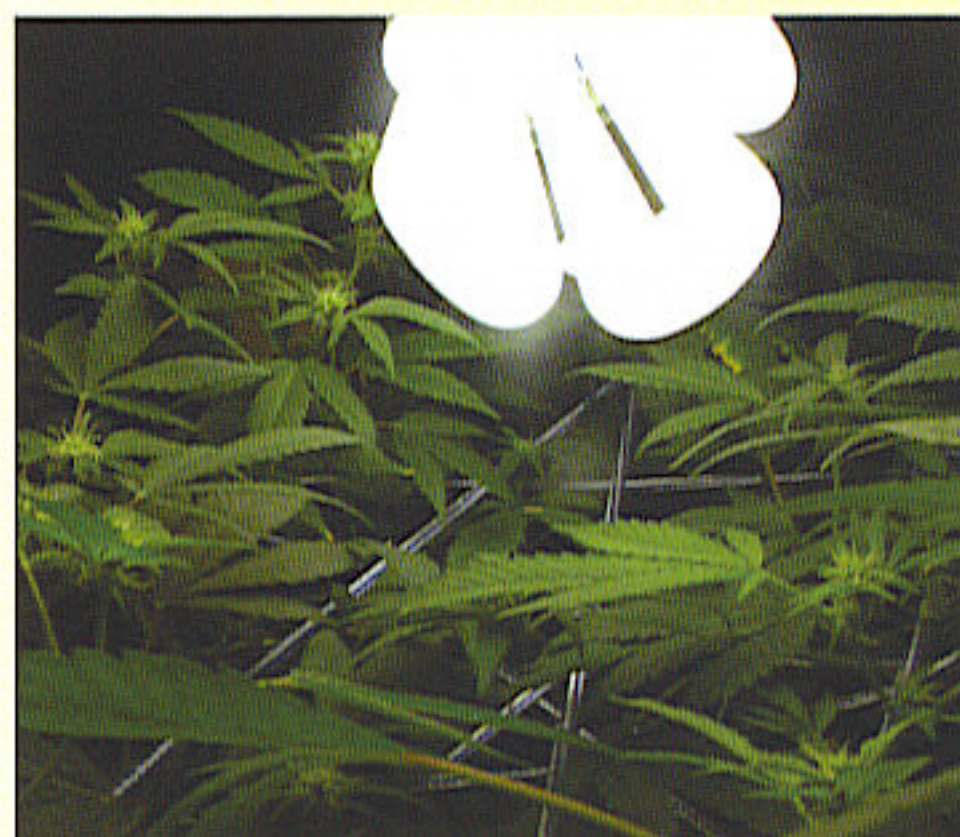


A horizontal reflector is not as efficient as vertical operation with no reflector with this bulb.



The ballast is attached to the lamp in this compact fluorescent.

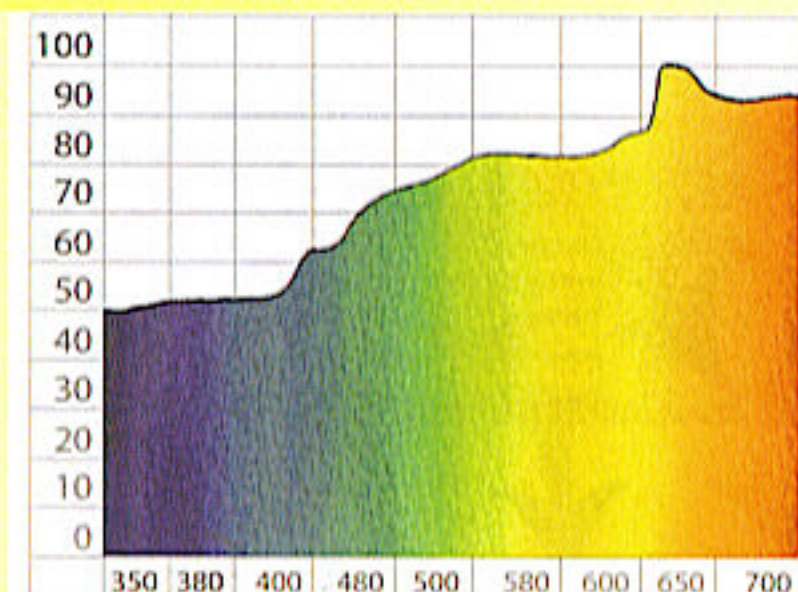
Compact fluorescent lamp box shows 65 actual watts that is comparable to a 500-watt incandescent.



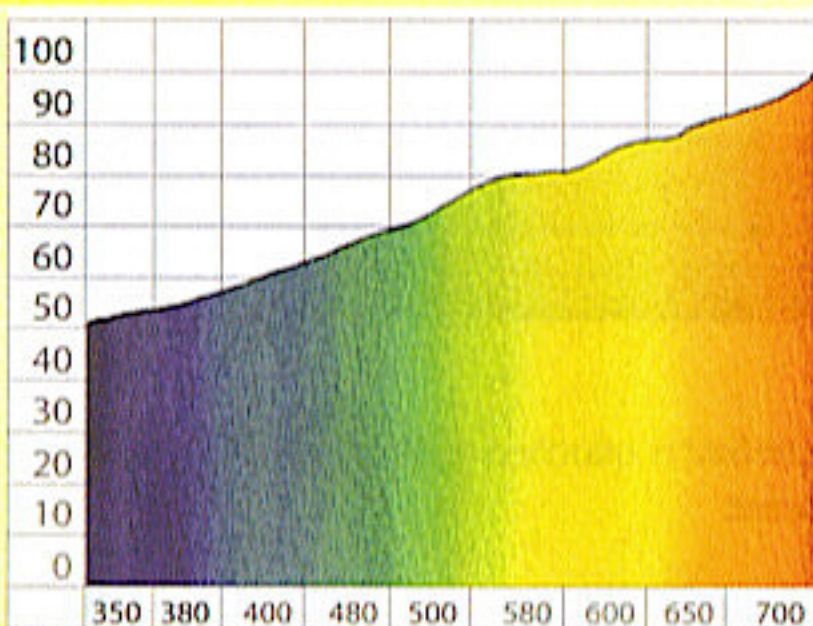
CF lamps produce plenty of light of the proper spectrum to grow and flower a decent crop.



The inside of an electronic CFL ballast is compact and creates very little heat.



The light spectrum of an incandescent lamp will grow plants but is best suited to generating heat.



Tungsten halogen bulbs really crank in the red end of the spectrum. Too bad they are so inefficient.



Tungsten halogen lamps are a poor choice to grow cannabis.

Power Law: $\text{amps} \times \text{volts} = \text{watts}$. This is strange; the answer was supposed to be 1000 watts. What is wrong? The electricity flows through the ballast, which uses energy to run. The energy drawn by the ballast must amount to 104 watts.

Watt-hours: measure the amount of watts that are used during an hour. One watt-hour is equal to one watt used for one hour. A kilowatt-hour (kWh) is 1000 watt-hours. A 1000-watt HID will use roughly one kilowatt per hour, and the ballast will use about 100 watts. Electrical bills are charged out in kWh.

Electrical wire comes in many thicknesses (gauges) indicated by number. Higher numbers indicate smaller wire and lower numbers indicate larger wire. Most household circuits are connected with 14-gauge wire. Wire thickness is important for two reasons—ampacity and voltage drop. Ampacity is the amount of amperes a wire is able to carry safely. Electricity flowing through wire creates heat. The more amps flowing, the more heat created. Heat is wasted power. Avoid wasting power by using the proper thickness of well-insulated wire (14-gauge for 120-volt applications and 18-gauge for 240-volts) with a grounded wire connection.

Using too small of a wire forces too much power (amperes) through the wire, which causes voltage drop. Voltage (pressure) is lost in the wire. For example: by forcing an 18-gauge wire to carry 9.2 amperes at 120 volts, it would not only heat up, maybe even blowing fuses, but the voltage at the outlet would be 120 volts, while the voltage ten feet away could be as low as 108. This is a loss of 12 volts that you are paying for. The ballast and lamp run less efficiently with fewer volts. The further the electricity travels, the more heat that is generated and the more voltage drops.

A lamp designed to work at 120 volts that only receives 108 volts (90 percent of the power it was intended to operate at), would produce only 70 percent of the normal light. Use at least 14-gauge wire for any extension cords, and if the cord is to carry power over 60 feet, use 12-gauge wire.

Chapter NINE

When wiring a plug-in or socket:
The hot wire attaches to the brass or gold screw.
The common wire attaches to the aluminum or silver screw.
The ground wire always attaches to the ground prong.
Take special care to keep the wires from crossing and forming a short circuit.
Plugs and outlets must have a solid connec-



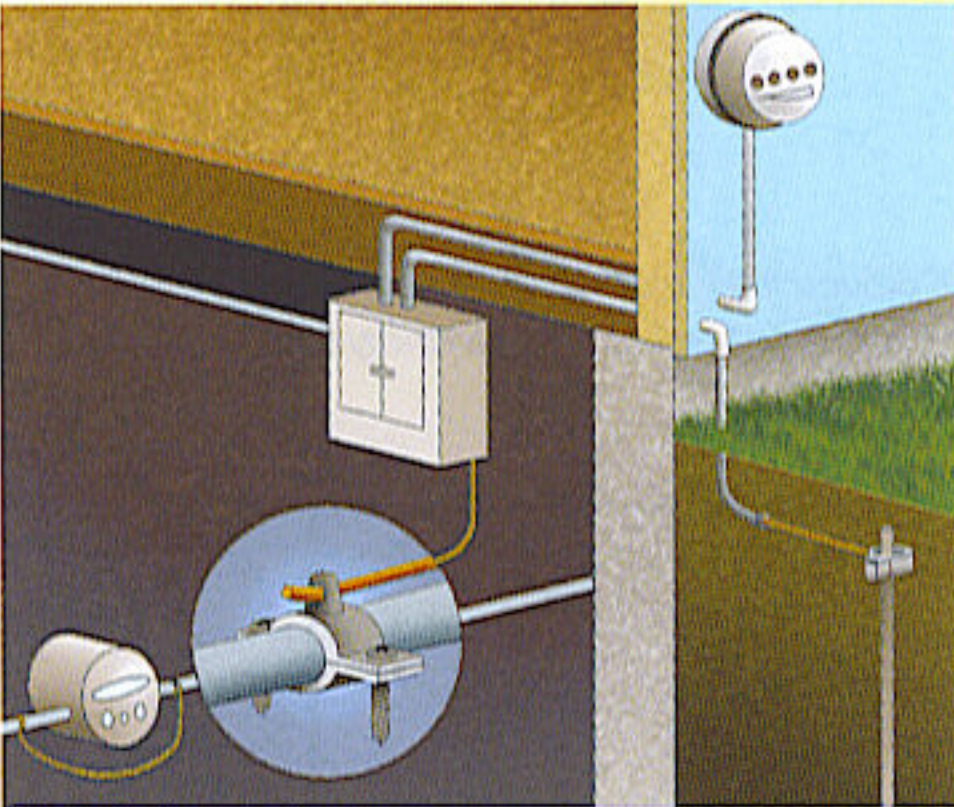
Water and electricity don't mix. Always work with a grounded system, and keep all standing water off the floor!



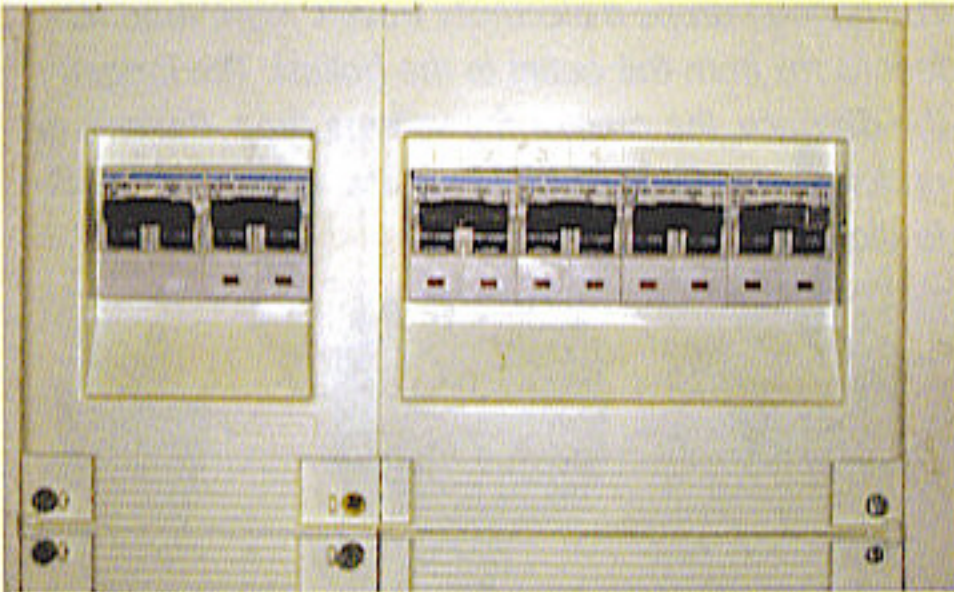
Avoid scenes like this, and never operate lamps on an overloaded circuit.

LIGHT, LAMPS & ELECTRICITY

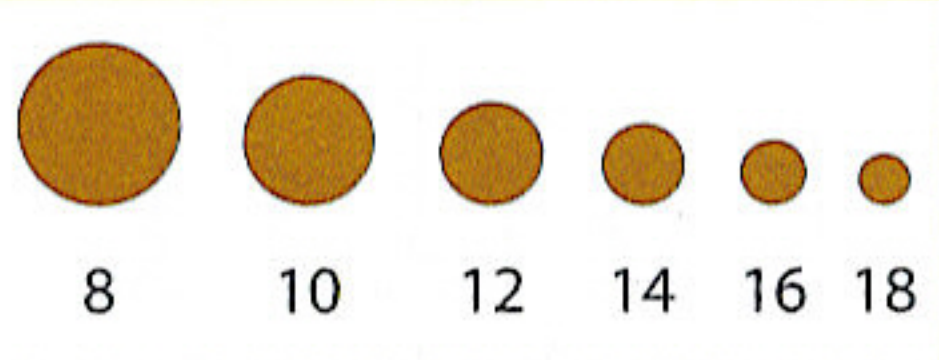
tion. If they are jostled around and the electricity is allowed to jump, electricity is lost in the form of heat; the prongs will burn, and a fire could result. Periodically check plugs and outlets to ensure they have a solid connection.
If installing a new circuit or breaker box, hire an electrician or purchase *Wiring Simplified* by H. P. Richter and W. C. Schwan. It costs about \$10 and is available at most hardware stores in the USA. Installing a new circuit in a breaker box is very easy, but installing another fuse in a fuse box is



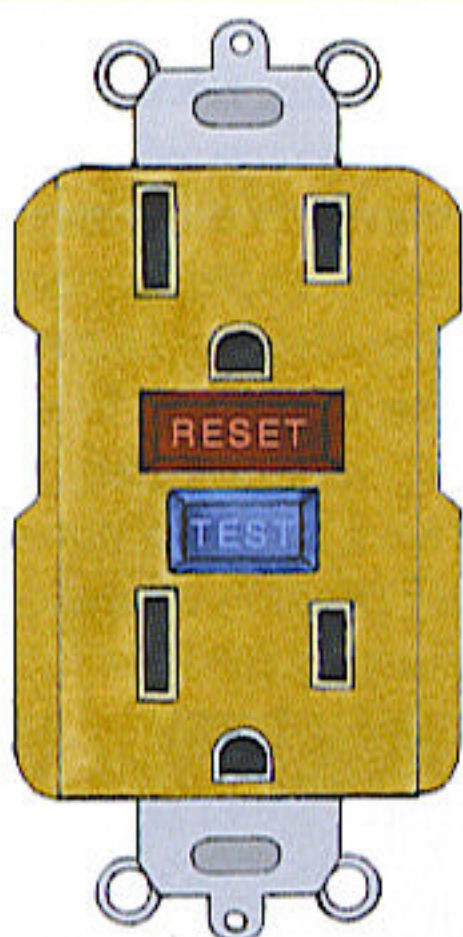
Electrical ground



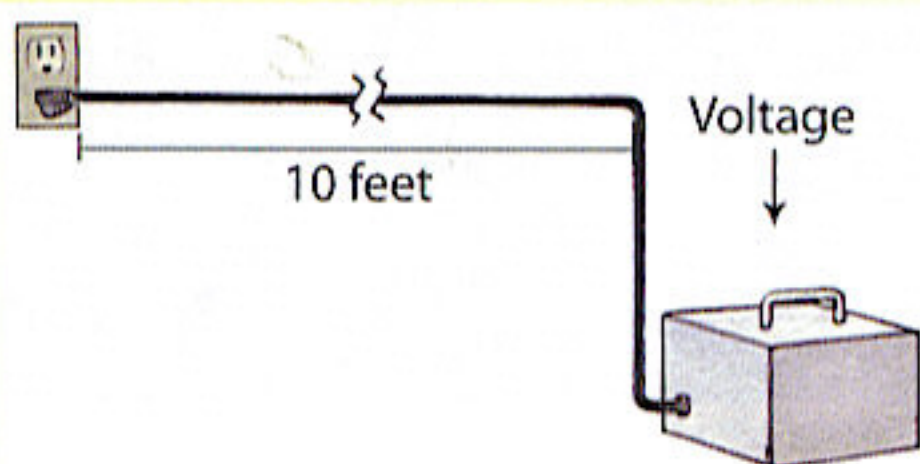
Breaker switches have their ampere rating printed on the face.



