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ARTIFICIAL LIGHTING INTENSITIES

Tables for Calculating Light Intensities for Artificial Lighting *by Anton M. Kofranek, UCLA*

Many California growers are using lights on field crops such as asters, daisies, and chrysanthemums. Greenhouse chrysanthemums, begonias, stephanotis and poinsettias are also being lighted. Practically every grower has a special problem in lighting these crops because his greenhouse or field may be an odd shape. Since the farm advisor has the opportunity to examine the crop and the shape of the area to be lighted, perhaps he should also recommend the spacing of lights for that particular situation. The basic light intensity required for a specific crop remains the same, but there are many combinations of bulb sizes and spacings that can be used to obtain that desired light intensity. The attached tables give adequate data to figure out most lighting set-ups in the field or greenhouse.

How the Tables Were Prepared

Five sizes of bulbs, with and without reflectors, were suspended at various distances above the soil and light readings were taken at one-foot intervals from the source of light. See the first table for the following example: When a 40-watt bulb without reflector was suspended 3 feet above the soil, it gave readings on a Weston Lightmeter, Model 603, of 5.7 foot candles at zero feet (directly under the bulb), 4.9 FC at 1 foot, 3.2 FC at 2 feet, etc. Readings were only taken to a point where the light intensity recorded on the meter was slightly less than one-half foot candle.

All readings were taken with the photoelectric cell lying flat on the ground, therefore these readings are not cosine corrected. This merely means that each light reading would have been higher if the photoelectric cell were held perpendicular to the angle of light at each foot distant from the bulb. However, the error is in your favor because the actual light intensity you recommend will be slightly higher than you calculate from these tables.

All light readings were made from new 120 volts incandescent bulbs of good quality, when the line voltage was 120 volts. This means that the light

THREE FEET FROM THE BOTTOM OF THE BULB TO THE SOIL SURFACE

No Reflectors

Distance from bulb (feet)	Bulb Size (Watts) 40	60	75	100	150
0	5.7	9.4	14.0	19.0	32.5
1	4.9	8.0	12.5	16.0	27.0
2	3.2	5.2	7.2	9.5	17.0
3	1.8	3.1	3.8	5.0	8.4
4	1.0	1.8	2.0	2.4	4.2
5	.6	.9	1.0	1.3	2.3
6	.4	.6	.6	.8	1.4
7		.4	.4	.4+	.9
8				.3	.5
9					.4
10					

With a 10" Cone Reflector

Distance from bulb (feet)	Bulb Size (Watts) 40	60	75	100	150
0	19.0	33.0	44.0	65.0	105.0
1	14.5	25.0	31.5	45.0	80.0
2	7.2	13.5	17.0	25.0	36.0
3	3.7	6.4	7.6	12.5	18.5
4	1.8	3.1	3.6	5.4	8.2
5	.8	1.5	1.7	2.7	4.1
6	.4	.8	.9	1.5	2.4
7		.4+	.5	.8	1.4
8		.2	.3	.5	.9
9				.4	.6
10					.4

FOUR FEET FROM THE BOTTOM OF THE BULB TO THE SOIL SURFACE

No Reflectors

Distance from bulb (feet)	Bulb Size (Watts) 40	60	75	100	150
0	3.1	5.1	7.3	9.9	17.5
1	2.8	4.8	6.8	9.2	15.5
2	2.1	3.6	5.1	7.9	12.0
3	1.7	2.6	3.1	4.5	8.2
4	.9	1.6	2.2	3.0	5.0
5	.6	1.0	1.4	1.8	3.1
6	.4	.6	.9	1.2	1.9
7		.4	.6	.8	1.3
8			.4	.5	.9
9				.4	.6
10					.5
11					.4

With a 10" Cone Reflector

Distance from bulb (feet)	Bulb Size (Watts) 40	60	75	100	150
0	9.8	17.5	24.0	33.0	51.0
1	8.6	15.0	20.0	27.0	40.0
2	5.7	9.7	13.0	17.5	26.0
3	3.3	5.9	7.4	11.0	16.0
4	2.0	3.4	4.4	6.0	9.1
5	1.2	2.0	2.6	3.5	5.0
6	.7	1.2	1.6	1.9	3.0
7	.4	.8	1.0	1.1	1.8
8		.5	.6	.6	1.0
9		.3	.4	.4	.6
10					.3
11					

emitted from each bulb was 100% of what it was capable of emitting. It is extremely important that your line voltage be equal to the voltage stamped on the bulb. Let us use 120 volt bulbs in our example to show why this is important. If the line voltage is only 115 volts due to voltage drop, the per cent light emitted will only be about 80%; if the line voltage is 100 volts, the light emitted will only be about 54%. An overloaded circuit caused by too many bulbs, too small a wire for the job, too long a line, or poor electrical connections, can produce a line voltage drop. It might be wise to consult an electrician to get the proper wiring for the amount and sizes of bulbs you recommend.

