Seeing the Light

When growing Fast Plants, the more light the better

Among the various environmental factors that influence the growth and development of Wisconsin Fast Plants, light is one that can have the greatest long term impact on the success of your classroom activities.

Continuous high light is essential to the growth of vigorous, robust plants that are capable of producing lots of flowers and seeds. Fast Plants were purposely developed to grow under inexpensive, white fluorescent lamps and have been bred for many generations to perform well when illuminated continuously (24 hours/day) with the relatively high light intensity provided by six or eight four foot 40 W fluorescent bulbs spaced at 5-6 cm apart (center to center).

High light provides energy for photosynthesis to support the accelerated growth of the Fast Plants and also is the source of energy that regulates the form and color of the plants. Basic rapid-cycling *Brassica rapa* plants growing with normal nutrition and temperature under the **ideal lighting** provided by eight 4-foot 40 W fluorescent bulbs will be stocky and dark green with purple anthocyanin pigment strongly expressed in the stem, leaves and buds. The plants will bear many flowers which, when pollinated, will produce abundant seed in the normal life cycle of

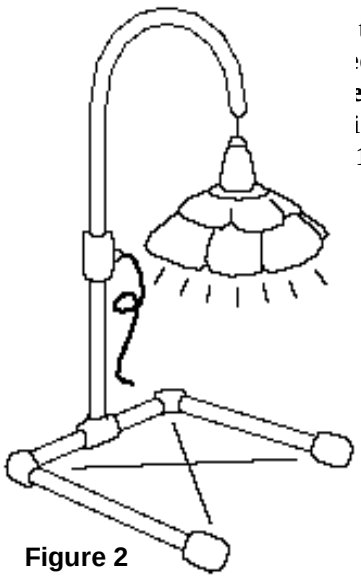
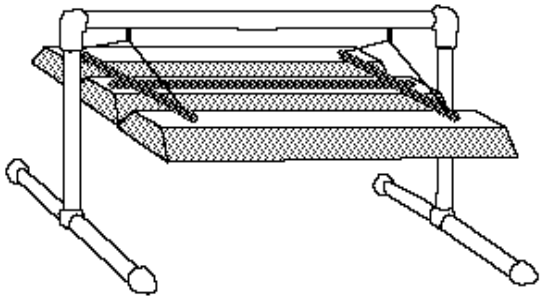


Figure 2

ts growing under the **quate, but less than eal**, lighting provided by ix 40 W bulbs spaced at 10 cm apart, or a 30 W circle light, will be somewhat less stocky and may require staking as the plants grow taller. Purple anthocyanin color will be less intense and seed set will be somewhat less than that from plants growing under higher light.



Plants growing under **less than adequate light** provided by four or fewer 40 W bulbs will be spindly and tend to fall over easily. The leaves will be thinner and plants will have weak expression of the purple color in their stems and leaves. Such plants may be delayed in flowering and will produce fewer flowers and seeds.

Our experience with Fast Plants is that the more fluorescent light they receive, the better they grow. Light intensity, or *irradiance*, is quantified as the flow of photons in the light spectrum and is measured in micromoles (µmoles) of photons impacting on a meter square surface (m^2) each second (s^{-1}). Irradiance can be measured by various kinds of photometers that provide an indication of the µMol m^2 s^{-1} of photons.

Measurement of Irradiance

In order to determine the relationship between light intensity and Fast Plant growth, we have measured the irradiance in the space under various combinations of 40 watt white fluorescent lamps, Figure 1, as well as under 22 W and 30 W fluorescent circle lights, Figure 2, and observed the growth of Fast Plants under various levels of irradiance.

Irradiance measurements in µMol m^2 s^{-1} of photons were made with a Licor L1-188 integrating quantum radiometer/photometer with a filter that transmitted photons in the photosynthetically active range (PAR) of 400-700 nanometers. Because it is known that irradiance from fluorescent lamps decreases with use, we measured irradiance with both new and used (<1000 hour) light bulbs.

