During the summer season the house is covered with Lumite Saran Shade, the plastic covered sash are in storage at this time, making it possible to get two season's use out of the plastic.

Turkey wire frames are used to support the plastic on the vapor-proof case on the lower level of the center bed. The plants are taken from the propagating house and put in the shade house in May. This planting operation is stepped up through the use of a plug planting board. At the end of the day, the planted area is given a good drink, making use of the portable two inch lines with low angle, shade house Rainbird nozzles.

MODERATOR MARCH: Thank you, Mr. Gray.

Our last talk, "The Application of Supplemental Lighting to Increase the Growth of Deciduous and Evergreen Seedlings", by Dr. Sidney Waxman, University of Connecticut, Storrs, Connecticut.

THE APPLICATION OF SUPPLEMENTAL FLASHING LIGHT TO INCREASE THE GROWTH OF DECIDUOUS AND EVERGREEN SEEDLINGS

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The use of artificial light in commercial nursery operations may soon become common practice. Some of you may recall the slides I showed several years ago of a flowering dogwood that grew nine foot tall in one year from a cutting by lighting it during the night.

Although getting plants to grow tall in a relatively short period of time has its value, there are many other purposes for which photoperiodic treatment can be applied. By using long or short day-lengths we can control growth of many, but certainly not all, trees and shrubs. Actually it is a tool that we can use to our advantage under various circumstances.

Before suggesting any of its applications there are several facts that I would like to discuss concerning the response of a plant to photoperiodic treatment.

First, many people confuse photoperiod with photosynthesis, the manufacture of sugar by the leaves in the presence of light. The production of sugars by the leaves requires a relatively high intensity of light in the range of several hundred to several thousand foot-candles.

A photoperiodic response, on the other hand, does not require such high light intensities; the plant that grows taller when we artificially light it at night does not make any more sugars in each of its leaves than a similar plant that is not artificially lighted at night.

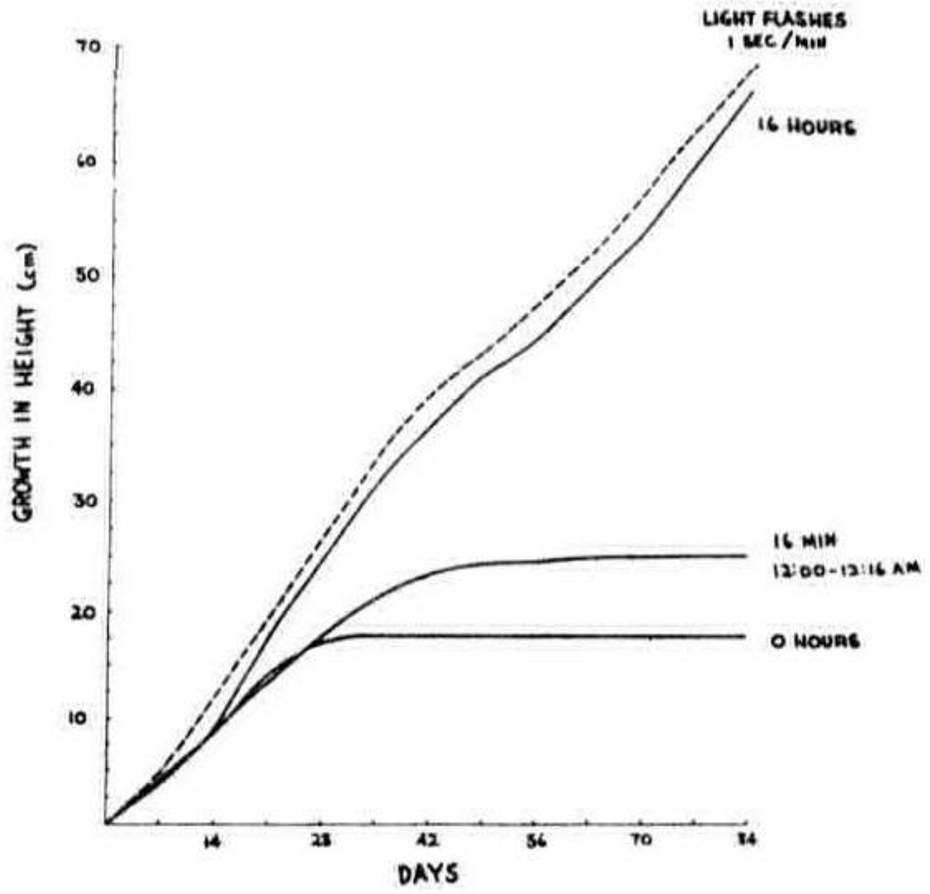

Figure I

WEIGELA GROWTH

All plants received sunlight from 8 a.m. to 4 p.m. Incandescent light (25 footcandles) was provided while plants were shaded with black cloth for 16 hours, 4 p.m. to 8 a.m.