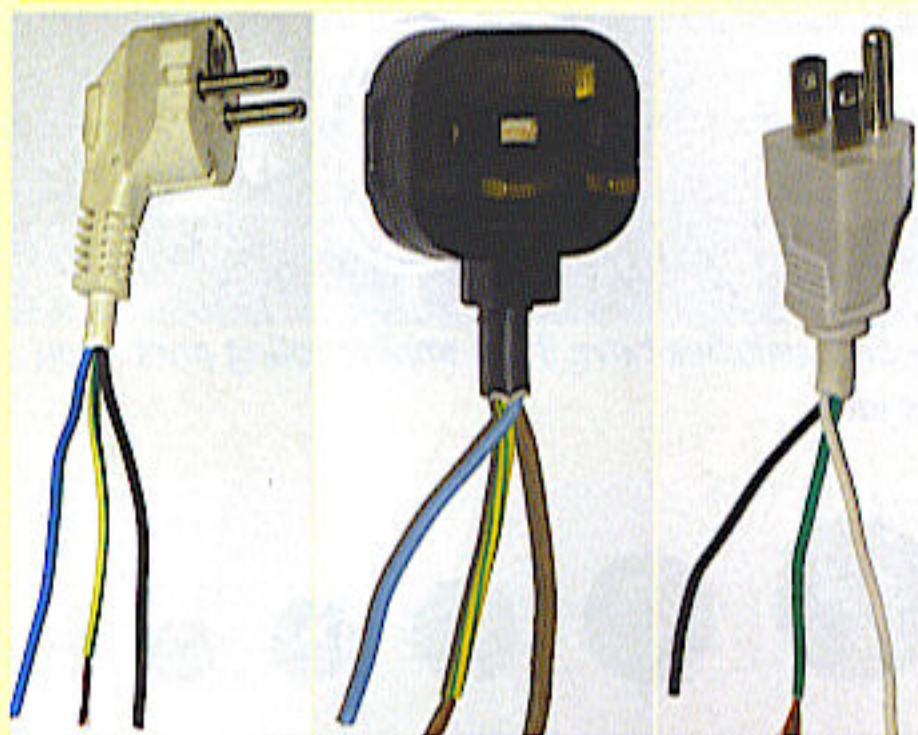
The diameter of electrical wire grows thicker as the gauge number decreases. Notice how much thicker a 14-gauge wire is than 16-gauge.



A ground fault interrupt (GFI) outlet contains a breaker switch and will turn off electricity when tripped.



The voltage drops if electricity travels more than ten feet (3 m) from the outlet to the ballast. The longer the distance, the greater the voltage drop. Ballasts are underpowered when voltage is low, causing the bulb to dim.



Left European 240-volt grounded plug. Center UK 240-volt grounded plug that contains a fuse. Right Grounded US and Canadian plug. The green or green-striped wires are ground wires.

more complex. Before trying anything of this scope, read about it, and discuss it with several professionals.

About Electricity Consumption

It is not a crime to use electricity that has been legally purchased. No sensible judge would issue a search warrant on the basis of suspicious electricity consumption. However, not all judges are sensible, and small communities with bored police officers or special marijuana task forces often take it upon themselves to investigate whatever information they are able to weasel out of electric company employees. Larger police forces do not have the desire, time, or money to look for small-time marijuana growers. I once went to check on the electricity consumption of a home I was thinking about renting; I went to the electric company and asked how much electricity the current tenant was using. The electric company employee called up the address on the computer and spun the screen around for me to examine. I could see the electrical consumption for the past few years as well as all the personal information about the tenant! If this is what I can do with a simple question and a smile, imagine what law enforcement officials can do with intimidation!

There are many ways to deal with the increase in consumption of electricity. One friend moved into a home that had all electric heat and a fireplace. He installed three HID lamps in the basement that also generated heat. The excess heat was dispersed via a vent fan attached to a thermostat/humidistat. He turned off the electric heat, bought a fireplace insert, and started heating with wood. Even running three lamps, consuming three kilowatts per hour, the electric bill was less than it had been with electric heat! Electric bills are controlled with and generated by a computer system. Monthly energy consumption is often displayed on a bar graph for the previous 12 months. This graph makes it easy to see fluctuations in electricity consumption.

A one- to three-bedroom home can run two to three 1000-watt lamps, and a four- to five-bedroom home can operate three to five lamps with little or no suspicion regarding electrical consumption. Powering any more lamps usually requires adding new incoming circuits, or the use of present circuits will be severely limited.

The amount of electricity consumption and the size of the home are proportional. Often, an increase in electric consumption is normal. For example, electric bills always increase if there is a baby in the home or if there are more residents living there. Changing to gas or wood heat and a gas stove and water heater will also lower the electricity bill. Some friends bought a new, efficient water heater and saved \$17 per month! Just by changing water heaters, they were able to add another 600-watt lamp. Another grower set her water heater for 130°F (54°C) instead of 170°F (77°C). This simple procedure saved about 25 kWh per month. But do not turn the water heater any lower than 130°F. Harmful bacteria can grow below this safe point.

The electric company might call to ask if you were aware of your increased electricity bill. This is nothing to worry about. Simply reply that you are aware of the electricity being used. If you like to make excuses, some appliances that draw a lot of electricity are: electric pottery kiln, arc welder, and hot tub. If the situation warrants, take showers at a friend's house or at a gym, use a Laundromat, and never use any electrical appliances.

The meter reader may think it is strange to see the electric meter spinning like a top during the middle of the day when nobody is home.

Cost of Electricity Chart

Cost per kWh	12-hour days		18-hour days	
	day	month	day	month
\$0.02	0.24	7.20	0.36	10.80
\$0.03	0.36	10.80	0.54	16.20
\$0.04	0.48	14.40	0.72	21.60
\$0.05	0.60	18.00	0.90	27.00
\$0.06	0.72	21.60	1.08	32.40
\$0.07	0.84	25.20	1.26	37.80
\$0.08	0.96	28.80	1.44	43.20
\$0.09	1.08	32.40	1.62	48.60
\$0.10	1.20	36.00	1.80	54.00

A circuit with a 20-amp fuse, containing the following items

1400-watt toaster oven

**100-watt incandescent light bulb
+ 20 watt radio**

1520 total watts

**$1520/120 \text{ volts} = 12.6 \text{ amps in use}$
or**

$1520/240 \text{ volts} = 6.3 \text{ amps in use}$

The above example shows 12.6 amps are being drawn when everything is on. By adding 9.2 amps, drawn by the HID to the circuit, we get 21.8 amps, an overloaded circuit!

There are three solutions:

1. Remove one or all of the high-amp-drawing appliances and plug them into another circuit.
2. Find another circuit that has few or no amps drawn by other appliances.
3. Install a new circuit. A 240-volt circuit will make more amps available per circuit.



This generator produces 4000 watts at full capacity.

Change the daylight cycle to be on at night, so the meter reader sees the meter when the lamps are off. Growers tend to know exactly when the meter reader is coming around. Now meter readers are using high-tech telescopes to read the dials on the meter and storing the readings in an integrated digital entry device. The information is then dumped into the larger computer at the central office. One friend had his

meter replaced by the power company. The company had noticed a major change in electricity consumption at the residence and thought that it could be due to a defective meter, so the meter was changed, but no difference was realized. Large electricity consumers may use a heavy-duty commercial power meter.

Some people bypass the meter or figure out some other way to steal electricity. This is a bad idea. If you are stealing electricity from a power company, they might find out. Stealing electricity is a very good way to call unnecessary attention to your growing operation. If you steal electricity, you are making it easy for someone from the power company to investigate you. Of course, some people have stolen electricity for years and gotten away with it, and they might get away with it forever. Ironically, one of the main reasons that people steal electricity in the first place is because of security. If conspicuous electricity consumption is a problem, a generator will help.

Generators

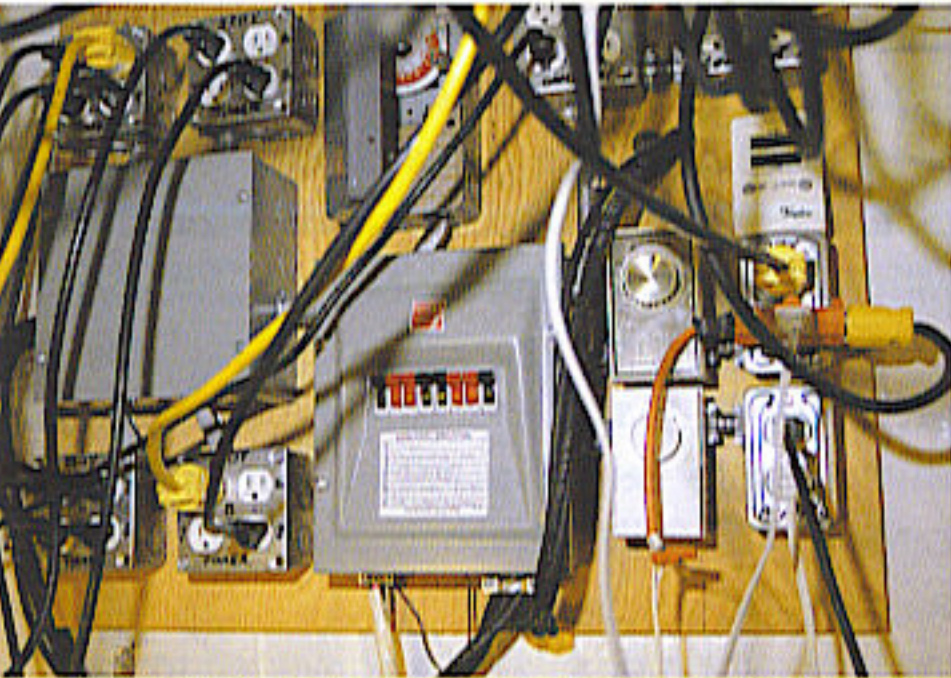
Generators can supply all the electricity necessary for a grow room, and you can grow "off the power grid." Reliability, ampere output, and noise are important to consider when shopping for a generator.

Buy the generator new. It should be water cooled and fully automated. Start it up, and check its noise output before purchasing. Always buy a generator that is big enough to do the job. A little extra cushion will be necessary to allow for power surges. If it fails, the crop could fail! Allow about 1300 watts per lamp to be run by the generator. The ballast consumes a few watts as does the wire, etc. A 5500-watt Honda generator will run four lamps.

Honda generators are



This generator on wheels provides complete "off the grid" security. Check into their consumption and maintenance before purchasing. Some models make quite a bit of noise that must be muffled. You can park it anywhere!



If you must wire your own grow room electricity, make sure to plan ahead of time. Attach junction boxes, timers, etc., to a board, and mount the board on the wall once the appliances are in place.



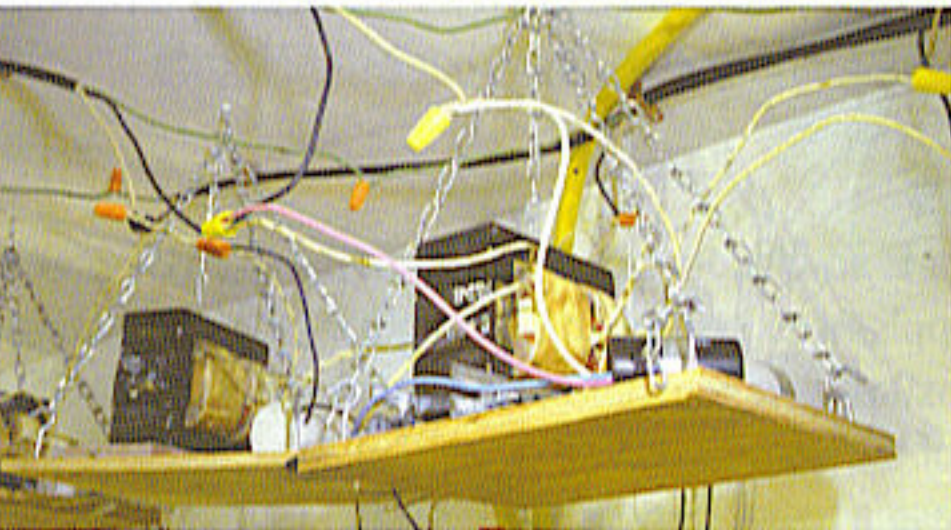
Grow room controllers make dialing in the exact temperature and humidity for your grow show easy.



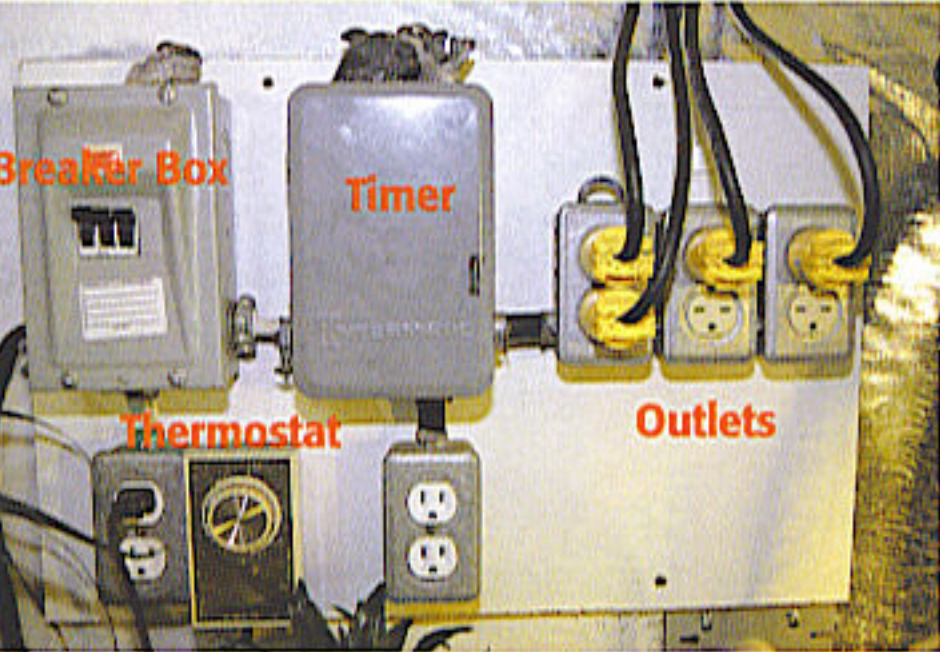
The mechanical timer on the left will operate several lamps at the same time. The digital timer on the right operates a single 1000-watt HID.



The timer on the right controls the entire lighting system in the grow room.



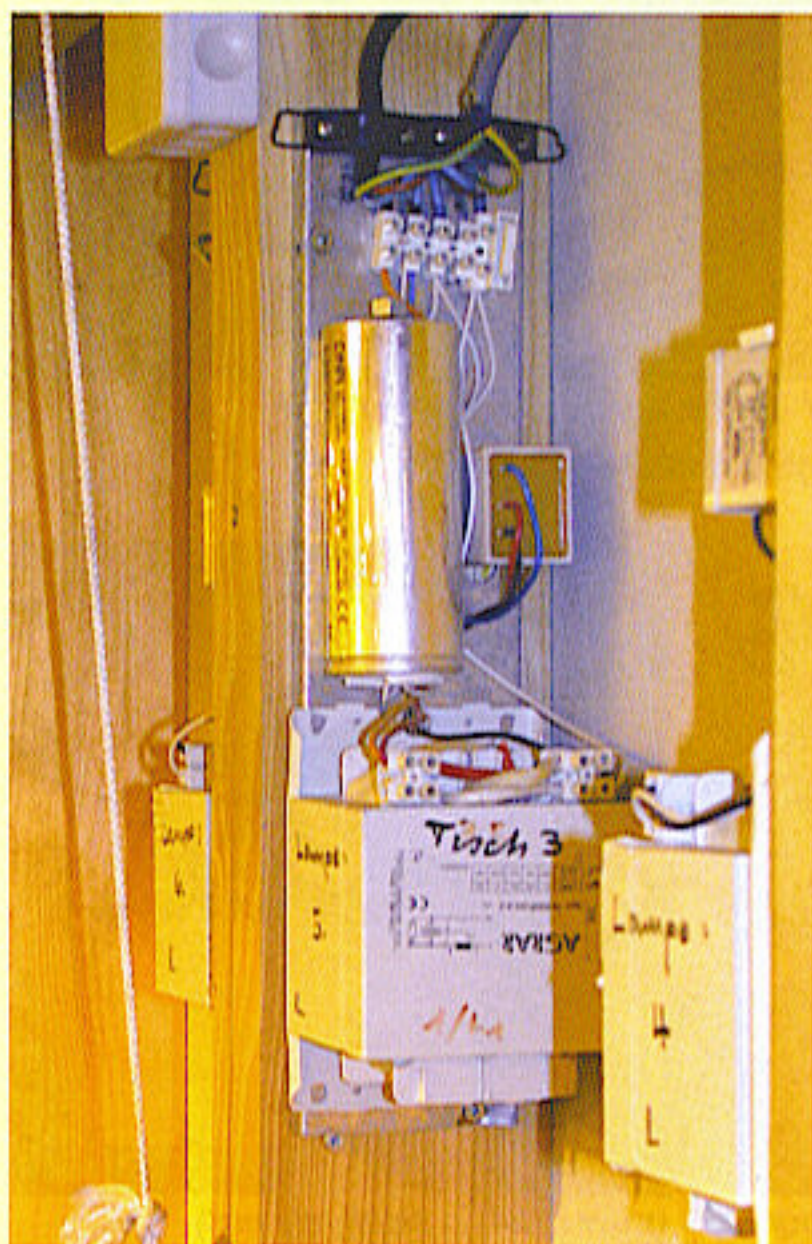
Place ballasts on shelves so that they are up and out of the way.