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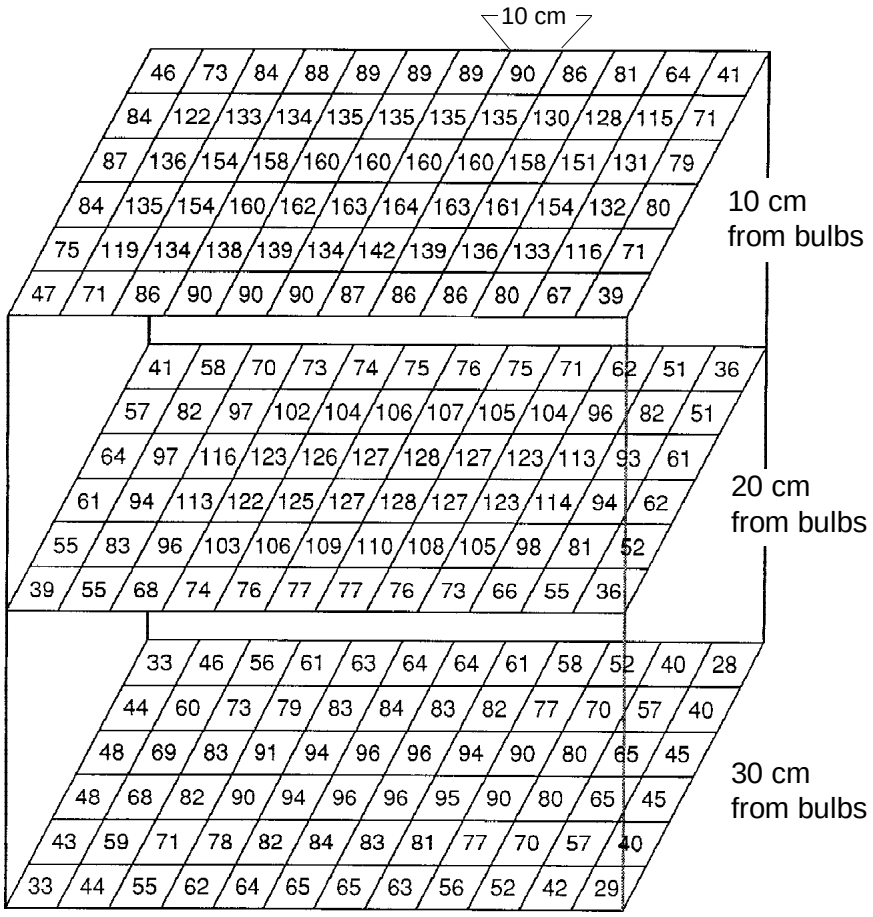
Measurements under 40 W bulbs

Measurements under 40 W bulbs were made on a 60 x 120 cm grid at 10 cm intervals, and at 10, 20, and 30 cm from the plane of the bulbs. Figure 3 depicts the irradiance at 10 cm intervals 10, 20 and 30 cm below a 6-bulb light bank. Four configurations of bulbs were compared, 8 bulbs spaced at 5-6 cm apart, 6 bulbs spaced at 10 cm, 4 bulbs spaced at 10 cm and 2 bulbs spaced at 10 cm apart centered on the measuring grid. As expected, light intensities were greatest under eight lamps, Figures 4 and 5. Irradiance decreased rapidly at the edges of the light banks with lowest intensities in the corners. Intensities decreased 20-30% with each 10 cm increase in distance from the plane of the bulbs. Plants growing at irradiances of greater than 200 µMol m^2 s^{-1} exhibit ideal growth and development, plants growing between 199 and 100 µMol m^2 s^{-1} grow adequately, whereas plants grown at less than 100 µMol m^2 s^{-1} perform less than adequately.

Figure 3: Irradiance on a 120 x 60 cm grid measured at 10 cm intervals, 10, 20, and 30 cm below six 40 W fluorescent bulbs.



Our research indicates that light banks with a minimum of six 40 W bulbs should be used for Fast Plants. Eight or more bulbs spaced over a 60 x 120 cm area is preferred. More light is better and reflective sides placed along the edges of light banks can increase the irradiance received by plants by a few percent. Four and two bulb units generally provide **inadequate** lighting for Fast Plants.

How many 4-foot fluorescent light bulbs do you need to grow Fast Plants?

