PHOTOPERIOD, SUPPLEMENTAL LIGHT, AND ROOTING OF CUTTINGS

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Plant scientists have known for over 40 years that the length of day controls many phases of plant growth and development and this control has been called photoperiodism. Since the phenomenon was discovered in 1920, they have learned through systematic experimentation which plants flower or grow best on long days and conversely which like short days best (1,2,3,4,5,6). Later, they learned that the response depends on the daily duration of darkness. If the middle of a long night was interrupted with some white light, the plant responded as though it had received short nights, hence long days. Since white light is a mixture of many colors, one wondered whether any color controlled plant growth and flowering more effectively than another. When plant physiologists tested the responses of plants to the various pure colors, they learned that red was most effective. Subsequently, they also found that many kinds of plant responses other than flowering were controlled in much the same manner by red light. More recently, studies in the U. S. Department of Agriculture showed that the action of red light could be nullified by far red given immediately after the red (1). Far red is the name given to part of the infrared just at the red end of the visible spectrum. If you were in the dark and saw this kind of light, it would appear as a rosy glow.

During the 1940's, when fluorescent lamps became generally available, plant physiologists noted that plants grew differently in fluorescent light than in incandescent. For example, sugar beets produced flowering stems on 16-hour days if the supplemental light was obtained from incandescent-filament lamps, but not if it was from fluorescent ones. Since then we have seen many plants differentiate between the two light sources in similar fashion and we know the different response is due to the relative amounts of red and far-red light emitted by the two kinds of lamps. The fluorescent lamp emits a very small amount of far red compared with red, whereas the incandescent lamp emits a high proportion of far-red light. In general, far-red light results in elongation of internodes and red light does not. Hence, with an incandescent source, stems would be longer and flowering would be earlier if flowering is associated with stem elongation.

All this information indicated to the plant physiologist and biochemist something about the nature of a substance involved in the light control. He knows that the controlling substance is a pigment because it absorbs red light; that very little of the pigment occurs in plants because even albino, or colorless, plants respond to red light; that because the pigment absorbs red light so strongly it must be blue when it is seen; and that the pigment has two interchangeable forms because of its characteristic reversible reaction with red and far-red light. In short, the plant physiologist knows many of the characteristics of the controlling pigment without ever actually seeing it.

During 1959 very precise and sensitive spectrophotometers enabled U. S. Department of Agriculture scientists to detect the operative pigment in intact plants. The pigment was not destroyed by grinding the tissue and subjecting it to precipitation, centrifugation, and other procedures designed to aid in separation and purification.

A mixture containing the pigment has been extracted from certain plants and held in the test tube for several months without loss of its character. It is a large molecule: a protein. The form that absorbs the far-red light is believed to be the active one and the red-absorbing form is blue, as predicted by results of earlier physiological experiments. The pigment has been detected in many plants and its purification and identification are expected. For the present, this pigment is called phytochrome. Although we do not yet know its specific action, phytochrome is obviously involved in a basic reaction controlling many features of growth and development of plants.

A rather recent development in plant-growth control with supplemental light is the use of intermittent lighting during the night to regulate flowering of chrysanthemums. The light procedure generally used to provide the long-day effect depends upon application of light continuously for a 3- to 4-hour period near the middle of the night. Light given intermittently is as effective as light given continuously during the interruption period in causing long-day responses of plants and was suggested by Waxman (7) as a horticultural procedure. More recently, this lighting procedure has been used by U. S. Department of Agriculture scientists to study the mechanism of growth control by light. Although the early experiments of Waxman and the others were done with chrysanthemum, various woody plant materials also are apparently responsive (7). The use of intermittent lighting as a substitute for a continuous light break is based on the knowledge that the controlling action of light continues for a time after the light goes out and the control can be directly related to the phytochrome system.

Most of the classical photoperiod studies involved plants of the Temperate Zone, where natural day lengths vary greatly through the seasons. One might wonder about the response of plants growing at or near the Equator, where a natural 12-hour daylength is more or less constant.

Physiologists have known for many years that tropical and subtropical plants are highly sensitive to photoperiod control. Such plants tend to be short-day with respect to flowering. Some, however, are long-day or indeterminate and some have highly specialized photoperiod requirements. At Beltsville, studies of Cacao, Rauvolfia, Coffea, Hevea, Psidium, and several kinds of Citrus showed that the longer the photoperiod the more the total growth in a given time. Tropical plants respond to a light break in the middle of the dark period the same as plants on very long photoperiods and in this respect they are like plants from latitudes higher than the tropics. Tropical plants are thus controlled by the same pigment system as other plants.

Plant propagators now know that the duration of light influences the rooting of cuttings. The daylength to which the stock plant is exposed also exerts a marked effect on the ability of the cuttings to root. The woody plant Weigela is a good example. If grown continuously on long days, Weigela continues to grow and flower. Softwood cuttings can be taken anytime and these root readily in the greenhouse on the same long days. If grown on short days, less than 12 hours, the plants become quiescent and their cuttings are more difficult to root. In general, too, long days provided as artificial light to extend the natural day during the rooting period cause an increase in the speed and the extent of rooting as measured by the number and length of roots produced (4).

