THE USE OF FLUORESCENT LIGHT IN EXPERIMENTAL WORK

Aubrey W. Naylor
University of Chicago, Chicago, Illinois

Light is one of the most important environmental factors. One of the most difficult problems confronting the plant physiologist in his effort to control the environment has been the finding of a suitable artificial light source. Obviously the ideal light source for physiological work depends entirely upon the type of experiment being performed. If light, however, is not a variable the best type of light would be one approaching daylight in both visible and invisible radiations. Therefore, the most important criterion which might be used in selecting an efficient light source is concerned with the nature of the spectral distribution. Of primary importance also is the determination of whether the spectral distribution follows the photosynthetic curve. In addition it should be remembered, that radiations other than those efficiently involved in photosynthesis may exert considerable effect upon the formation of hormones and other substances which influence the general growth form of the plant.

There have been many objections to the light sources used in the past; some of these were on the basis of quality or intensity or both, and others were on the basis of cost of installation and maintenance of equipment. Until recently the best source of artificial light from the standpoint of quality was carbon-arc light. Light from this source approximates that of sunlight except that its radiations are higher in ultra-violet and the blue. Other than that it is of excellent quality. One of the more important objections to its use, however, is that the units are heavy and relatively non-portable; thereby practically forcing one to use them in the rooms where they are installed. Also such units are both costly to install and to maintain.

Comparatively recently lamps emitting fluorescent light have become available. Some experimentation has been done with arrangement, spacing, color and wattage of tubes, and with various reflecting surfaces in order to ascertain the usefulness of fluorescent light in various types of experimental work. As a further test the lamps have been used as the sole source of illumination in light tight compartments and supplemental to the normal daylight period.

Good results have been obtained from reflectors built to hold six 36-inch tubes, the reflecting surface being painted with a water soluble white casein paint (fig. 1A). These reflectors have been used successfully as a source of supplementary illumination when suspended over the greenhouse benches, where during the day they can be raised by means of pul-

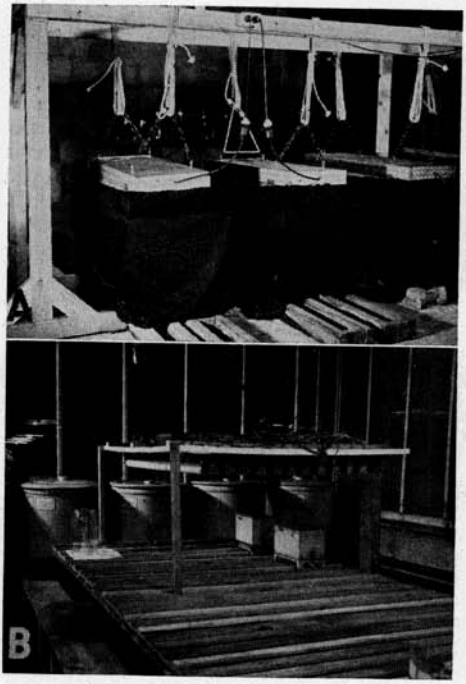

Plate I.—A. Reflectors arranged on scaffolding in light-tight basement with double thickness black sateen cloth curtains around flanges to exclude light from adjacent sources. B. Flat type reflector mounted over a greenhouse bench for use as a supplementary light source. One side can be tilted to prevent shading during the day either by using a chain suspended from the ceiling or by props.

leys to such a height that their shadows will not be cast over the plants. Such a suspension system may also be conveniently used to adjust intensities to the desired level. Best results, however, have been obtained with flat reflecting surfaces to which were attached twelve 48-inch tubes spaced 1½ inches apart at the center of the electrodes. The suspension system has been satisfactorily used with this type of reflector; and another way in which it may be used to advantage is to provide it with legs which may be readily replaced as the plants grow (fig. 1B). Such a reflector may be used for supplementary illumination during the night. During the daylight hours it may be tilted at such an angle that shadows are not produced either on the bench which it covers or the adjacent one.