8 tubes = ideal growth
6 tubes = adequate growth
4 tubes or less = less than adequate growth

Since the irradiance grades off from the center of the light bank, it is important to rotate plants under the bank every day or two so that over the growing cycle all plants will receive about the same amount of energy. If you have the luxury of ample space under your lights, keep the plants in the center of the bank where the light is highest. Do not try to grow plants that extend beyond the edges of the light bulbs. If your plants are receiving inadequate light they will let you know by "reaching" toward the light.

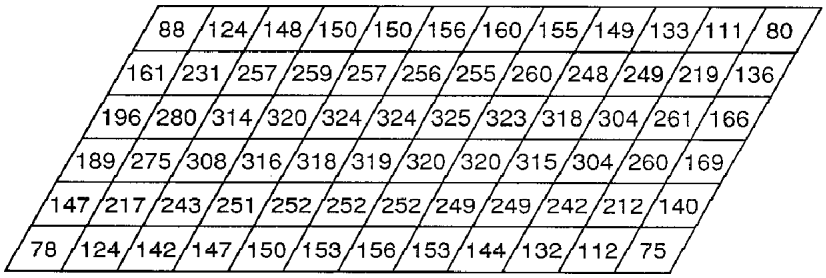


Figure 4: Irradiance on a 120 x 60 cm grid measured at 10 cm intervals, 10 cm below eight 40 W fluorescent bulbs. Numbers are µMol of photons (PAR) m^2 s^{-1}. These numbers conform to grid A in Figure 5.

An interesting experiment is to place plants at various fixed distances and positions from the lights and observe and record their responses. It is best to keep young plants as close to the bulbs as possible without overheating them. Plants grow best if they can be kept within 10 cm of the bulbs. **Young seedlings kept between 4 and 6 cm from the plane of the bulbs will produce stocky stems that are less likely to fall over when the plants elongate.**

Measurements with 22 W and 30 W circle lights

Thirty-watt fluorescent circle lights ("energy saver" type) are also suitable for growing Fast Plants. Measurements were made at 5 cm distances on four 20 cm radii from the center of the circle light. One radius transected the attachment point of the circle light. Measurements were made at 5 cm distances from the plane of the bulb up to 30 cm distance from the light. Measurements were made with both new and used bulbs and with and without a white reflective shade.

Figure 6 (page 248) shows irradiance patterns for a new 30 W circle light with a plastic reflector. **The 30 W light provides adequate irradiance as long as plants are grown within a 30 cm diameter circle 10 cm from the plane of the bulb.** Irradiance is lower under the attachment point and plants should be rotated to equalize light distribution.