Wiring your own grow room is relatively easy. This grower hardwired a separate breaker box and timer that supports four lamps.



Fixing all wiring and electric devices to a control panel makes control and troubleshooting easy.



Attach ballasts to the wall so they are out of the way in the garden.

most often, used because they are reasonably priced, dependable, and quiet. But, they are not designed to work for long periods. One grower I met hooked up a generator to a six-cylinder gasoline motor. It could run five lamps with ease, but it guzzled a lot of gas. Diesel motors are more economical to run, but noisy, and the toxic fumes reek. Always make sure gasoline or diesel-powered generators are vented properly. The exhaust produces carbon monoxide, which is toxic to plants and humans.

Gasoline generator motors can be converted to propane, which burns much cleaner, and the exhaust may be used as a source of CO₂.

Diesel generators for truck and train car refrigerators are fairly easy to acquire and last for years. Once set up, one of these "Big Bertha" generators can run many, many lights. Check with wholesale railway and truck wrecking yard outlets for such generators. The generators are usually moved to a belowground location and covered with a building. With a good exhaust system and baffling around the motor, the sound is soon dissipated. Muffling the exhaust and expelling the fumes is a little complex but very effective. The exhaust must be able to escape freely into the atmosphere.

Maintaining a generator that runs 12 hours a day is a lot of work. The generator will need fuel and must be monitored regularly. If the generator shuts down prematurely, plants stop growing.

I once interviewed a grower who ran a generator for six years. He seemed to know a lot about the idiosyncrasies of the machine. He also had the innate feeling that the machine would do something outrageous if he were not there to make it right. This underlying theme dominated the entire interview. Running the generator motor—making sure it had oil, fuel, and ran quietly—was all he thought about when he was growing in the country with "Big Bertha," who produced 20 kilovolts of electricity. Check this site for more information, www.hardydiezel.com.

Timers

A timer is an inexpensive investment that turns lights and other appliances on and off at regular intervals. Using a timer ensures that your garden will receive a controlled light period of the same duration every day.

Purchase a heavy-duty grounded timer with an adequate amperage and tungsten rating to meet your needs. Some

timers have a different amperage rating for the switch; it is often lower than that of the timer. Timers that control more than one lamp are more expensive, because they require the entire force of electricity to pass through them. Many pre-wired timers are available at stores that sell HID lights.

How many lights (total watts) will the timer handle? If you are running more than 2000 or 3000 watts, you may want to attach the lamps to a relay, and control the relay with a timer. The advantage of a relay is it offers a path for more electricity without having to change the timer. There are numerous sophisticated timers on the market that will solve every last need you have.

Setting up the HID System - Step-by-Step

Step One: Before setting up the HID system, read "Setting Up the Grow Room" in Chapter Six, and complete the step-by-step instructions.

Step Two: Both the lamp and ballast radiate quite a bit of heat. Take care when positioning them, so they are not so close to plants or flammable walls and ceiling that they become hazardous. If the room has limited space with a low ceiling, place a protective, non-flammable material like metal between the lamp and ceiling to protect from heat. An exhaust fan will be necessary to keep things cool. It is most effective to place the remote ballast near the floor to keep things cool. Place it outside the grow room if the room is too hot. When hanging the lamp on the overhead chain or pulley system, make sure electrical cords are unencumbered and not too close to any heat source.

Step Three: Buy and use a good timer to keep the photoperiod consistent. A decent timer costs from \$20 to \$30 and is worth its weight in buds!

Step Four: To plug in the HID lamp, it will be necessary to find the proper outlet. A 1000-watt HID lamp will use about 9.5 amperes (amps) of electricity on a regular 120-volt house current.

A typical home has a fuse box or a breaker box. Each fuse or breaker switch controls an electrical circuit in the home. The fuse or breaker switch will

be rated for 15, 20, 25, 30, or 40-amp service. Circuits are considered overloaded when more than 80 percent of the amps are being used. (See: "Overload Chart" on page 212). The fuse will have its amp rating printed on its face, and the breaker switch will have its amp rating printed on the switch or on the breaker box. To find out which outlets are controlled by a fuse or breaker switch, remove the fuse or turn the breaker switch off. Test each and every outlet in the home to see which ones do not work. All the outlets that do not work are on the same circuit. All outlets that work are on another circuit. When you have found a circuit that has few or no lights, radios, TVs, stereos, etc., plugged into it, look at the circuits' amp rating. If it is rated for 15 amps, you can plug one 1000-watt HID into it. A leeway of 5.5 amps is there to cover any power surges. If the circuit is rated for 20 or more amps, it may be used for the 1000-watt HID and a few other low-amp appliances. To find out how many amps are drawn by each appliance, add up the number of total watts they use, and divide by 120.

Never put a larger fuse in the fuse box than it is rated for. The fuse is the weakest link in the circuit. If a 20-amp fuse is placed into a 15-amp circuit, the fuse is able to conduct more electricity than the wiring. This causes wires to burn rather than the fuse. An overloaded circuit may result in a house fire.

Use an extension cord that is at least 14-gauge wire or heavier if the plug will not reach the outlet desired. Thick 14-gauge extension cord is more difficult to find and may have to be constructed. Smaller 16- or 18-gauge cord will not conduct adequate electricity and will heat up, straining the entire system. Cut the 14-gauge extension cord to the exact length. The further electricity travels, the weaker it gets and the more heat it produces, which also strains the system.

Step Five: Always use a three-prong grounded plug. If your home is not equipped with working three-prong grounded outlets, buy a three-prong grounded plug and outlet adapter. Attach the ground wire to a grounded ferrous metal object like a grounded metal pipe or heavy copper wire



A bulb hanging crookedly under a reflective hood causes light to be reflected unevenly, which creates "hot spots" and "cold spots" of light in the garden.

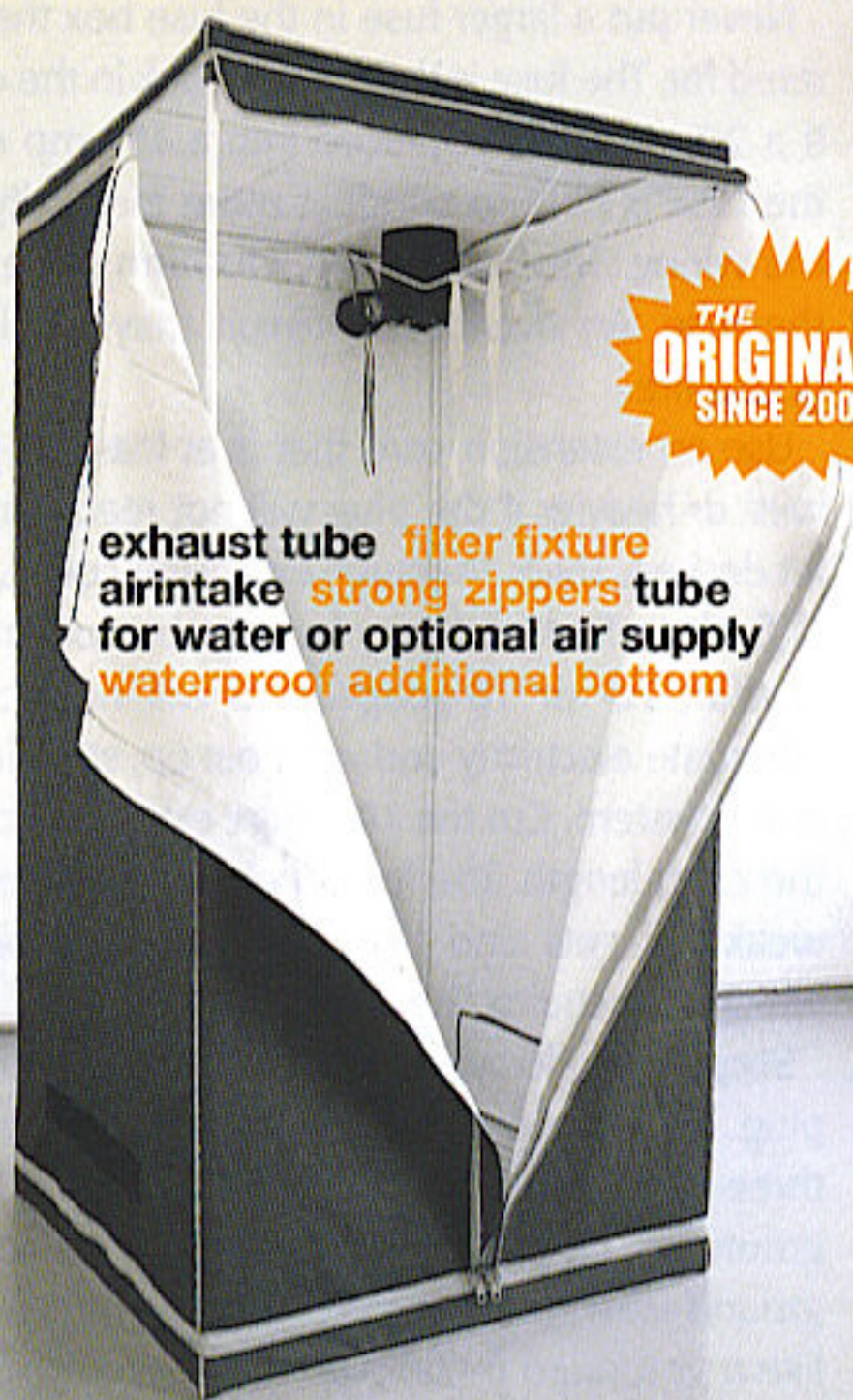
driven into the earth to form a ground, and screw the ground into the plug-in face. You will be working with water under and around the HID system. Water conducts electricity about as well as the human body.

Step Six: Once the proper circuit is selected, the socket and hood are mounted overhead, and the ballast is in place (but not plugged in), screw the HID bulb finger-tight into the socket. Make sure the bulb is secured in the socket tightly, but not too tight, and make certain there is a good connection. When secure, wipe off all smudges on the bulb to increase brightness.

Step Seven: Plug the three-prong plug into the timer that is in the OFF position. Plug the timer into the grounded outlet, set the timer at the desired photoperiod, and turn the timer on. Shazam! The ballast will hum; the lamp will flicker and slowly warm up, reaching full brilliance in about five minutes.



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HOMEBOX

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SUITABLE FOR:

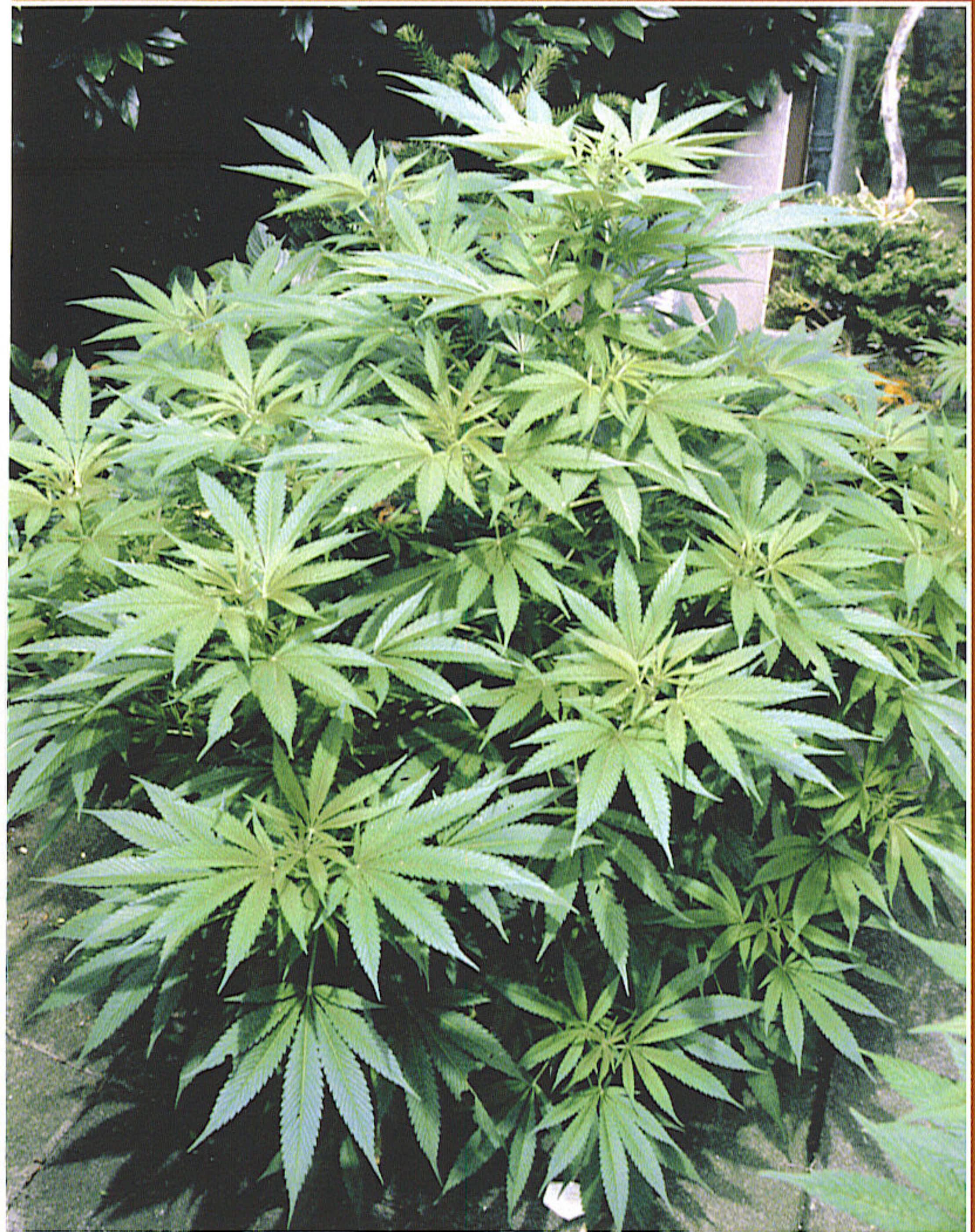
- * flowering
- * for mother plants and clones
- * medical users

sizes

100 x 100 x 200, 120 x 120 x 200 (centimeter)

Chapter TEN

SOIL AND CONTAINERS



This plant is growing in sandy soil 30 feet (10 m) below sea level in Amsterdam.



This cutaway drawing shows how the roots penetrate the soil. Note: There must be enough air trapped in the soil to allow biological activity and absorption of nutrients.

Soil

Introduction

Soil is made up of many mineral particles mixed together with living and dead organic matter that incorporates air and water. Three basic factors contribute to the cannabis root's ability to grow in a soil: texture, pH, and nutrient content.