How to Use the Tables

The light intensity reading at any point in the field is the result of the total light emission from all the bulbs. All the foot candle readings are directly additive. An example will better illustrate this point. Look up the "Six Foot (above the soil) Table" and find the 150 watt bulb with no reflector. If the bulbs are placed 18 feet apart on the square, the light intensity at 9 feet (between 2 lights) would be 2.0 FC, or 1.0 plus 1.0 FC from each bulb. In the center of all four bulbs, which is about 12.8 feet from any one bulb, the intensity would be about 1.6 FC, or 0.4 FC x 4. Therefore, if you needed a minimum of 2

FIVE FEET FROM THE BOTTOM OF THE BULB TO THE SOIL SURFACE

No Reflectors

Distance from bulb (feet)	Bulb Size (Watts)				
	40	60	75	100	150
0	2.1	3.2	4.5	6.2	11.0
1	2.0	3.1	4.4	5.9	9.9
2	1.7	2.7	3.8	5.0	8.5
3	1.3	2.0	2.9	4.0	6.6
4	1.0	1.5	2.0	2.7	4.7
5	.7	1.1	1.4	1.9	3.2
6	.5	.8	1.0	1.3	2.3
7	.4	.6	.7	.9	1.6
8		.4	.5	.6	1.2
9			.4	.5	.9
10				.4	.6
11					.5
12					.4
13					

With a 10" Cone Reflector

Distance from bulb (feet)	Bulb Size (Watts)				
	40	60	75	100	150
0	6.2	12.0	15.5	22.0	32.0
1	5.9	11.0	13.0	20.0	28.0
2	4.4	7.8	9.4	14.0	21.0
3	3.0	5.3	6.6	9.6	15.0
4	2.1	3.5	4.3	6.2	9.5
5	1.4	2.3	2.9	4.2	6.5
6	1.0	1.6	1.9	2.8	4.4
7	.7	1.1	1.3	1.9	3.0
8	.5	.8	.9	1.3	2.1
9	.4	.6	.6	.9	1.0
10		.4	.4	.6	1.5
11				.4	.8
12					.7
13					.6
14					.4

SIX FEET FROM THE BOTTOM OF THE BULB TO THE SOIL SURFACE

No Reflectors

Distance from bulb (feet)	Bulb Size (Watts)				
	40	60	75	100	150
0	1.3	2.3	3.2	4.3	7.1
1	1.3	2.2	3.1	4.2	7.0
2	1.2	2.0	2.7	3.8	6.2
3	1.0	1.7	2.3	3.2	5.2
4	.6	1.3	1.8	2.5	4.1
5	.4	1.0	1.3	1.9	3.2
6		.8	1.0	1.5	2.4
7		.6	.7	1.2	1.8
8		.4	.5	.9	1.3
9			.4	.7	1.0
10				.4	.7
11					.6
12					.5
13					.4
14					

With a 10" Cone Reflector

Distance bulb from (feet)	Bulb Size (Watts)				
	40	60	75	100	150
0	4.3	8.0	9.6	15.0	24.0
1	4.2	7.4	9.4	13.0	19.5
2	3.4	5.8	7.5	9.6	15.5
3	2.6	4.4	5.5	7.4	12.0
4	1.9	3.2	4.0	5.4	8.2
5	1.4	2.4	3.0	3.9	5.8
6	.9	1.7	2.0	2.8	4.2
7	.7	1.2	1.5	2.1	3.1
8	.6	.8	1.1	1.6	2.2
9	.4	.6	.8	1.2	1.6
10		.4	.6	.9	1.1
11			.4	.6	.8
12				.5	.7
13				.4	.6
14					.4

