Candela Lux measurement

MCD mean millicandela or CD, Candela. Lux is not the same as mcd, and is
not measured with a lux meter.

There is a lot more technical information from the links on this page;
http://www.theledlight.com/technical.html

Good for definitions and pictures
http://www.ledtronics.com/pages/tech4.htm

LED output measurements:
one lux=0.0929 footcandles

http://www.highend.com/news/lightingfaq.html

Nowadays we use the term CANDELA instead of candlepower. Candlepower, or CANDELA is a measure of how much light the bulb produces, measured at the bulb, rather than how much falls upon the thing you want to light up

And for you figuring out LED equivalents, first you must know how many lumens your LED's each produce. Then divide that value by 12.57 and you have candlepower of the LED. You don't have foot-candles, remember foot-candles are illuminance. And we are measuring radiance.

Candlepower is a rating of light output at the source, using English measurements.
   Foot-candles are a measurement of light at an illuminated object.
   Lumens are a metric equivalent to foot-candles in that they are measured at an object you want
   to illuminate.
   Divide the number of lumens you have produced, or are capable of producing, by 12.57 and you
   get the candlepower equivalent of that light source.

http://www.theledlight.com/lumens.html

How to convert footcandles and lux to candelas:

     Candelas are equal to the square of the distance multiplied by the number of footcandles.
     For example, if your meter is ten feet away from the light source and your meter reading is
     10 footcandles, the equivalent candelas equals 10 feet squared (e.g. 100) times 10 --
     which equals 1,000 candelas.

     The conversion of footcandles and lux to candelas is most accurately achieved in the
     context of a single point source of light measured in the dark. If the light source is diffused,
     you should take several readings at different angles in order to calculate an "average"
     candela measurement.

http://www.clubfree.com/spectra/candela/index.htm#candelas

Lighing hand book
good

http://www.intl-light.com/handbook/flux.html

From an earler posting to TT I found this that I sent

One candle = 12.5 Lumen = amount of energy (as light) a light source emits. Light bulbs some times are rated in this way. You can look on some bulb packages and get watts and number of Lumen or amount of light it puts out.

Lux = is the rate of energy falling on a surface as a result of light hitting it. One can think of it as the amount of light hitting a given square area of a surface.

I found the following Equivalents:

One foot-candle (foot-candle)= One Lumen per SQ. Ft. = 10.76 Lumens per Sq. Meter (or LUX) = .00176 Lumen per sq. Cm. (Phot)

One Lumen (at 5,550 Angstroms) = .00147 Watts
one Sq. Ft. = .0929 Sq. Meters

Thus at 5,550 Angstroms of light:
on foot-candle = .00147 watts per Sq. Ft. = .0158 Watts per Sq. Meter
Or, one Lux = .000136 Watts per sq. ft = .00147 watts per sq. meter
or, one watt per Sq. meter = 680 Lux
or, one watt per sq. ft.   = 7320 Lux

Brightness Values: (electronics reference (Magnavox))

light source	Lux	Watts/ft2	Watts/m2
Office fluorescent Lighting	300-500	.04-.07	.44-.73
Halogen lamp	750	.102	1.10
Sunlight, 1 hour before sunset	1000	.136	1.47
Daylight, Cloudy sky	5000	.680	7.35
Daylight, Clear sky	10,000	1.36	14.7
Bright Sunlight	> 20,000	2.72	29.4

Note that the above watts/sq. ft and watts/sq. meter is the amount of energy in the light and not the amount of watts that it took to make the light. Many light bulbs are inefficient. Typically only 10% of the energy goes to make light in vacuum tungsten filament light or possibly up to 20% with halogen bulbs. Florescent are about 70-90% efficient.

I pulled the following quotes from link:
http://www.litemanu.com/lightingqa.html

"Under natural conditions, maximum rates of Photosynthesis are attained in single leaves of many species at 25-35% of full sunlight intensity and in some shade species at even lower intensities."

If one now takes 25-35% of 14.7-29.4 watts/sq. meter one gets 3.7 to 10.3 watts/sq. meter or an average of 7 Watts/sq. meter. Note that this is very close to 6 watts/sq. meter. Thus I believe Steve is correct.

Now lets start from scratch and calculate an estimate amount of light hitting your plants.

From "Handbook of Engineering Fundamentals" by Eshbach second edition.
Efficiency of light sources table 4 page 10-33.

Light source   efficiency (lumens/watt)

```
tungsten gas filled      20
tungsten vacuum lamp     10
Fluorescent: (includes ballast loss)
 standard cool white     46.5
 standard warm white     51.2
 de luxe cool white      29.0
 de luxe warm white      31.0
 daylight                41.3
```

Depending on the bulb used you could be putting out 29lumens/watt*40watts= 1160 lumens or 51.2*40= 2048 lumens of light.