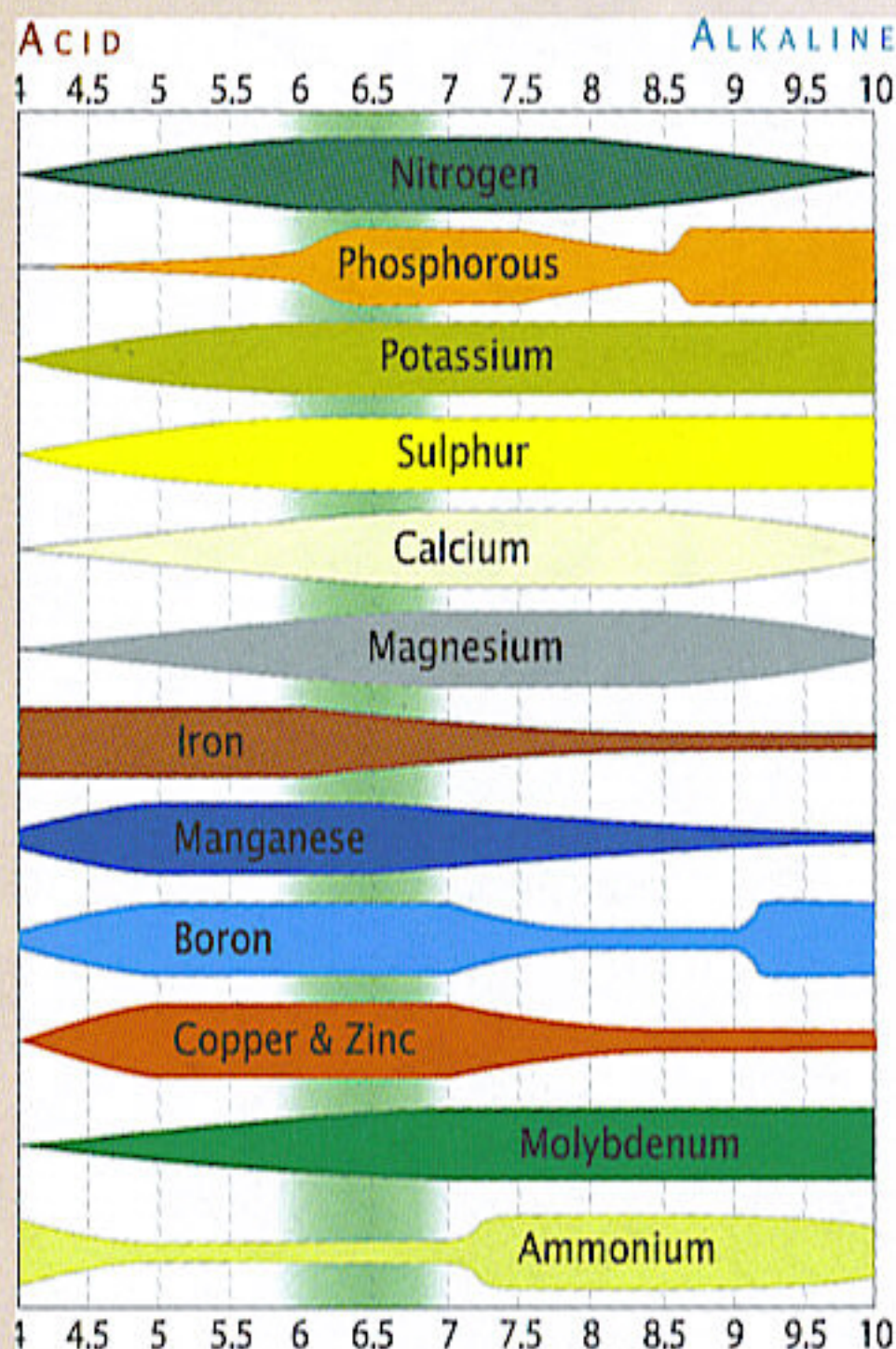
Soil texture is governed by the size and physical makeup of the mineral particles. Proper soil texture is required for adequate root penetration, water, and oxygen retention and drainage as well as many other complex chemical processes.

Clay or adobe soil is made up of very small, flat mineral particles; when it gets wet, these minute particles pack tightly together, slowing or stopping root penetration and water drainage. Roots are unable to breathe because very little or no space is left for oxygen. Water has a very difficult time penetrating these tightly packed soils, and once it does penetrate, drainage is slow.

Sandy soils have much larger particles. They permit good aeration (supply of air or oxygen) and drainage. Frequent watering is necessary because water retention is very low. The soil's water- and air-holding ability and root penetration are a function of texture.

Loam soil is ideal for growing cannabis. It contains a mix of clay, silt, and sand. The different sized particles allow a large combination of pore spaces, so it drains well and still retains nutrients and moisture.

To check soil texture, pick up a handful of moist (not soggy) soil and gently squeeze it. The soil should barely stay together and have a kind of sponge effect when you slowly open your hand to release the pressure. Indoor soils that do not fulfill these requirements should be thrown out or amended. See "Soil Amendments" below.



This pH Chart shows the Safe Zone is between 5.8 and 6.8.

pH

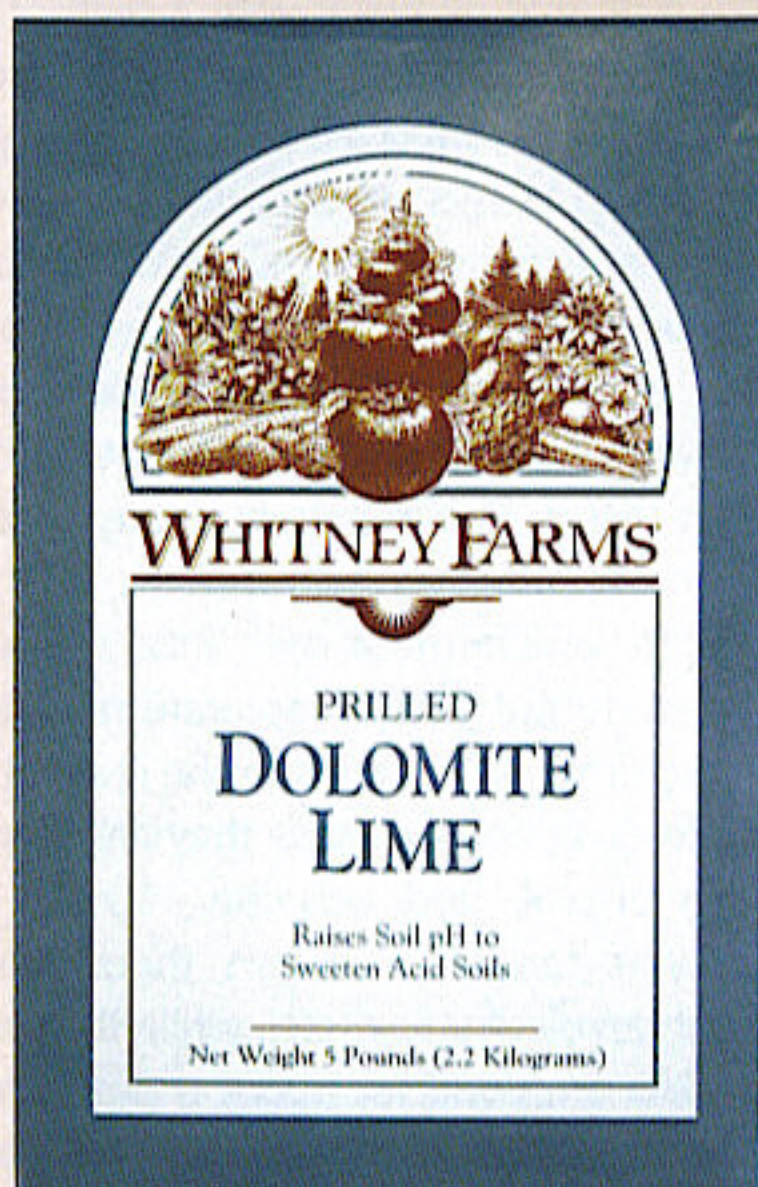
The pH scale, from 1 to 14, measures acid-to-alkaline balance. 1 is the most acidic, 7 is neutral, and 14 most alkaline. Every full point change in pH signifies a ten-fold increase or decrease in acidity or alkalinity. For example, soil or water with a pH of 5 is ten times more acidic than water or soil with a pH of 6. Water with a pH of 5 is one hundred times more acidic than water with a pH of 7. With a ten-fold difference between each point on the scale, accurate measurement and control is essential to a strong, healthy garden.

Cannabis grows best in soil with a pH from 6.5 to 7.0. Within this range marijuana can properly absorb and process available nutrients most efficiently. If the pH is too low (acidic), acid salts chemically bind nutrients, and the roots are unable to absorb them. An alkaline soil with a high pH causes nutrients to become unavailable. Toxic salt buildup that limits water intake by roots also becomes a problem. Hydroponic solutions perform best in a pH range a little lower than for soil. The ideal pH range for hydroponics is from 5.8 to 6.8. Some growers run the pH at lower levels and report no problems with nutrient uptake. The pH of organic soil mixes is very important because it dictates the ability of specific pH-sensitive bacteria.

Measure the pH with a soil test kit, litmus paper, or electronic pH tester, all of which are available at most nurseries. When testing pH, take two or three samples and follow instructions supplied by the manufacturer "to the letter." Soil test kits measure soil pH and primary nutrient content by mixing soil with a chemical solution and comparing the color of the solution to a chart. Every one of these kits I have seen or used is difficult for novice gardeners to achieve accurate measurements. Comparing the color of the soil/chemical mix to the color of the chart is often confusing. If you use one of these kits, make sure to buy one with good, easy-to-understand directions and ask the sales clerk for exact recommendations on using it.



An inexpensive electronic pH tester is easy to use.



When planting, add one cup of fine dolomite lime to each cubic foot (one ounce per gallon) of planting medium to stabilize the pH and provide calcium and magnesium.

For an accurate pH test with an electronic pH meter:

- Clean the probes of the meter after each test and wipe away any corrosion.
- Pack the soil around the probes.
- Water soil with distilled or neutral pH water before testing.

If using litmus paper, collect samples that demonstrate an average of the soil. Place the samples in a clean jar, and moisten the soil samples with distilled water. Place two pieces of the litmus paper in the muddy water. After ten seconds, remove one of the strips of litmus paper. Wait a minute before removing the other one. Both pieces of litmus paper should register the same color. The litmus paper container should have a pH-color chart on the side. Match the color of the litmus paper with the colors on the chart to get a pH reading. Litmus paper will accurately measure the acidity of the substance to within a point. The pH readings will not be accurate if altered by water with a high or low pH, and the litmus paper could give a false reading if the fertilizer contains a color-tracing agent.

Electronic pH testers are economical and convenient. Less expensive pH meters are accurate enough for casual use. More expensive models are quite accurate. Pay special attention to the soil moisture when taking a pH test with an electronic meter. The meters measure the electrical current between two probes and are designed to work in moist soil. If the soil is dry, the probes do not give an accurate reading. I prefer electronic pH meters over the reagent test kits and litmus paper because they are convenient, economical, and accurate. Once purchased, you can measure pH thousands of times with an electronic meter, while the chemical test kits are good for about a dozen tests. Perpetual pH-metering devices are also available and most often used to monitor hydroponic nutrient solutions.

Check the pH of irrigation water. In dry climates, such as the desert Southwest United States, Spain, Australia, etc., irrigation water is

often alkaline with a pH above 6.0. The water in rainy climates, such as the Pacific Northwest of North America, the United Kingdom, Netherlands, and maritime Northern Europe, is often acidic with a pH below 6.0. The pH and EC of water supplies in municipalities and cities can also change throughout the year in some countries. After repeated watering, water with a pH that is too high or low will change the pH of the growing medium, especially in organically amended soils. Raw-water pH above 6.0 helps keep fertilizer mixes from becoming too acidic. Climatic conditions can also affect irrigation water pH. For example, the pH can become more acidic in late autumn, when leaves fall and decompose. Large municipalities carefully monitor and correct the pH, and there are few water-quality problems. Check the pH at least once a week.

Cannabis will grow in almost any soil*, but it flourishes when the pH is between 6.5 and 7. Commercial potting soil almost never has a pH above 7.5. A lower pH is more common, even as low as 5.5. Some potting soils purchased at a nursery are pH balanced and near a neutral 7. However, most potting soils have a tendency to be acidic. The easiest way to stabilize soil pH is to mix in one cup of fine dolomite lime per cubic foot (0.25 liters) of potting soil. Mix dolomite lime thoroughly into dry soil. Remix the soil in the container after it has been watered.

Fine Dolomite Lime has long been a favorite pH stabilizer for gardeners. It is difficult to apply too much as long as it is thoroughly mixed into soil. Dolomite has a neutral pH of 7, and it can never raise the pH beyond 7.0. It stabilizes the pH safely. Compensate for acidic soil by mixing dolomite with soil before planting. It will help

**Cannabis is a well-known accumulator plant that takes in heavy metals and sequesters toxins in vacuoles, which are impermeable. The heavy metals remain toxic. Cannabis was planted around Chernobyl, the toxic nuclear site in Russia, to absorb toxic heavy metals.*

keep the pH stable, and maintain the correct pH when applying mild acidic fertilizers. Dolomite, a compound of magnesium (Mg) and calcium (Ca), is popular among indoor and outdoor growers in rainy climates with acidic soil. Dolomite does not prevent toxic-salt accumulation caused by impure water and fertilizer buildup. A proper fertilizer regimen and regular leaching helps flush away toxic salts. When purchasing, look for dolomite flour, the finest fast-acting dust-like grade available. Coarse dolomite could take a year or more before it becomes available for uptake by roots. Mix dolomite flour thoroughly with the growing medium before planting. Improperly mixed, dolomite will stratify, forming a cake or layer that burns roots and repels water.

Hydrated Lime contains only calcium and no magnesium. As the name hydrated implies, it is water-soluble. Fast-acting hydrated lime alters the pH quickly. Mix it thoroughly with warm water and apply with each watering for fast results. Many growers use a mix of 0.25 cup hydrated lime and 0.75 cup (18 cl) dolomite lime. Hydrated lime is immediately available, whereas the slower acting dolomite buffers the pH over the long term. Do not use more than 0.5 cup (12 cl) of hydrated lime per cubic foot of soil. The larger quantity is released so fast that it can toxify soil, and stunt or even kill plants. The beauty of hydrated lime is that it washes out of the soil in about two weeks. Leach it quicker by flushing pots with copious quantities of water. Hydrated lime is also used as a grow room fungicide. Sprinkle it on the floor and around the room. It kills fungus on contact.



The pH of these large sativa plants growing on a terrace is kept at 6.5 to 6.8.

Do not use **quicklime**; it is toxic to plants. Calcic lime (quicklime) contains only calcium and is not a good choice. It does not have the buffering qualities of dolomite nor does it contain any magnesium.

Raise the pH of a growing medium or irrigation water by adding some form of alkali, such as calcium carbonate, potassium hydroxide, or sodium hydroxide. Both hydroxides are caustic and require special care when handling. These compounds are normally used to raise the pH of hydroponic nutrient solutions but can be used to treat acidic nutrient solutions when applied to soil. The easiest and most convenient way to raise and stabilize soil pH is to add fine dolomite lime and hydrated lime before planting. To raise the pH one point add 3 cups of fine dolomite lime to one cubic foot of soil. An alternate fast-acting mix would be to add 2.5 cups (590 cl) of dolomite and 0.5 cup (12 cl) of hydrated lime to one cubic foot of soil.

Pulverized eggshells, clam or oyster shells, and wood ashes have a high pH and help raise soil pH. Eggshells and oyster shells take a long time to decompose enough to affect the pH; wood ashes have a pH from 9.0-11.0 and are easy to overapply. Ashes are often collected from



Outdoors, the soil temperature can climb quickly when sunshine warms the containers.

fireplaces or wood stoves that have been burning all kinds of trash and are, therefore, unsafe. Do not use wood ashes on indoor gardens unless you know their origin, pH, and nutrient content. You can add cottonseed meal, lemon peels, coffee grounds, or a high-acidity fertilizer to lower pH in soil to below 7.0.

Commercial potting soils and soilless mixes are often acidic and the pH seldom needs to be lowered. If new soil pH is under 6 or above 8, it is easier and less expensive in the long run to change soil rather than experiment with changing the pH. Fertilizers are naturally acidic and lower the pH of the growing medium. Sulfur will lower the pH, if necessary, but it is tricky to use. I advise using an acid to alter the pH. Add distilled white vinegar at the rate of one teaspoon per gallon of irrigation water, allow the water to sit for a few minutes, and then recheck it. The pH should drop by a full point. If it does not, add more vinegar in small increments. Often when using vinegar, the pH drifts up overnight. Check the pH the next day. Hydroponic growers use phosphoric and nitric acid to lower pH. Calcium nitrate can also be used, but is less common. Keep a close eye on the pH and control it accordingly. After altering



Soil temperature should stay between 65-70°F (18-24°C) for best results.

the pH, check it, and then check it again daily to make sure it remains stable.

Aspirin also lowers the pH. However, hormonal reactions appear to be triggered by aspirin. Some growers have reported more hermaphrodites when using aspirin to alter the pH.

Humates Chelate

Humic and fulvic acids chelate metallic ions making them readily transportable by water. This ability is dependent upon the pH level. Copper, iron, manganese, and zinc are difficult to dissolve. When mixed in

a chelated form, they become readily available for absorption.

Soil Temperature

Raising the soil temperature speeds the chemical process and can hasten nutrient uptake. Ideally, the soil temperature should range from 65-70°F (18-24°C) for the most chemical activity. Warm the soil with soil-heating cables or a heating pad. Fasten heating cables to a board or table and set a heat-conducting pad on top of the cables to distribute heat evenly. Set cuttings and seedlings in shallow flats or growing trays on top of the heat-conducting pad. The added heat speeds root growth when soil temperature is below 65°F (18°C).