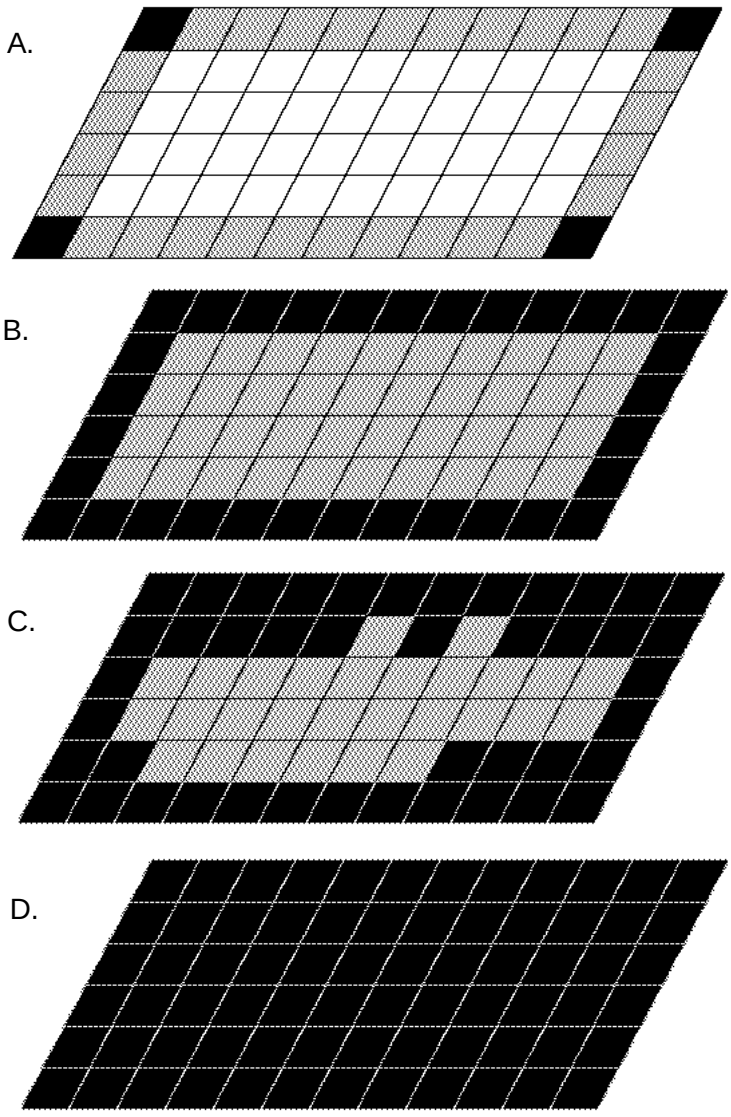


Figure 5: A comparison of the irradiance patterns on a 120 x 60 cm grid measured at 10 cm below the plane of (A) 8 bulbs, (B) 6 bulbs, (C) 4 bulbs, and (D) 2 bulbs. White = ideal (>200), shaded = adequate (199-100), and black = less than adequate (<100 micromoles photons m2 s-1).

Since the circle light provides energy only from a single bulb, it is particularly important to grow the plants within the cylinder of space defined by adequate irradiance. A convenient way of defining the adequate area under the 30 W lamp and of rotating the plants is to use a dinner plate or to place the Fast Plant growing systems on a 27 cm (10.5 inch) diameter circular Rubbermaid™ 'lazy susan'. The 22 W circle light produces less than 100 µMol m2 s-1 photons at 5-10 cm and is unsatisfactory for growing Fast Plants.

Detailed irradiance data available

Detailed irradiance measures from all of the grids under the various lighting configurations are available by writing Wisconsin Fast Plants. These data grids can provide you and your students with information for understanding the irradiance under your own lights. The data could be used for interesting math and physics activities related to Fast Plants.

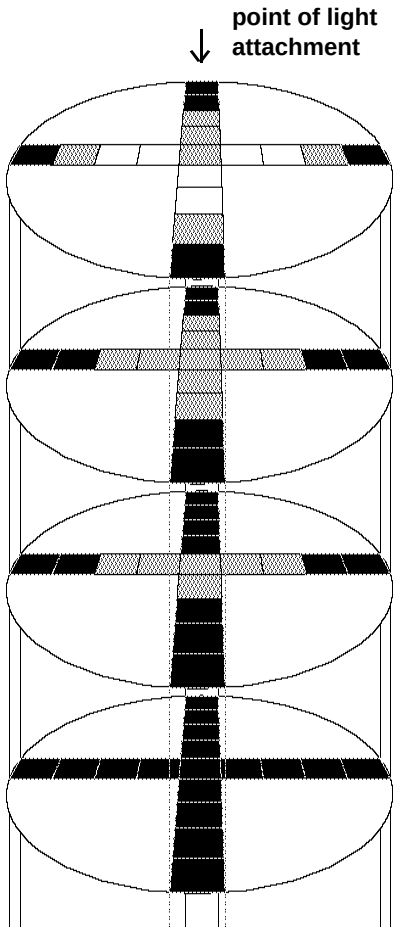


Figure 6: Irradiance patterns for a 30 W circle light with a white plastic reflector (see Figure 2, page 245) measured at 5 cm intervals on four radii at 5 cm distances from the bulb. White and shaded areas depict zones of ideal and adequate irradiance for growing Fast Plants.

Formula for growing successful Fast Plants:

Six 40 W bulbs or the new 32 W high efficiency bulbs* should be used for growing Fast Plants	+	Rotate your plants. Irradiance (light intensity) grades off from the center of the light bank.	+	Keep tops of plants between 5 and 10 cm from the lights.	=	**Healthy Fast Plants**