At Beltsville we recently conducted experiments indicating that rooting of holly and boxwood is favorably influenced when the short natural days of winter are lengthened with incandescent light. In our experiments with holly we studied the response of cuttings taken in the fall and rooted on short and long days during a 4-month period from mid-November to mid-March. For the short photoperiods, cuttings were given natural days, which ranged from 9-1/2 to 12 hours during the experiment. Long-photoperiod conditions were provided by interrupting the middle of the natural night with 3 hours of incandescent light. The light was given from 11 p.m. to 2 a.m. nightly. The supplemental light source was 100-watt incandescent lamps with reflectors spaced at 4-foot intervals 4 feet above the plants. One-hundred-fifty uniform terminal cuttings were taken from a single stock plant clone of each of the following holly (Ilex) taxa: I. aquifolium L., I. altaclarensis (Loud.) Dallimore, I. cornuta Lindle. & Paxt. (male) I. cornuta (female), I. cornuta 'Rotunda', I. crenata Thunb., I. crenata f. microphylla (Maxim. ex Matsum.) Rehd., I. opaca Ait. (male), I. opaca (female), I. pedunculosa Miq. (male), I. pedunculosa (female), and I. pernyi Franch. Seventy-five cuttings were placed on each photoperiod.

Intermittent mist was used and the temperature of the propagating medium (Perlite) was kept at 70°F by thermostatically controlled heating cable. The air temperature was never below 70°. Root-inducing chemicals were not used.

In general, in these conditions the light interruption of the long night caused earlier and heavier rooting. The heavier rooting was due to fibrous roots rather than to more main roots. The light interruption also stimulated bud break and growth of some clones. Clones of I. crenata were the most responsibe and those of I. opaca and aquifolium the least. No consistent differences in rooting were associated with sex of a given holly species.

With boxwood we studied the rooting response of nine clones of the following species: Buxus harlandii Hance, B. sempervirens 'Handsworthii' Boom, B. sempervirens f. pyramidalis (Simon-Louis) Rehd., and B. sempervirens L. The boxwood experiment was conducted more recently than the holly one but during the same season with the same facilities and in the manner previously described for holly except that temperatures of the rooting medium were 70 and 80°F.

In general, more than 95 percent of the cuttings of all clones rooted on all treatments except on the interrupted night at 80°F, where the rooting was slightly below 90 percent. More main roots tended to form at 70° than at 80° regardless of daylength. The longest main roots were produced at 70° and the shortest ones formed at 80° on the interrupted night. Roots produced at 80° in the interrupted night were thick and heavily branched or fibrous.

Cuttings of holly and boxwood formed characteristic fibrous roots when grown in interrupted night: holly at 70° and boxwood at 80°F. One now suspects that the fibrous-root character of the two plant materials is controlled by a temperature-photoperiod interaction in which the temperature requirement varies with the plant. Boxwood requires a warmer rooting medium for production of fibrous roots than does holly. Studies must now be made to re-examine the response of holly at different rooting temperatures in interrupted nights.

LITERATURE CITED

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MODERATOR STOUTEMYER: Thank you, Dr. Piringer. I think that we can resolve some points now by questions.

MR. HERMAN SANDKUHLE: Al, what type of light was used?

DR. PIRINGER: Incandescent light was used.

MR. HERMAN SANDKUHLE: And how far away was it from the plants?

DR. PIRINGER: The light intensity was 20 foot candles at plant level. Incandescent lamps were hung 4 feet above the plants at 4 foot intervals. We give a 3 hour light interruption of the long dark period and we don't know how much less than that is required.

MR. HERMAN SANDKUHLE: But did you use a "hormone" treatment?

DR. PIRINGER: No, we did not use any chemicals. We were interested in studying the effects of light, per se. There is no question, in the case of Ilex aquifolium and I. opaca, that had we used rooting chemicals, we'd have had better rooting responses. However, we were interested only in the effect of light itself. I might make another point, if I may. There are reports in the literature that a light interruption has done no good, but no place has it done any harm, unless you call accelerated growth in the propagating bench harmful. If you consider accelerated growth as detrimental, then this light interruption will have a detrimental effect.

QUESTION: Has this light been used on any seedlings - such as right after they germinated?

DR. PIRINGER: Yes - and seedling growth will be stimulated. I might say that many years ago when Dr. Stoutemyer was still with the USDA Dept. of Agriculture, he wrote a publication called "Propagation Under Fluorescent Lights" and it is still one of our most popular items. What he said 20 years ago about the use of fluorescent lights in plant propagation is still true today. There is a great merit in the use of fluorescent lights to lengthen the day or give supplemental light. Fluorescent lights cause short internodes and compact plants. Far-red light in the incandescent source causes long internodes. So where you are going to start seedlings and use supplemental light it would be best to use a fluorescent rather than incandescent source because of difference in the quality of the two light sources.

MODERATOR STOUTEMYER: Our next speaker will present some ideas that I think may mean some money in your pocket. Most doctoral dissertations should not be published at all, but occasionally somebody "rings the bell". Well, this man from his thesis obtained a couple of landmark papers on an entirely different type from the usual long-day or short-day plants. He made the first laboratory proof of the existence of a combination long-day, short-day plant. Our next speaker attended the Massachusetts Institute of Technology to get his degree in plant science and then came out to the California Institute of Technology where he took his doctorate. Later he went to Italy on a post doctorate, and did some work on gibberellin. He's much like Dr. van Overbeek - a "hormone" physiologist. He's quite a plant anatomist and is also interested in morpho-genesis. It gives me great pleasure