Soil heating cables cost much less than soil heating pads but must be installed, whereas the pads are ready to use. Most commercial nurseries carry cables, and hydroponic stores carry heating pads. When rooting clones, a heating pad or cables virtually ensure success and expedite root growth.

Cold soil slows water and nutrient uptake and stifles growth. Growers often overwater when

the soil is too cold or the room cools unexpectedly, which further slows growth. Pots on cold concrete floors stay as cold as the concrete, which is always colder than the ambient temperature. Increase soil temperature by moving pots up off the floor a few inches. Set them on an insulating board or piece of Styrofoam™.

Soil temperatures that climb above 75°F (39°C) dehydrate roots, and at higher temperatures the roots actually cook! It is relatively easy to heat the soil in a pot. If the light or any heat source is too close to small pots, it can easily heat up the outside layer of soil where the majority of the feeder roots are located. Once destroyed, roots take one or two weeks to grow back. Two weeks accounts for one quarter of the flowering cycle!

The more *feeder root hairs* there are to absorb water and nutrients, the faster and stronger plants will grow. Once roots go beyond their comfort zone, they send stress signals to foliage and stomata via hormones to close and conserve moisture.

Oxygen is essential for clones that are growing roots. Water holds under one percent dissolved oxygen at 70°F (21°C). Bump the temperature up to 85°F (29°C) and it holds less than 0.5 percent oxygen.

Root temperatures below 40°F (4°C) make water expand, which causes cell damage. Temperatures above 92°F (33°C) cause excessive vapor pressure within the roots, which can cause damage. At high temperatures roots send stress signals to shut the leaves down before damage can occur.

Potting Soil

Potting soil fresh out of the bag often fulfills all requirements for a growing medium: good texture that allows good root penetration, water retention, and good drainage, a stable pH between 6 and 7, and a minimum supply of nutrients.

Premium fast-draining soils with good texture that will not break down quickly are the best choice. Potting soils found at nurseries are often formulated with a wetting agent and retain water and air evenly, drain well, and allow easy root penetration. Organic potting soils are very popular. These soils are often fortified with organic nutrients including readily available high-nitrogen worm castings. Potting soils are very heavy, and transportation costs tend to keep them somewhat localized. There are many good brands of high-quality potting soil. Ask your nursery person for help in selecting one for fast-growing vegetables.



Quality potting soil



Quality organic potting soil



MushroomCompost

Stay away from discount brands of low-quality potting soil. These soils can be full of weed seed and diseases, hold water unevenly, and drain poorly. Ultimately, saving a few pennies on soil will cost many headaches and a low yield later.

Many potting soils supply seedling transplants and clones with enough food (fertilizer) for the first two to four weeks of growth. After that, supplemental fertilization is necessary to retain rapid, robust growth. Add fine-grade dolomite lime to buffer and stabilize the pH. Trace elements in fortified soil and soilless mixes can leach out and should be replenished with chelated nutrients, if deficiency signs occur. Organic growers often add their own blends of trace elements in mixes that contain seaweed, guanos, and manures.

Although some growers reuse their potting soil, I do not recommend it. If used for more than one crop, undesirable microorganisms, insects and fungi start growing; nutrients are depleted; water and air retention are poor, causing compaction and poor drainage. Some growers mix their old potting soil with new potting soil to stretch their mix. Cutting corners this way most often costs more in production than is saved in soil.

Potting soil or soilless mix that contains more than 30 percent lightweight pumice or perlite may float and stratify when saturated with water before planting. Mix water-saturated soil thoroughly with your hands until it is evenly mixed before planting or transplanting, if necessary.

Mushroom Compost

Mushroom compost is an inexpensive potting soil and soil amendment that is packed with organic goodies. Mushroom compost is sterilized chemically to provide a clean medium for mushroom growth. After serving its purpose as a mushroom growing medium, it is discarded. Laws usually require that it sit fallow for two years or more to allow all the harmful sterilants to leach out. After lying fallow for several years,

mushroom compost is very fertile and packed with beneficial microorganisms. The high-power compost could also foster antifungal and antibacterial properties in foliage and below the soil line, which helps guard against disease. Mushroom compost is loaded with beneficial bacteria that hasten nutrient uptake. The texture, water holding ability, and drainage in some mushroom compost should be amended with perlite to promote better drainage. Check your local nursery or extension service for a good source of mushroom compost. Some of the most abundant harvests I have seen were grown in mushroom compost.

Soilless Mix

Soilless mixes are very popular, inexpensive, lightweight, and sterile growing mediums. Commercial greenhouse growers have been using them for decades. The mixes contain some or all of the following: pumice, vermiculite, perlite, sand, peat moss, and coconut coir. Premixed commercial soilless mixes are favorites of countless growers. These mixes retain moisture and air while allowing strong root penetration and even growth. The fertilizer concentration, moisture level, and pH are very easy to control with precision in soilless mix.

Soilless mixes are the preferred substrate for many bedding plant and vegetable seedling commercial growers. Soilless mixes have good texture, hold water, and drain well. Unless fortified with nutrient, soilless mixes contain no nutrients and are pH balanced near 6.0 to 7.0. Coarse soilless mixes drain well and are easy to push plants into growing faster with heavy fertilization. The fast-draining mixes can be leached efficiently so nutrients have little chance of building up to toxic levels. Look for ready-mixed bags of fortified soilless mixes such as Jiffy Mix®, Ortho Mix®, Sunshine Mix®, Terra-Lite®, and ProMix®, etc. To improve drainage, mix 10-30 percent coarse perlite before planting. Fortified elements supply nutrients up to a month, but follow directions on the package.

Soiless components can be purchased separately and mixed to the desired consistency. Ingredients always blend together best when mixed dry and wetted afterwards using a wetting agent to make water more adhesive. Mix small amounts right in the bag. Larger batches should be mixed in a wheelbarrow, concrete slab, or in a cement mixer. Blending your own soil or soiless mix is a dusty, messy job that takes little space. To cut down on dust, lightly mist the pile with water several times when mixing. Always wear a respirator to avoid inhaling dust.

The texture of soiless mixes—for rapid-growing cannabis—should be coarse, light, and spongy. Such texture allows drainage with sufficient moisture and air retention, as well as providing good root penetration qualities. Fine soiless mix holds more moisture and works best in smaller containers. Soiless mixes that contain more perlite and sand drain faster, making them easier to fertilize heavily without excessive fertilizer-salt buildup. Vermiculite and peat hold water longer and are best used in small pots that require more water retention.

The pH is generally near neutral, 7.0. If using more than 15 percent peat, which is acidic, add appropriate dolomite or hydrated lime to correct and stabilize the pH. Check the pH regularly every week. Soiless mixes are composed mainly of mineral particles that are not affected by organic decomposition, which could change the pH. The pH is affected by acidic fertilizers or by water with a high or low pH. Check the pH of the runoff water to ensure the pH in the medium is not too acidic.

Cutting and Seedling Cubes and Mixes

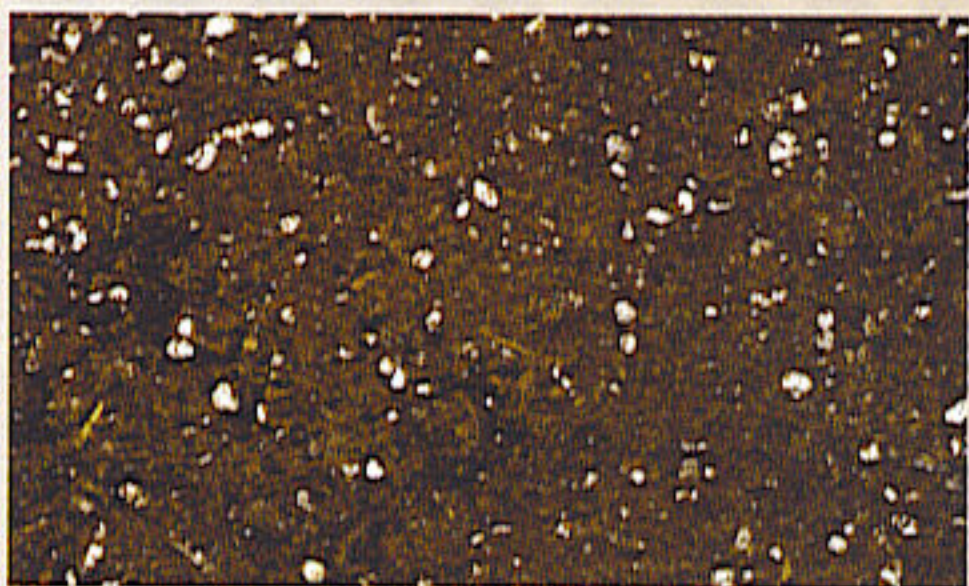
Rockwool root cubes, peat pellets, and Oasis® blocks are pre-formed containers that make rooting cuttings, starting seedlings, and transplanting them easy. Root cubes and peat pots also help encourage strong root systems. Peat pots are small, compressed peat moss contain-



Lightweight horticultural perlite is available in large bags.



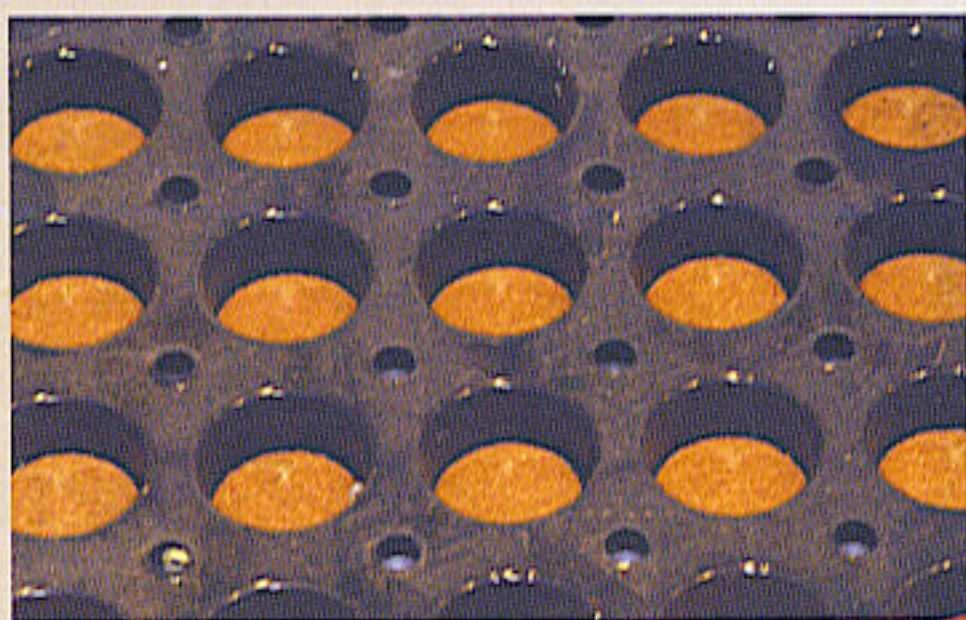
This soiless mix contains 50 percent perlite and 50 percent coco. Drainage is rapid and water retention is good. This mix must be watered daily.



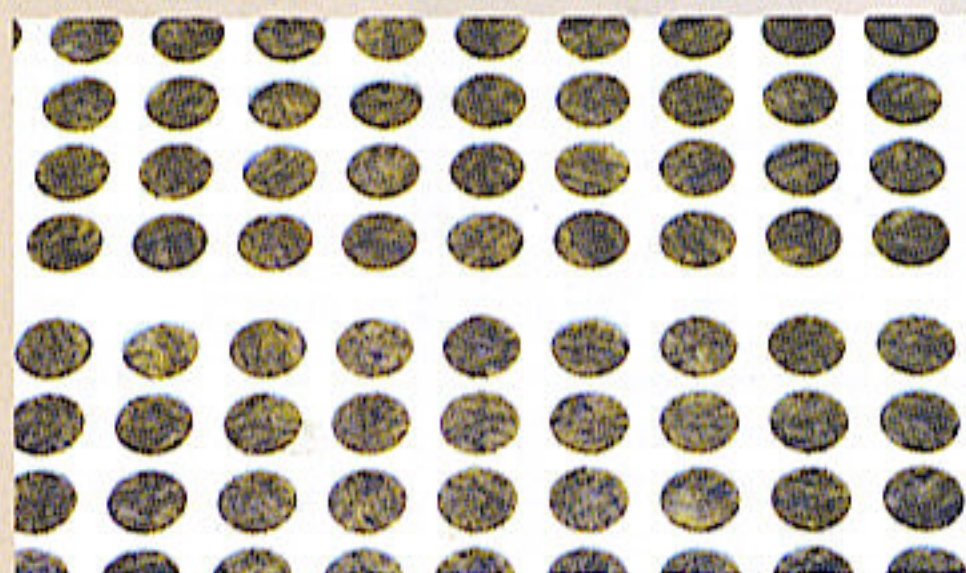
This soiless mix contains 10 percent perlite and 90 percent peat moss. It holds water very well and the perlite assists drainage.



Make a seedbed from fine-screened soil.



Seedling trays are easy to use.



Small rockwool plugs are fast to plant and easy to maintain.



Rockwool plugs grow strong root systems in about two weeks.



Coarse perlite is lightweight.

ers with an outer wall of expandable plastic netting. The flat pellets pop up into a seedling pot when watered.

Place a seed or cutting in a moist peat pot or root cube. If the little container does not have a planting hole, make one with a chopstick, large nail, or something similar. Set the seed or clone stem in the hole. Crimp the top over the seed or around the stem so it makes constant contact with the medium. In one to three weeks, roots grow and show through the side of the cube. Cut the nylon mesh from peat pots before it gets entangled with roots. To transplant, set the peat pot or root cube in a pre-drilled hole in a rockwool block or into larger pot. Clones and seedlings suffer little or no transplant shock when transplanted properly.

Check moisture levels in peat pots and root cubes daily. Keep them evenly moist but not drenched. Root cubes and peat pots do not contain any nutrients. Seedlings do not require nutrients for the first week or two. Feed seedlings after the first week and clones as soon as they are rooted.

Coarse sharp sand, fine vermiculite, and perlite work well to root cuttings. Sand and perlite are fast draining, which helps prevent damping-off. Vermiculite holds water longer and makes cloning easier. A good mix is one third of each: sand, fine perlite, and fine vermiculite. Premixed seed starter mixes sold under such brand names as Sunshine Mix and Terra-Lite are the easiest and most economical mediums in which to root clones and start seedlings. Soilless mix also allows for complete control of critical nutrient and root stimulating hormone additives, which are essential to asexual propagation.

Soil Amendments

Soil amendments increase the soil's air-, water-, and nutrient-retaining abilities. Soil amendments fall into two categories: mineral and organic.

Mineral amendments are near neutral on the pH scale and contain few, if any, available nutri-

ents. Mineral amendments decompose through weathering and erosion. Add mineral amendments to augment air and increase drainage. They have the advantage of creating no bacterial activity to alter nutrient content and pH of the growing medium. Dry mineral amendments are also very lightweight and much easier to move in and out of awkward spaces.

Perlite is sand or volcanic glass expanded by heat. It holds water and nutrients on its many irregular surfaces, and it works especially well for aerating the soil. This is a good medium to increase drainage during vegetative and flowering growth, and it does not promote fertilizer-salt build-up. Versatile perlite is available in three main grades: fine, medium and coarse. Most growers prefer the coarse grade as a soil amendment. Perlite should make up one third or less of any mix to keep it from floating and stratifying the mix.

Pumice, volcanic rock, is very light and holds water, nutrients, and air, in its many catacomb-like holes. It is a good amendment for aerating the soil and retaining moisture evenly. But like perlite, pumice floats and should constitute less than a third of any mix to avoid problems.

Hydroclay is used more and more as a soil amendment in containers. The large expanded clay pellets expedite drainage and hold air within the growing medium. See Chapter Twelve "Hydroponics" for more information.

Vermiculite is mica processed and expanded by heat. It holds water, nutrients, and air within its fiber and gives body to fast-draining soils. Fine vermiculite holds too much water for cuttings, but does well when mixed with a fast-draining medium. This amendment holds more water than perlite or pumice. Used in hydroponic wick systems, vermiculite holds and wicks much moisture. Vermiculite comes in three grades: fine, medium, and coarse. Use fine vermiculite as an ingredient in cloning mixes. If fine is not available, crush coarse or medium vermiculite between your hands, rubbing palms back and forth. Coarse is the best choice as a soil amendment.



Pumice is lightweight.



Vermiculite is lightweight and absorbent.