We now will calculate the Lux using the formulas following table 1 in the following link:

Environmental Effects of Roadway Lighting
http://www.darksky.org/ida/info125.html

Street lamps are designed to direct a high percentage of their light toward the street (45%). Let assume your lamps are less efficient say 30-40% of the light generated falls with in the .39 area of useable space. Lets assume we can keep the bulbs clean and that aging is the only factor of say about (.8).

Illuminance of 4 (40 watt florescent tubes) =
(L*CU*LLF)/(S*W)=
[4*(1160 to 2048 lumens)*(.3 to .4)*.8]/(.39 sq. meters)
= 2855 Lux to 6721 Lux. (Or an average of 4788 Lux)

What should we expect to need? (7 watt)*(680 Lux/watt per Sq. meter) = 4760 Lux would be the minimum from above.
Steve says: Tomatoes grow best at 4000 Lux, 18 hours a day. If the hrs decrease to 12 hrs that 22% decrease in time and now if we add 22% to 4000 Lux we get 4880 Lux. Very close to the same result.

Bottom line: Depending on the bulb you are using and the actual efficiency of light delivered to the useable area of .39 sq. meters you both are talking about the same order of magnitude of light.

More information on definition of terms can be found at:
FAQ: Lighting and Illumination
http://www.ie.psu.edu/courses/ie408W/lectures/lightingfaq.html

Feel better now? I know I do it took quite a while to get this subject straight in my mind. This is one subject we may need at least one person proficient at understanding the calculations in each community after the PS. So as to not waste energy.

Ok summery of all this

"mcd" is the amount of light that is produced by a source in milli-candela. 1 candela = 1 candlepower or the amount of light produced by one candle.

To measure this we use a light meter that measures in Lux. 1 footcandle = 10.76 Lux. 1 meter sq sphere has suface area of 4 pi r^2 = 12.56 sq meters. 1 Lux = 1 lumen/sq-m. Thus

1 footcandle = 10.76 Lux
1 lumen (lm) = .07958 Candela (cd) (4 pi steradian)
12.56 lumen = 1 Candela
1 meter sphere has surface area of 4 pi r^2 = 12.56 sq. meters.
1 Lux = 1 lumen/sq-m = .0796 Candela/sq-m
1 cd = 12.56 LUX*sq-m measured at 1 meter= .00817 *LUX* area(sq in) at 1 meter
amount of light emiting from a LED in cd can be measured in LUX at 1 meter radus

times area in square meters times 12.56.

6400 mcd = 6.4 cd = 12.56 (10,500 Lux measured) * x (sq-m)
x sq meter = .0000485 sq meters = .0745 sq in or .27 by .27 inch at 1 meter

39.2*39.2 = 1537 sq inch/sq meter

Measured 14 LUX at 1 meter diameter of circle about x sq inches.

6.4 Cd = .00817*14*x *1.26 (factor from a reference equation) =
X = 6.4/.14 = 45.7 sq in or radius of 7.3"

6.4 cd at 14 lux would mean an area of

Assume 1 cd = .0082* Area(sq in) * x where x is correction factor area is
circle of with 1/2 the lux at the edge as in the center.

Measured 5" radius circle area = pi*d = 3.14*10 = 31.4 sq in
6.4 cd = .0082*14*31.4*x = 3.59x
x = 6.4/3.59 = 1.78

How to use a LUX meter to measure total light emitted from a flash light bulb or LED. The manufactures use "mcd" milli-candela as a measure of the total amount of light emitted. The following equation expresses how this can be roughly measured.

Cd (Candela) = .0082 *LUX measured* area(sq in) at 1 meter*k where k is typically between 1.2 and 2 depending on light distribution of the beam. The light intensity maximum is measured in LUX at one-meter distance from the LED. The diameter of a circle is determined by measuring the distance from the center of the beam to a point at which the light intensity drops off to 1/2 the amount of the maximum. For example I found k= 1.8 for a 20 degree LED.

A LUX meter is used to capture and measure nearly all the light emitted from each test. The following curves show voltage, current, power, and power ratios, for conventional incandescent bulbs and several common LED configurations.

Technical notes: Relative light efficiency of flash light bulbs and LED can be approximately measured by use of a LUX (light intensity meter). One uses the reflector that comes with small flashlight to reflect almost all of the light into the meter sensor. Done by placing the bulb-reflector as close as one can to the LUX meter sensor. Shield against outside light and minimizing light leakage from the bulb being tested so that the maximum amount of light from the bulb enters the LUX meter senor. This allows your LUX meter to measure the total light emitted thus it becomes a relative Lumen (total amount of light emitted) measuring meter. 1 Lumen = 1 LUX * 1sq. meter. We don't know what the fraction of a sq. meter is being used, but we don't care it will be the same for each bulb we measure. Thus we have a meter that can measure relative Lumens or total amount of light. Lumens are proportional to cd (candela) or candlepower. LEDs are rated in the amount of light they emit "mcd" (milli-candela).