In terms of foot-candles of light obtainable, it is found, within limits, that the higher the wattage and the closer the tubes are spaced the higher the obtainable intensity. Because of the difference in surface illumination of the different colored tubes the height at which a given intensity may be obtained by a given bank of lights is variable. The highest intensity obtained with the 36-inch (30-watt) white fluorescent tubes has been 1200 foot-candles; while a bank of twelve 48-inch (40-watt) tubes will give 2000 foot-candles at a distance of from 4-5 inches below their surface. But a similar number of daylight type tubes of the same wattage give lower intensity readings.

The quality of light obtainable from fluorescent tubes varies with the kind of phosphore which is used to coat the inner surface of the tube. Inasmuch as these phosphores may be mixed, a variety of colors can be obtained. The spectral distribution curves for the different colored tubes, when compared with the photosynthetic curve given by Hoover(1) indicate that the daylight type would be the most efficient because the two maxima for both curves occur in the same regions. It should be noted, however, that the highest maximum reached in the two curves is exactly reversed, the highest peak being in the red end of the photosynthetic curve while the highest energy level obtained from the fluorescent tube is in the blue region. Distribution curves for all the other tubes, with the exception of the white tube seemingly indicate that they would be comparatively inefficient in plant growth.

When used as the sole source of illumination both the white and daylight tubes have proved to be exceptionally efficient in the growth of a number of plants. Those most successfully grown under them include cabbage, corn, a variety of annual beet, red kidney bean, Biloxi, soybean, dill, tobacco and tomato (2, 3). All of these have been grown in soil, while tomato and bean have also been grown in sand culture. Those plants tried—dill, annual beet, red kidney bean, and tomato—have flowered as rapidly or almost as rapidly when the intensity was sufficiently high as those grown under the best greenhouse conditions at Chicago.

Tubes of the 30-watt type emitting gold, green, and blue light have been used for growing beans and tomatoes. Although these lamps are far from supplying monochromatic light their radiations are confined to certain regions of the spectrum and because they do cover a fairly large spectral range can be successfully used in a variety of preliminary experiments designed to determine the effects on growth of variables such as mineral nutrition and temperature within certain portions of the spectrum. More refined techniques can then be used to determine effects produced by spectral lines within any given band.

An illustration of this point may be found in one of the bean experiments. Two series of beans were given similar environmental conditions under different reflectors supplying gold, green, blue, daylight, white, and a mixture of all these plus red. Half the plants received ammonium sulphate as a source of nitrogen while the other was supplied with calcium nitrate. Those plants supplied with nitrate as a source of nitrogen have invariably grown more vigorously than those supplied with ammonium. Yet with ammonium there were distinctive differences in the growth rate depending upon the color of light used. The plants which first showed adverse effects of ammonium were those grown under blue light while retardation in growth appeared last in those grown under gold light. Within the nitrate series there have also been striking differences. One outstanding difference which might not be expected on the basis of the efficiency curve for photosynthesis was that the size of leaves and height of plants growing under the blue lamps was much greater than under the gold lamps. This obviously indicates that factors of a photochemical nature other than photosynthesis are involved.

An effect which was noted in both series was that under gold light leaves of bean assumed the position of "sleep movement," while normal leaf position was evident under all the others. Blue light seemingly induces the leaves to stand out more rigidly. This same response has also been noted in *Oxalis violacea*. Evidently then light quality as well as intensity is related to sleep movement. More exact experiments could be designed to determine the effects of narrow bands of yellow, orange, and red.

In conclusion it may be said that with the aid of fluorescent lamps it is possible to control satisfactorily the quality and quantity of light in experimental work, whether the lamps are used as the sole source of illumination or for supplementary illumination.

LITERATURE CITED

1. Hoover, W. H., The dependence of carbon dioxide assimilation in a higher plant on wave length of radiation. Smithsonian Misc. Coll. Vol. 95, No. 21. 1937.
2. Naylor, A. W., Effects of some environmental factors on photoperiodic induction of beet and dill. Bot. Gaz. 102:557-575. 1941.
3. Naylor, A. W., and Gerner, G., Fluorescent lamps as a source of light for growing plants. Bot. Gaz. 101:717-718. 1940.