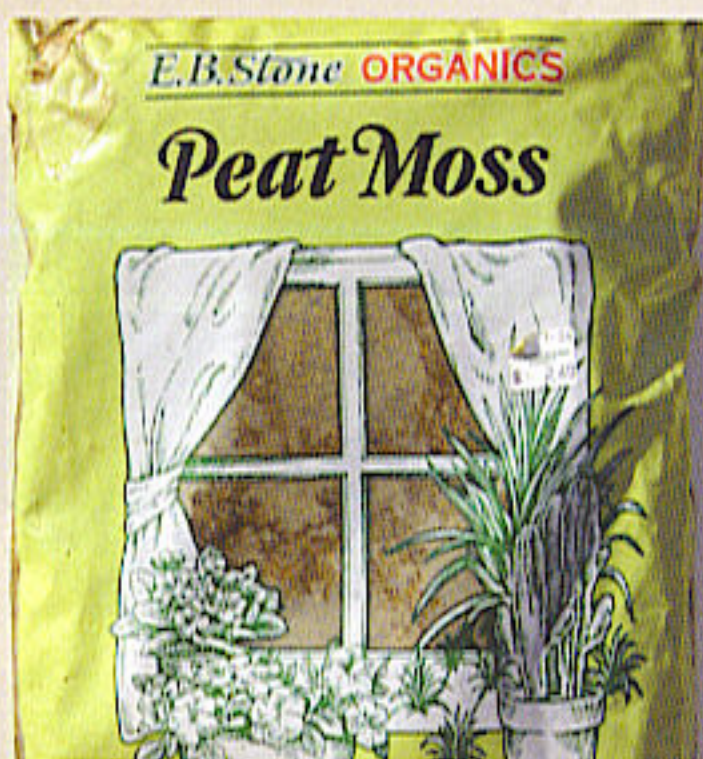
Some growers use organic potting soil as a soil amendment.



This bag of soil amendments contains well-rotted mulch and chicken manure.

Organic soil amendments contain carbon and break down through bacterial activity, slowly yielding humus as an end product. Humus is a soft, spongy material that binds minute soil particles together, improving the soil texture. New, actively composting organic soil amendments require nitrogen to carry on bacterial

Peat moss is available in bags or compressed bales.



Coco bricks are ideal for guerilla growers. They expand to nine times their original size when wet.

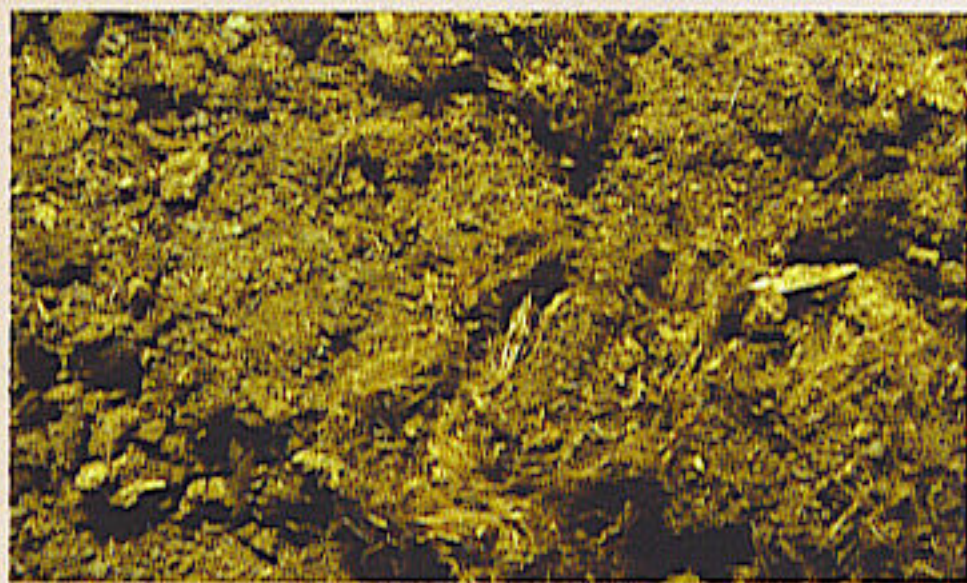


decomposition. If they do not contain at least 1.5 percent nitrogen, the organic amendment will get it from the soil, robbing roots of valuable nitrogen. When using organic amendments, make sure they are thoroughly composted (at least one year) and releasing nitrogen rather than stealing it from the soil. A dark, rich color is a good sign of fertility.

Rich, thoroughly composted organic matter amends texture and supplies nutrients. Leaf mold, garden compost (at least one year old), and many types of thoroughly composted manure usually contain enough nitrogen for their decomposition needs and release nitrogen rather than using it. Purchase quality organic amendments at a reputable nursery. Look carefully at the descriptive text on the bag to see if it is sterilized and is guaranteed to contain no harmful insects: larvae, eggs, and fungi or bad microorganisms. Contaminated soil causes many problems that are easily averted by using a clean mix.

Garden compost and leaf mold are usually rich in organic nutrients and beneficial organisms that speed nutrient uptake, but they can be full of harmful pests and diseases, too. For example, compost piles are a favorite breeding ground for cutworms and beetle larvae. Just one cutworm in a container means certain death for the defenseless marijuana plant. Garden compost is best used in outdoor gardens and not indoors. See below for more information on garden compost.

Manure: Barnyard manure, a great fertilizer for outdoor gardens, often contains toxic levels of salt and copious quantities of weed seeds and fungus spores that disrupt an indoor garden. If using manure, purchase it in bags that guarantee its contents. There are many kinds of manure: cow, horse, rabbit, and chicken, etc. See Chapter Eleven for a complete rundown on manures, all of which help retain water and improve soil texture when used as soil amendments. When mixing manures as amendments, do not add more than 10-15 percent, to avoid salt buildup and overfertilization. The nutrient



Coconut peat is becoming very popular among growers.



Rent a commercial cement mixer to mix large quantities of soil.

content of manures varies, depending upon the animal's diet and the decomposition factors.

Peat is the term used to describe partially decomposed vegetation. The decay has been slowed by the wet and cold conditions of the northern United States and Canada where it is found in vast bogs. The most common types of peat are formed from sphagnum and hypnum mosses. These peats are harvested and used to amend soil and can be used as a growing medium. Peat moss is very dry, and difficult to wet the first time, unless you bought it wet. Wet peat is heavy and awkward to transport. When adding peat moss as a soil amendment, cut your workload by dry-mixing all of the components before wetting. Use a wetting agent. Another trick to mixing peat moss is to kick the sack a few times to break up the bale before opening.

Peat tends to break down and should be used for only one crop.

Sphagnum peat moss is light brown and the most common peat found at commercial nurseries. This bulky peat gives soil body and retains water well, absorbing 15 to 30 times its own weight. It contains essentially no nutrients of its own, and the pH ranges from 3-5. After decomposing for several months, the pH could continue to drop and become very acidic. Counter this propensity for acidity and stabilize the pH by adding fine dolomite lime to the mix.

Hypnum peat moss is more decomposed and darker in color with pH from 5.0 to 7.0. This peat moss is less common and contains some nutrients. Hypnum peat is a good soil amendment, even though it cannot hold as much water as sphagnum moss.

Coconut fiber is also called palm peat, coco peat, cocos, kokos, and coir. Coir is coconut pith, the fibery part just under the heavy husk. Pith is soaked in water up to nine months to remove salts, natural resins, and gums in a process called retting. Next, they beat the straw-brown coir to extract the husk.

Coir is biodegradable and a good medium for propagation through flowering and fruit growth. Coir holds lots of water while maintaining struc-

ture. It is durable, rot-resistant, and a good insulator, too. It is inexpensive, easy to control, and holds lots of air.

Washed, pressed blocks or bricks of coir are virtually inert. Bricks weigh about 1.3-2.2 pounds (0.6-1 kg.) The pH is between 5.5 and 6.8. Some of the best coconut coir is from the interior of the Philippine Islands, where the environment is not packed with coastal salts. Quality coconut coir is guaranteed to have sodium content of less than 50 ppm.

Growers use coir by itself or mixed 50/50 with perlite or expanded clay to add extra drainage to the mix. Some growers sprinkle coconut coir on top of rockwool blocks to keep the top from drying out.

Flake dry bricks of coconut coir apart by hand or soak the bricks in a bucket of water for 15 minutes to expand and wet. One brick will expand to about 9 times its original size. Growing in coconut coir is similar to growing in any other soilless medium. Coconut coir may stay a little too wet and require more ventilation and air circulation.

Hit the site www.canna.com for more information on coconut fiber and growing marijuana.

Soil Mixes

Outdoor soil mixes that incorporate garden soil, compost, manure, coco peat, and rock powders grow some of the best plants in the world. Outdoor soil mixes can be mixed a few months early and left in the hole to blend and mature. Outdoor organic soil mixes are alive, and controlling the soil life is a matter of paying attention to a few details.

Indoors, outdoor soil mixes often create more trouble than they are worth. Too often misguided novices go out to the backyard and dig up some good-looking dirt that drains poorly and retains water and air unevenly. The problems are compounded when they mix the dirt with garden compost packed with harmful microorganisms and pests. This lame soil mix grows bad dope. By saving a few bucks on soil, such growers create unforeseen problems and pay



Solarize used soil to kill pests and diseases.



Compost piles must be at least 3 feet (90 cm) square in order to retain more heat than they give off.

Soil mixes with compost:

- 0.5 compost**
0.5 soilless mix

- 0.3 compost**
0.3 soilless mix
0.3 coco coir

- 0.5 compost**
0.5 coco coir

- 0.3 compost**
0.3 soilless mix
0.16 worm castings
0.16 perlite

for their savings many times over with low-harvest yields. Avert problems with soil mixes by purchasing all of the components. Use garden soil or compost only if they are top quality and devoid of harmful pests and diseases. Use only the richest, darkest garden soil with a good texture. Amend the soil by up to 80 percent to improve water retention and drainage. Even a soil that drains well in the outdoor garden needs amending to drain properly indoors. Check the pH of the garden soil before digging to ensure it is between 6.0 and 7.0. Add fine dolomite to stabilize and buffer pH. Check pH several times after mixing to ensure it is stable.

Solarize garden soil by putting it out in the sun in a plastic bag for a few weeks. Turn the bag occasionally to heat it up on all sides. Make sure the bag receives full sun and heats up to at least 140°F (60°C). This will kill the bad stuff and let the beneficial bacteria live.

You can also sterilize soil by laying it out on a Pyrex plate and baking it at 160°F for 10 minutes, or microwave it for two minutes at the highest setting. It is much easier and more profitable in the end to purchase good potting soil at a nursery.

Compost

Compost is outstanding. It solves most problems outdoors. Compost is an excellent soil amendment. It holds nutrients and moisture within its fiber. However, using backyard compost indoors is tricky.

Some growers have no trouble with organic composts, but others have bad luck and even lose their entire crop when growing in backyard compost. Good compost recipes are available from monthly publications such as *Sunset*, *Organic Gardening*, *National Gardening*, etc., or from the companies specializing in organic composts. Outdoor growers love compost. It is inexpensive, abundant, and works wonders to increase water retention and drainage. It also increases nutrient uptake because of biological activity. Indoors,

compost is not very practical to use in containers. It could also have unwanted pests. If using compost indoors, make sure it is well-rotted and screened.

A good compost pile includes manure—the older the better. Manure from horse stalls or cattle feedlots is mixed with straw or sawdust bedding. Sawdust uses available nitrogen and is also acidic and not recommended. Look for the oldest, and most-rotted manure. Well-rotted manure is less prone to have viable weed seeds and pests. Fresh nitrogen-packed grass clippings are one of my favorites to use in a compost pile. Put your hand down deep into a pile of grass clippings. The temperature one or two feet down in such a pile ranges from 120° to 180°F (49° to 82°C). Heat generated by chemical activity kills pests, breaks down the foliage, and liberates the nutrients.

Build compost piles high, and keep turning them. Good compost pile recipes include the addition of organic trace elements, enzymes, and the primary nutrients. The organic matter used should be ground up and in the form of shredded leaves and grass. Do not use large woody branches that could take years to decompose.

Before using compost indoors, pour it through 0.25-inch mesh hardware cloth (screen) to break up the humus before mixing with soil. Place a heavy-duty framed screen over a large garbage can or a wheelbarrow to catch the sifted compost. Return earthworms found on the screen to the medium and kill cutworms. Make sure all composts are well rotted and have cooled before mixing with indoor soil. For more information about com-

posting, see *Let It Rot!, Third Edition*, by Stu Campbell, Storey Press, Prowal, VT.

Some growers mix up to 30 percent perlite into organic potting soil that contains lots of worm castings. Heavy worm castings compact soil and leave little space for air to surround roots. Adding perlite or similar amendments aerates the soil and improves drainage.

Growing Medium Disposal

Disposing of used growing medium can be as big a problem as finding the proper soil. Most soilless mixes and soils contain perlite, which leaves white telltale traces when dumped anywhere. Grow soil is also packed with incriminating cannabis roots. The plug was pulled on more than one grow-show because soil residuals were found in the back yard.

Dry soil is easier to work and transport. Press and rub dry soil through a 0.25 to 0.5-inch screen to remove roots, stems, and foliage. Screening also transforms the cast-container shape of the soil to an innocuous form. Once the roots are removed, dry, used soil can be bagged up or compacted. Place the dry soil in a trash compactor to make it smaller and more manageable. Do not throw the spent growing medium into your trash can. Remember, it is not a crime for law enforcement in America to dig through your garbage. In fact, picking through a suspected grower's garbage is a tactic often used by American authorities to secure a search warrant. Remove the depleted soil from the property. Take it to the dump or dispose of it in a very discreet locale. Never throw away the transporting bags with the used soil. Reuse the bags.

Used indoor growing mediums make excellent outdoor amendments when mixed with compost and garden soil. Do not reuse the depleted soil in outdoor pots. Many of the same problems that occur indoors will happen in outdoor pots.

Used Soil

Let soil dry.

Screen to separate roots, stems, and foliage from the soil.

Pack in plastic bags.

Remove soil from property.

Dispose of discreetly.

Grow Medium Problems

These maladies are caused by growing medium problems but manifest as nutrient problems. The solution is found within the growing medium.

When water is abundant in the growing medium, roots easily absorb it. Roots use more energy to absorb more water as it becomes scarce.

Visible Signs of Grow Medium Stress

- Dry, crispy, brittle leaves
- Patchy or inconsistent leaf color
- Yellow leaf edges that worsen
- Crispy, burnt leaf edges
- Chlorosis—yellowing between veins while veins remain green
- Irregular blotches on leaves
- Purple stems and leaf stems
- Leaf edges curl up or down
- Leaf tip curls down
- Super-soft pliable leaves
- Branch tips stop growing
- Leggy growth

CEC of popular growing mediums measured in Milli-Eq/100 grams

Compost	90
Sunshine Mix	90
Peat moss	80
Garden soil	70
Expanded clay	20
Vermiculite	20
Perlite	0
Rockwool	0

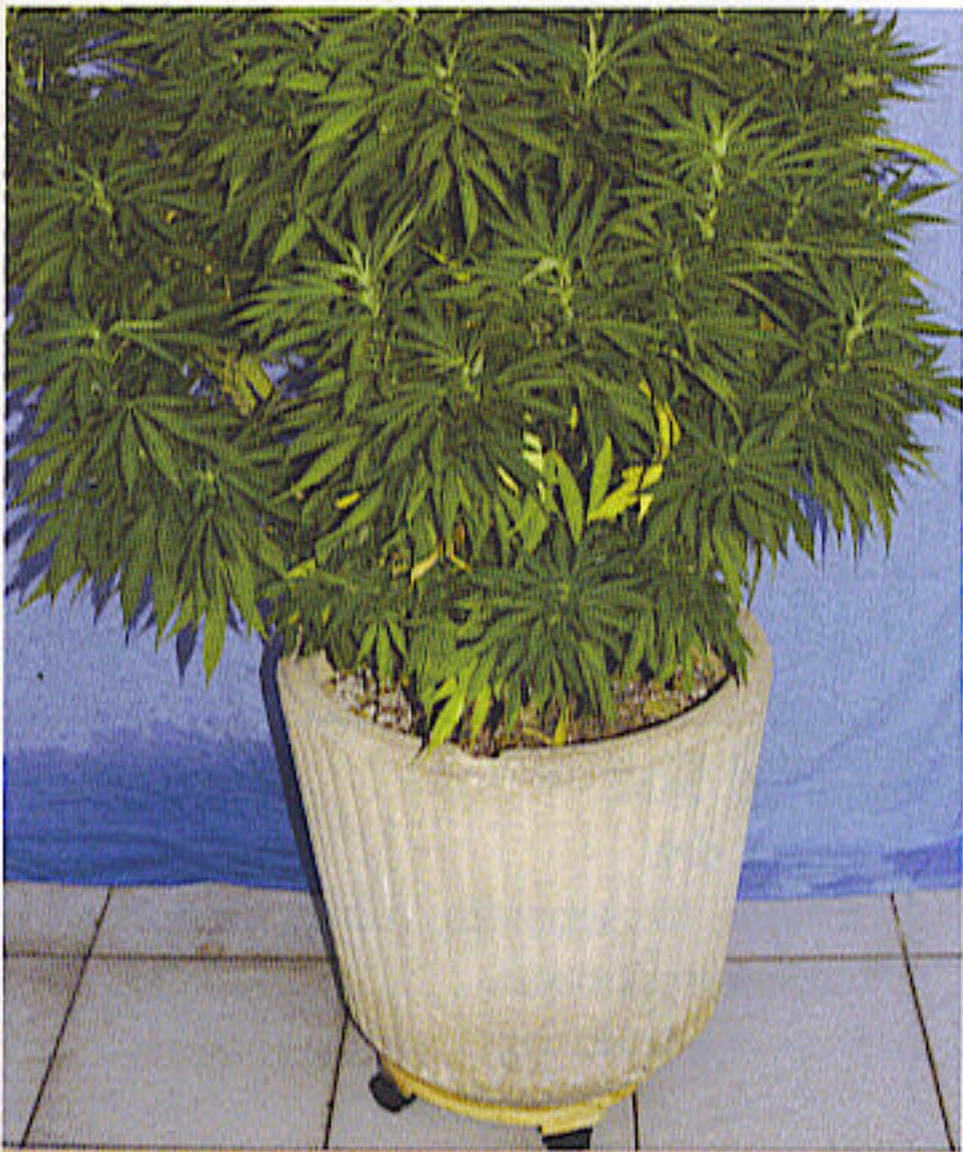
This chart shows different growing mediums' ability to hold positive charges that are ready for root uptake. Note the zero CEC of perlite and rockwool. Roots must be constantly bathed in nutrients. Other mediums do not provide a constant flow of nutrients and the CEC regulates the ability to hold a positive charge to make nutrients available for root uptake.