SEVEN FEET FROM THE BOTTOM OF THE BULB TO THE SOIL SURFACE

Distance from bulb (feet)	Bulb Size (Watts)				
	40	60	75	100	150
0	1.0	1.6	2.3	3.2	5.3
1	.9	1.6	2.3	3.1	5.3
2	.9	1.5	2.2	2.9	5.0
3	.8	1.3	1.9	2.6	4.3
4	.7	1.1	1.7	2.2	3.7
5	.6	.9	1.3	1.7	3.0
6	.4	.7	1.0	1.4	2.3
7		.5+	.8	1.1	1.8
8		.5-	.6	.9	1.4
9		.4-	.4	.6	1.1
10				.5	.8
11				.4	.7
12					.6
13					.4
14					

Distance from bulb (feet)	Bulb Size (Watts)				
	40	60	75	100	150
0	3.1	5.8	7.5	10.8	17.0
1	3.0	5.2	6.9	9.8	15.0
2	2.5	4.4	5.6	8.0	12.0
3	2.0	3.6	4.5	5.0	9.8
4	1.4	2.7	3.6	3.8	7.6
5	1.1	2.1	2.6	2.8	5.8
6	.8	1.6	2.0	2.1	4.4
7	.6	1.2	1.5	1.6	3.3
8	.4	.8	1.1	1.3	2.5
9		.6	.8	1.0	1.9
10		.4	.6	.7	1.4
11			.4	.6	1.0
12			.4	.4	.8
13					.6
14					.4

FC for your crop, you would space the 150 watt bulbs without reflectors about 17 feet apart. Or, if you used a 150 watt bulb with the 10 inch cone reflector, you would space the bulbs on about 19-foot centers. In the latter case, your first string of lights should not be less than 8 feet from the side of the field because at this distance the light intensity would be 2.2 FC. In the former case the first string would have to be about 6.5 feet from the side of the field. Remember, that light only comes from one side here and is dependent wholly on the first string of lights.

A few practice calculations can be made with the aid of a compass and graph paper for making concentric circles to demonstrate how easily bulb spacings can be figured if the light intensities are totaled from each bulb at any one point. Bulbs can be spaced in a rectangular fashion such as 18 x 16 feet, etc. to fit the shape of the greenhouse or field. Whatever pattern is desired (square or rectangular) the spacings can be easily planned by calculating distances on right triangles, or by using a trial and error method with a compass and graph paper. You will notice that the higher the wattage bulb used, the more efficient the spacing. The wider the spacing you recommend, the less the installation cost for the grower because he requires less wire, sockets, bulbs, etc.

Requirements, in Brief, of Some Crops

Below are brief recommendations on how much light certain crops require. One should familiarize himself thoroughly with the reaction of these crops to light before definite recommendations are made. You should know minimum size of plants when lights will be effective, height of plant to give desired stem lengths, minimum temperatures essential for growth and flower bud initiation, normal flower initiation dates, etc. It is essential to know when to turn the lights on and off to time for a specific season of forcing. Timing crops out of doors is touchy also because variation in temperature can sometimes control the flowering more than the artificial light given.

Outdoor Crops

Asters: 1 FC minimum with 4 hours light from about Jan. 15 or Feb. 1 to May 5.

Daisies: 1 FC minimum with 4 hours light from about Jan. 15 or Feb. 1 to May 5.

Feverfews: 1 FC minimum with 4 hours light from about Jan. 15 or Feb. to May 5.

Chysanthemums: 2 FC minimum from March 20 to May 1, and July 25 until Sept. 20, for about 2 to 3 hours.

Chrysanthemums: 5 FC after Sept. 20 to March 20, with 3 to 4 hours light. It is much more difficult to delay mums during the extreme short days with 2 FC for short periods.

Greenhouse Crops

Chrysanthemums: 5 FC minimum from July 25 to May 1, but vary length of time with day-length changes. From 2 hours to 4 hours, depending on length of the day at the time.

Tuberous Begonias: 5 FC minimum for 3 or 4 hours after October 10 to March 1. Temperature should be about 60° F. minimum.

Stephanotis: 8 FC minimum for about 3 to 4 hours at minimum temperatures of 65° F. Little or nothing is known about timing this crop.

Cymbidium seedlings: Approximately 5 FC minimum from 1 to 4 hours a night, depending on time of year. This crop needs more experimental work before definite recommendation can be made.

Cattleya orchids: See Cornell University Bullentin 885, October 1952.

Although few persons in our area would be lighting field crops, this information is of great use within the greenhouse.