Finally, the point comes when the substrate retains more moisture than it surrenders, and the roots receive no water. A good growing medium readily yields its bank of stored water and nutrients. A poor medium does not pass enough nutrients to a plant's roots. The more easily cannabis absorbs nutrients, the higher the yield.

The cation-exchange-capacity (CEC) of a growing medium is its capacity to hold cations that are available for uptake by the roots. The CEC is the number of cation charges held in 3.5 ounces (100 gm) or 100 cc of soil and is measured in milli-Equivalents (mEq) or Centi-Moles/kg on a scale from 0-100. CEC of 0 means the substrate holds no available cations for roots. CEC of 100 means the medium always holds cations available for root uptake. Growing mediums that carry a negative electrical charge are the best.

Containers

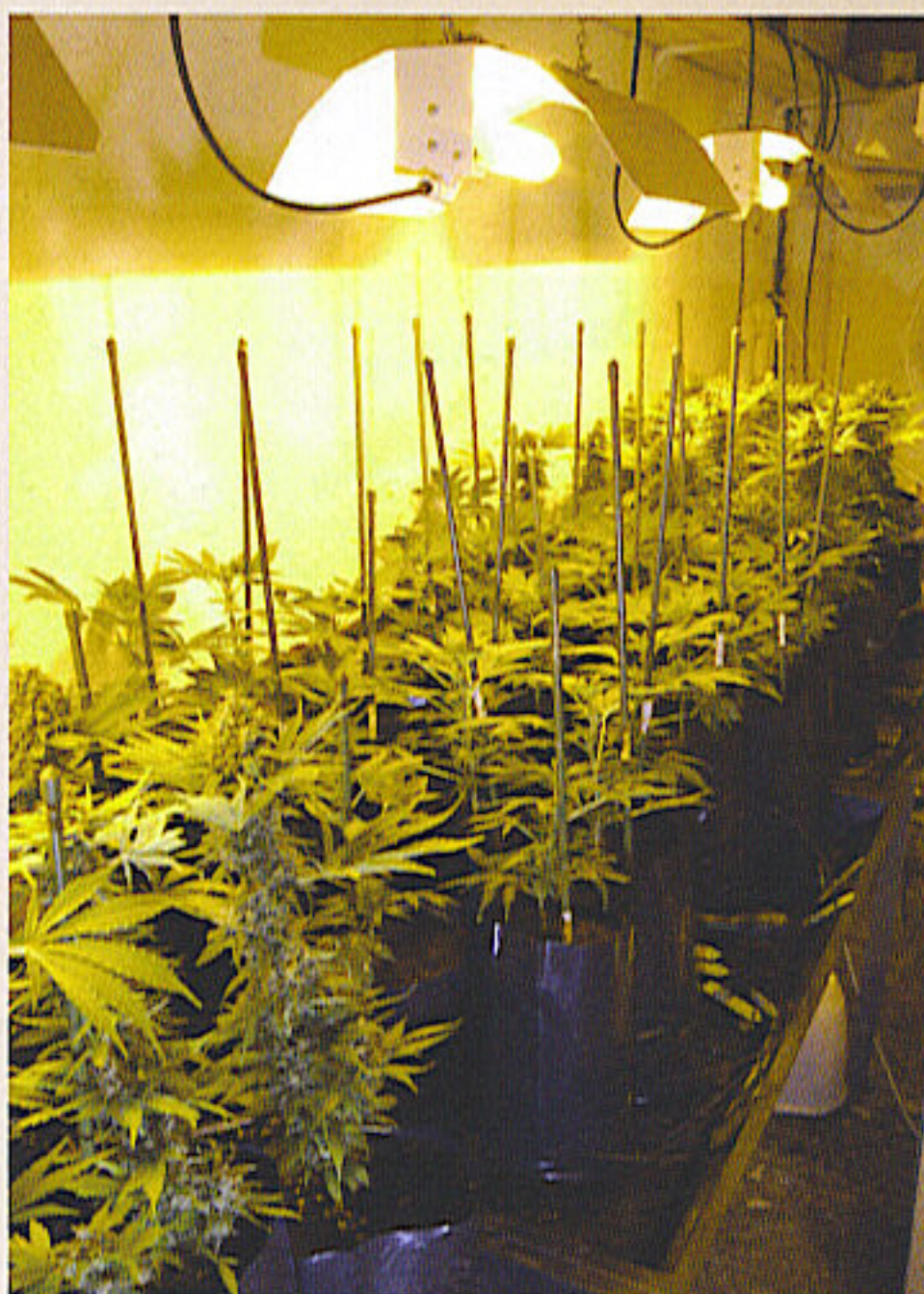
Container preference is often a matter of convenience, cost, and availability. But the size, shape, and color of a container can affect the size and the health of a plant as well as the versatility of the garden. Containers come in all



Ceramic containers are durable but heavy.

shapes and sizes and can be constructed of almost anything—clay, metal, plastic, wood, and wood fiber are the most common. Cannabis will grow in any clean container that has not been used for petroleum products or deadly chemicals. Clay fiber and wood containers breathe better than plastic or metal pots. Heavy clay pots are brittle and absorb moisture from the soil inside, causing the soil to dry out quickly. Metal pots are also impractical for grow rooms because they oxidize (rust) and can bleed off harmful elements and compounds. Wood, although somewhat expensive, makes some of the best containers, especially large raised beds and planters on wheels. Plastic containers are inexpensive, durable, and offer the best value to indoor growers.

Rigid plastic pots are the most commonly used containers in grow rooms. Growing in inexpensive, readily available containers is brilliant because they allow each plant to be cared for individually. You can control each plant's specific water and nutrient regimen. Individual potted plants can also be moved. Turn pots every few days, so plants receive even lighting and foliage will grow evenly. Huddle small, containerized plants tightly together under the brightest area below the HID lamp, and move them further apart as they grow. Set small plants up on blocks to move them closer to the HID. Individual plants are easily quarantined or



Grow bags are economical, lightweight, and reusable.



White pots reflect light and heat. Black pots set inside the white pots keep roots in a dark environment.



The potting soil bag can also be used as a container.



Woven coco fiber pots from General Hydroponics breathe well, do not compact, can be used several times, and are biodegradable.



Containers on casters are easy to move and stay warmer when up off the floor.

- Containers must be:**

 - Clean**
 - Have adequate drainage holes**
 - Big enough to accommodate plant**

dipped in a medicinal solution. Weak, sick, and problem plants are easy to cull from the garden.

Grow bags are one of my favorite containers. Inexpensive, long-lasting grow bags take up little space and are lightweight. A box of 100 3-gallon (13 L) bags weighs less than 5 pounds (2.3 kg) and measures less than a foot square. One hundred 3-gallon (13 L) grow bags can be stored in two 3-gallon (13 L) bags. Imagine storing 100 rigid pots in the same space!

Grow bags are very easy to wash and reuse. Empty out the soilless mix and submerge bags in a big container of soapy water overnight. Wash each one by hand the next day and fill with soil. I like them much better than rigid pots because they are so practical.

The potting soil sack can be used as a container. The moist soil inside the bag holds its shape well, and the bags expand and contract with the soil, lessening the chance of burned root tips that grow down the side of pots.

Fiber and paper-pulp pots are popular with growers who move their plants outdoors. The bottoms of the pots habitually rot out. Painting the inside of the fiber container with latex paint will keep the bottom from rotting for several crops.

Set large pots on blocks or casters to allow air circulation underneath. The soil stays warmer and maintenance is easier. Planters should be as big as possible but still allow easy access to plants. The roots have more room to grow and



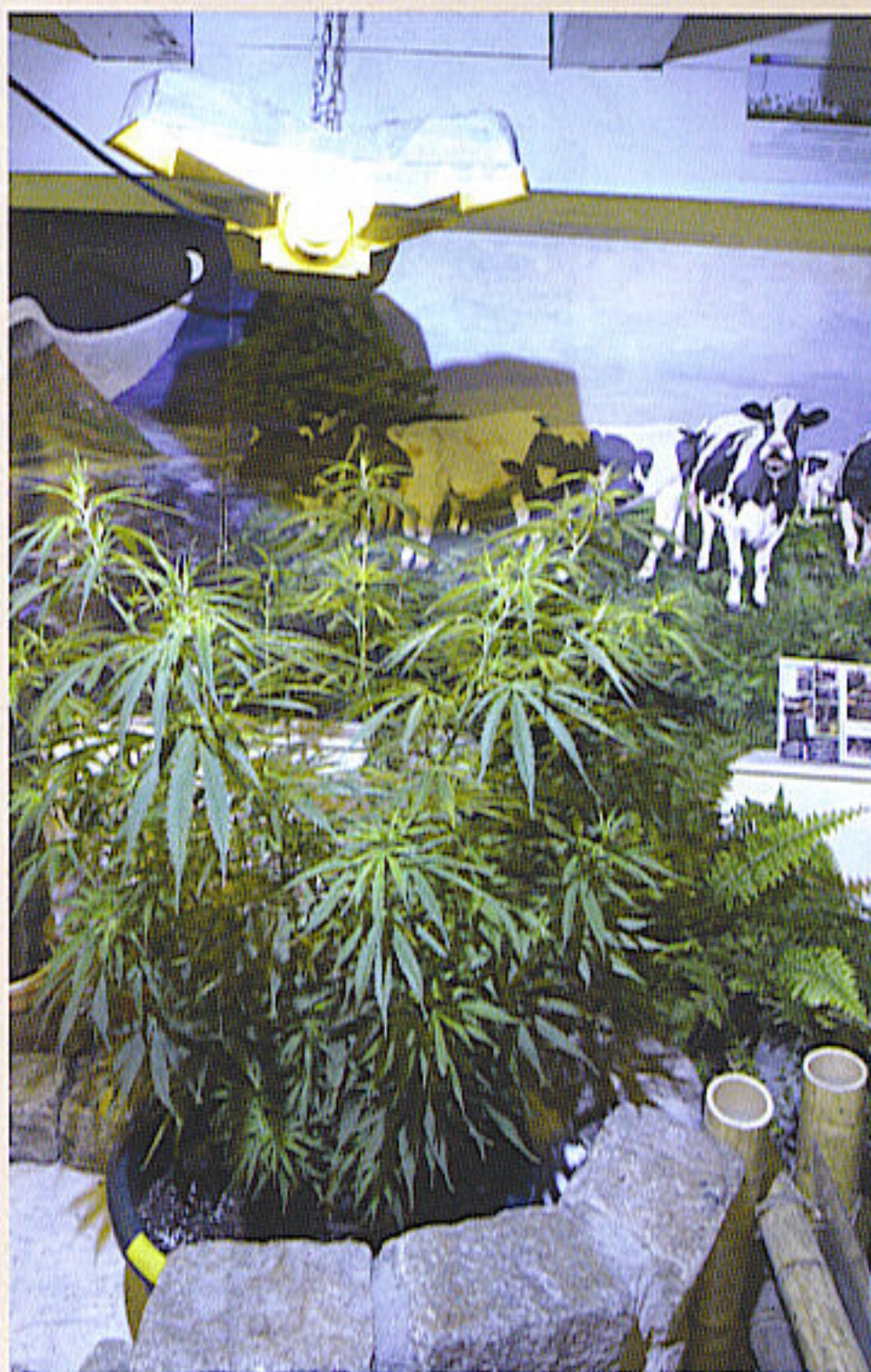
Planting directly in the floor of a basement or building gives roots plenty of space to expand.

less container surface for roots to run into and grow down. With large pots, roots are able to intertwine and grow like crazy.

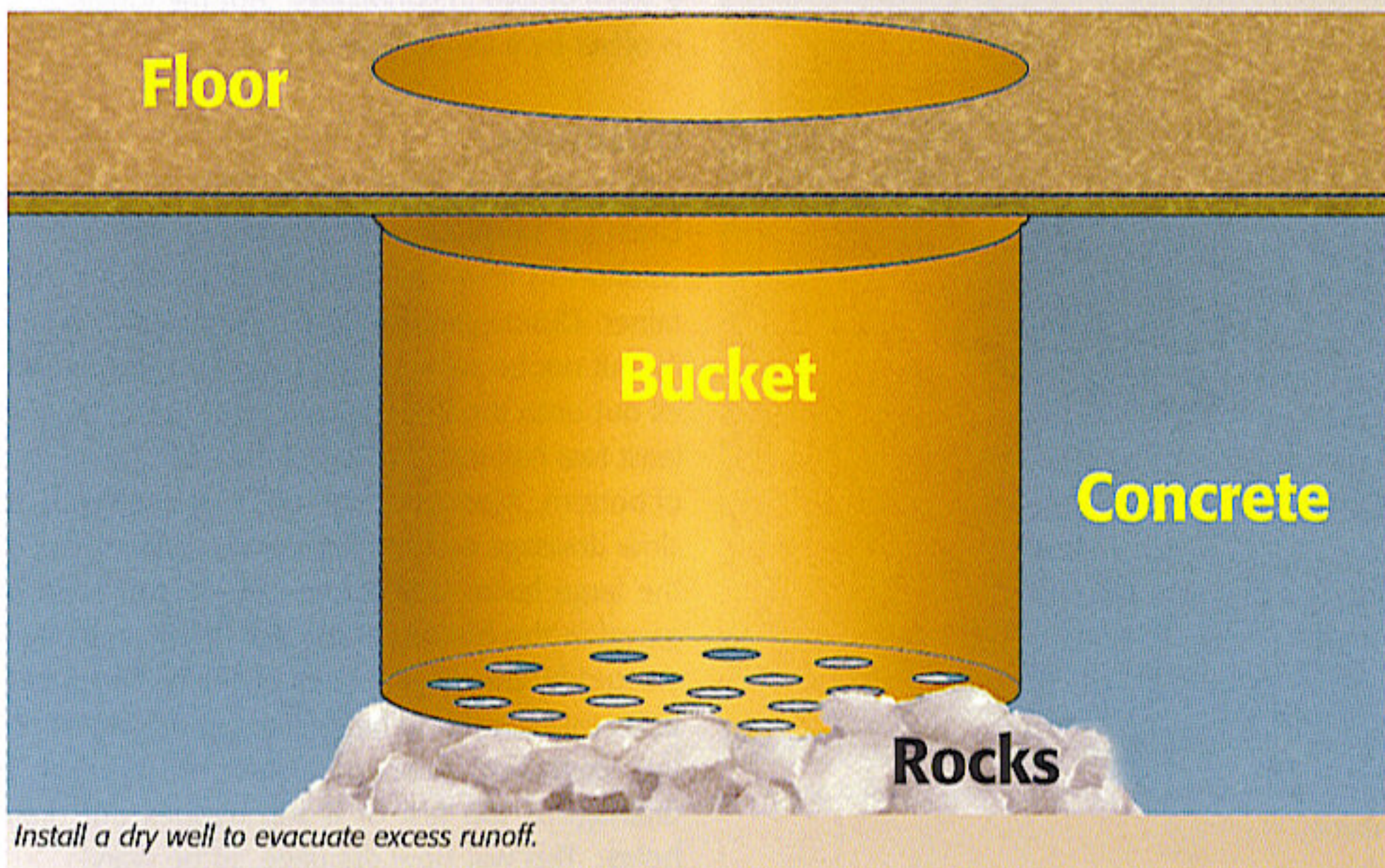
Grow beds can be installed right on the earthen floor of a garage or basement. If drainage is poor, a layer of gravel or a dry well can be made under the bed. Some growers use a jackhammer to remove the concrete floor in a basement to get better drainage. An easier option is to cut a hole in the basement floor and install a dry well. Knocking holes in basement floors could cause water seepage, where water tables are high. When it rains, the water may collect underneath; the garden seldom needs watering, but plants are kept too wet.

A raised bed with a large soil mass can be built up organically after several crops. To hasten organic activity within the soil, add organic seaweed, manure, and additives. When mixing soil or adding amendments, use the best possible organic components and follow organic principles. There should be good drainage and the soil should be as deep as possible, 12-24 inches (30-60 cm).

At the Cannabis College in Amsterdam, Netherlands, they are growing in large soil beds



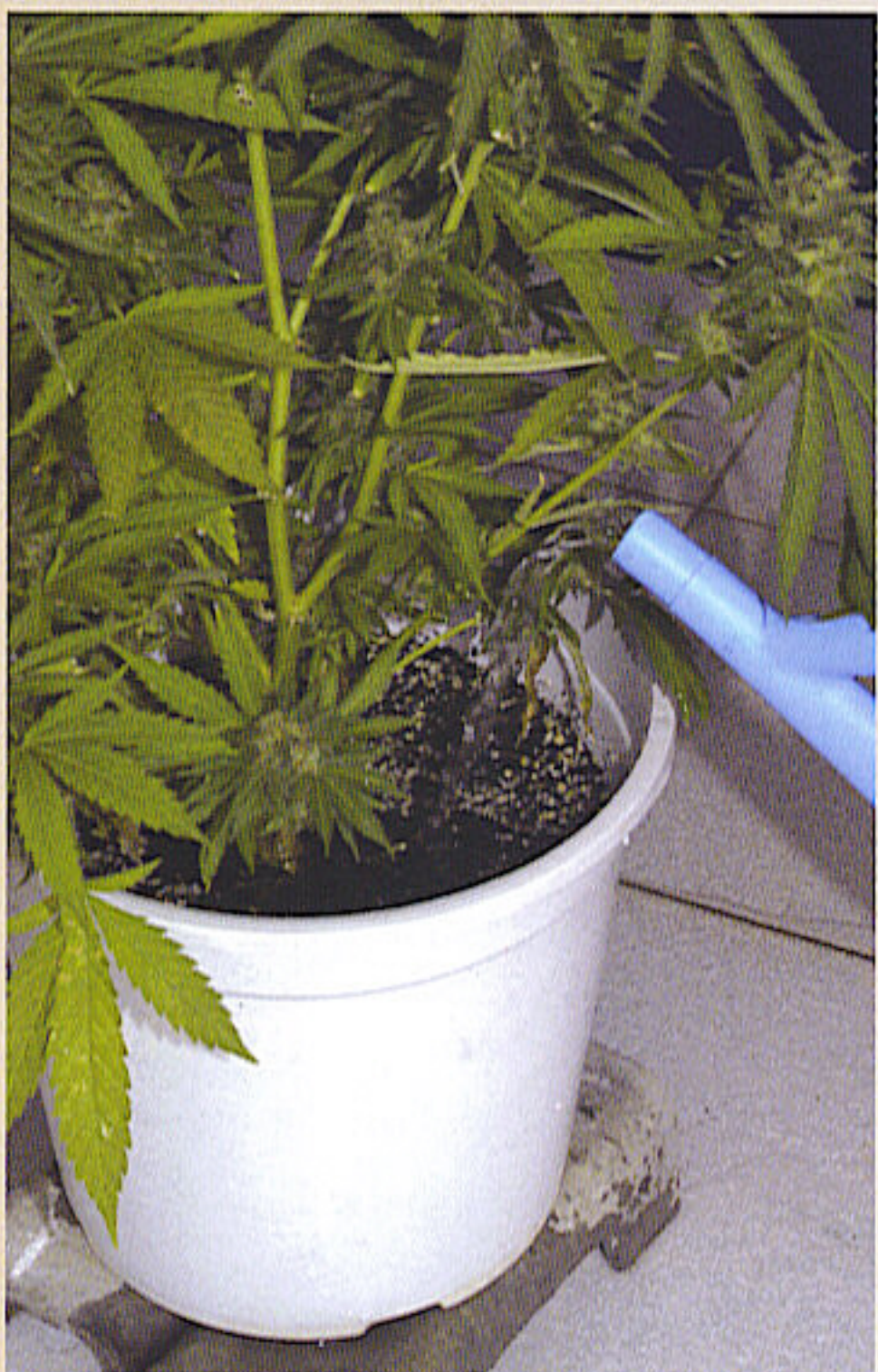
You can find this raised bed garden in the grow room at the Cannabis College in Amsterdam.



Install a dry well to evacuate excess runoff.



Flush containers with three times as much water volume of soil to leach out excess fertilizer salts. Flush containers every month to avoid many problems.



Flush containers with a mild nutrient solution every month.

set on a concrete floor. The basement beds are below sea level and filled with outstanding Dutch cannabis. They are able to treat the beds similar to outdoor soil beds, but when watered heavily, water runs out on the floor and it must be mopped up. They also have a problem with ventilation. The ambient climate is naturally humid and the extra water in the large basement increases humidity to above 90 percent, day and night. They employ a large extraction fan and a relatively small intake fan. Air is pulled through the long narrow basement room quickly and efficiently to evacuate moisture and lower the humidity. Even with this much soil, they have to flush individual beds at least once every four weeks to avoid nutrient buildup.

Much heat can be generated by decomposing organic matter, and it warms the room. Ventilation lowers heat and humidity, and helps keep the room free of pests and diseases. An organic garden sounds great, but it is a lot of work to replicate the great outdoors. Most organic growers opt for organic liquid fertilizers and a bagged commercial organic soil mix.

Another drawback to raised beds is that the crop will take a few days longer to mature than if it were grown in containers. But the longer wait is offset by a larger harvest.

Drainage

All containers need some form of drainage. Drainage holes allow excess water and nutrient solution to flow freely out the bottom of a container. Drainage holes should let water drain easily, but not be so big that growing medium washes out onto the floor. Containers should have at least two half-inch (1.2 cm) holes per square foot of bottom. Most pots have twice this amount. To slow drainage and keep soil from washing out of the large holes, add a one-inch (3 cm) layer of gravel in the bottom of the pot. Surface tension created by the varying sizes of soil and rock particles cause water to be retained at the bottom of the container. Line pots with newspaper if drainage is too fast or if soil washes out drain holes. This will slow drainage, so be wary!

Put trays under containers to catch excess water. Leaving water-filled saucers under pots often causes root rot. To avoid water-logging soil and roots, set containers up an inch or two on blocks when using trays.

Nursery trays used for rooting cuttings and growing seedlings must have good drainage throughout the entire bottom. Once clones and seedlings are in place in the tray, the tray should always drain freely with no standing water in the bottom.

Container Shape, Size, and Maintenance

Popular pot shapes include rectangular and cylindrical. Growers prefer taller pots rather than wide, squat containers because the cannabis root system penetrates deeply. Of all the gardens I have visited, squat pots were few and far between. Growers I queried said squat pots may hold more soil for their stature, but they do not produce as extensive a root system.

The volume of a container can easily dictate the size of a plant. Cannabis is an annual; it grows very fast and requires a lot of root space for sustained, vigorous development. Containers should be big enough to allow for a strong root system, but just big enough to contain the root system before harvest. If the container is too small, roots are confined, water and nutrient uptake is limited, and growth slows to a crawl. But if the container is too big, it requires too much expensive growing medium and becomes heavy and awkward to move.

Marijuana roots develop and elongate quickly, growing down and out, away from the main taproot. For example, about midsummer, nurseries have unsold tomato plants that are still in small 4-inch (10 cm) pots and one-gallon (4 L) containers. The stunted plants have blooming flowers and ripe fruit. But few branches extend much beyond the sides of the container; the plants are tall and leggy with curled down leaves and an overall stunted, sickly appearance. These plants are pot- or root-bound. Once a plant deteriorates to this level, it is often easier

and more efficient to toss it out and replace it with a healthy one.

Roots soon hit the sides of containers where they grow down and mat up around the bottom. The unnatural environment inside the container often causes a thick layer of roots to grow alongside the container walls and bottom. This portion of the root zone is the most vulnerable to moisture and heat stress and is the most exposed.



Large pots hold a lot of soil and require irrigation less frequently.



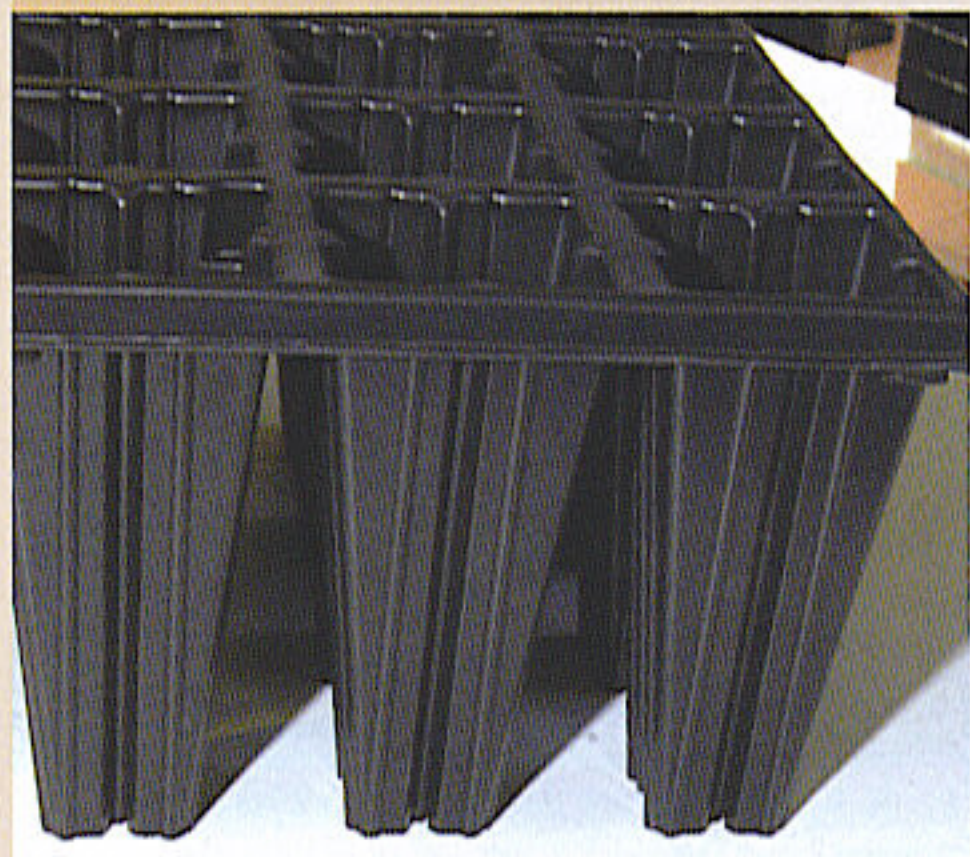
Large square pots are perfect for this hydroponic garden.



This room full of 3-gallon (11 L) pots is packed in so tight that you can walk on the pots.



Square containers are easy to bunch together when plants are small.



Deep containers are ideal for seedlings that will be planted outdoors.



Soil shrinks when dry; it causes a gap to form along-side the container wall.

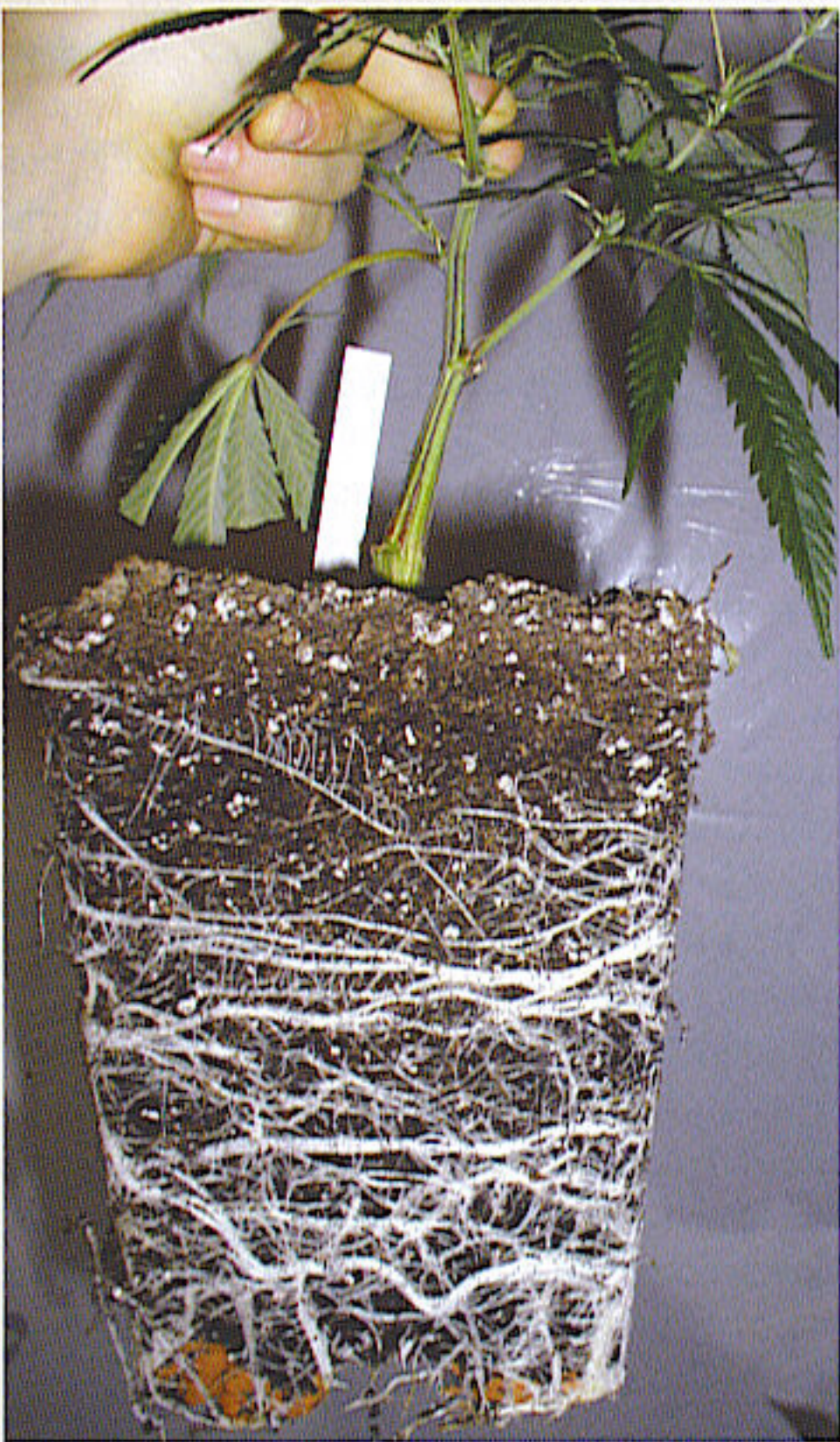
Plant age

0 – 3 weeks
2 – 6 weeks
6 – 8 weeks
2 – 3 months
3 – 8 months
6 – 18 months

Container size

root cube
4-inch pot
2-gallon pot
3-gallon pot
5-gallon pot
10-gallon pot

Allow 1 to 1.5 gallons (4 to 7 L) of soil or soilless mix for each month the plant will spend in the container. A 2- to 3-gallon (7.5-11 L) pot supports a plant for up to three months. 3- to 6-gallon containers are good for three to four months of rapid plant growth.



Roots grow quickly and soon encircle the inside of the container.



Cultivate the top layer of soil with a fork to break up the crusty surface.

When soil dries in a pot, it becomes smaller, contracting and separating from the inside of the container wall. This condition is worst in smooth plastic pots. When this crack develops, frail root hairs located in the gap quickly die when they are exposed to air whistling down this crevice. Water also runs straight down this crack and onto the floor. You may think the pot was watered, but the root ball remains dry. Avoid such killer cracks by cultivating the soil

surface and running your finger around the inside lip of the pots. Cultivate the soil in pots every few days and maintain evenly moist soil to help keep root hairs on the soil perimeter from drying out.

Do not place containers in direct heat. If soil temperature climbs beyond 75°F (24°C), it can damage roots. Pots that are in direct heat should be shaded with a piece of plastic or cardboard.



Feeder roots grow near the soil surface, just under the expanded clay mulch.



Lightly cultivate the soil surface, so water penetrates evenly. Be careful not to disturb roots.

A 1 to 2-inch (3-5 cm) layer of hydro clay mulch on soil surface keeps soil surface moist. Roots are able to grow along the surface, and the soil does not need to be cultivated. The mulch also decreases evaporation and helps keep irrigation water from damaging roots or splashing.

Green Roots

White containers reflect light and keep soil cooler. Always use thick, white containers so



Roots turn green and grow poorly when they receive direct light.

light does not penetrate and slow root growth. If roots around the outside of the root ball start turning green, you know they are receiving direct light. Remedy the problem by painting the inside of the container with a non-toxic latex paint.



These outdoor plants are thriving in Canada.