Light Treatment	Total Accumulated Incandescent Light Used Nightly
A. 1 Second of light each minute	16 Minutes
B. Continuous light	16 hours
C. 16 Minute "light-break"	16 minutes
D. No supplemental light - (8 hours of sunlight only)	0 hours

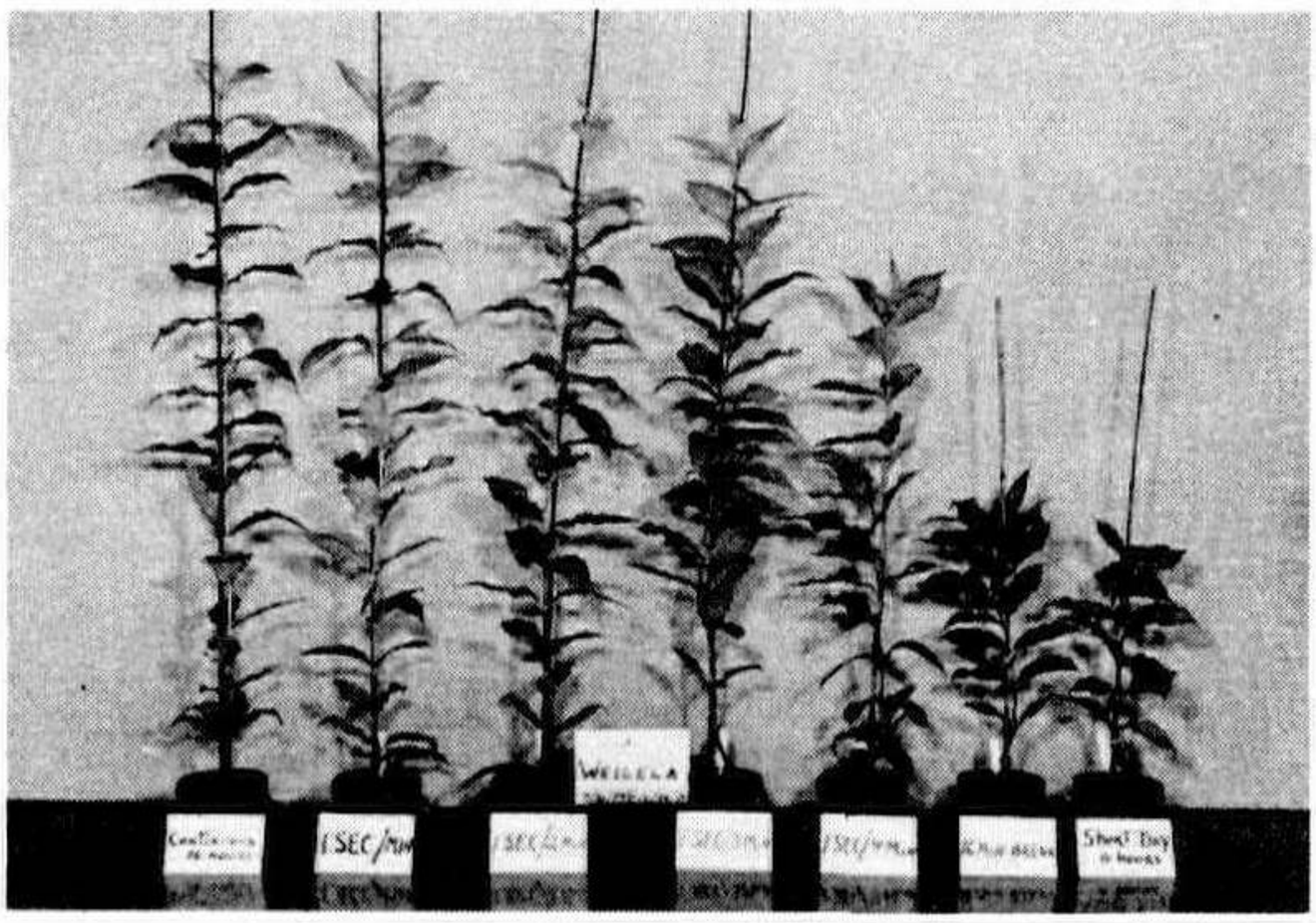

Figure II

WEIGELA

Plants were illuminated with 25 footcandles of incandescent light during the 16 hour dark period. All plants were exposed to sunlight from 8 a.m. to 4 p.m.

Light Treatment	Total Accumulated Incandescent Light Used Nightly
A. Continuous incandescent light	16 Hours
B. 1 Second each minute	16 minutes
C. 1 Second every 2 minutes	8 minutes
D. 1 Second every 3 minutes	5-1/3 minutes
E. 1 Second every 4 minutes	4 minutes
F. 16 Minute "light-break" 12:00 - 12:16	16 minutes
G. 8 Hours sunlight only	0 minutes

Groups C, D, and E, soon became dormant.

A plant will or will not produce new leaves and stems according to the length of the period of darkness it is exposed to each night. If the daily dark period is long, the plant will stop its growth. If it is short, the plant will continue to grow.

If during a long dark period we turn on a light for several hours we would have shortened the length of the dark period and the plant would start growing once again.

The light that shortens the dark period need be no more than 30 footcandles and not the hundreds or thousands of footcandles that are necessary for food manufacture.

Now what about this all-important dark period? Under natural conditions, outdoors, the gradual lengthening of the night, as the summer progresses, causes many plants to stop growth and become dormant long before cold weather approaches. The plants thereby have plenty of time to harden off before winter.

If plants such as these are grown in the greenhouse during the long nights of fall, winter, and early spring, they would either grow very slowly or not grow at all. The short days of winter need not be dormant ones as far as plants in the greenhouse are concerned.

By the correct manipulation of night lighting, we can use this time of the year to our advantage. Two researchers, Hammer and Bonner, in 1938, showed that it was the length of the dark period that controlled the flowering of cockleburr.

We know now that interrupting the darkness with short periods of light will, for many plants, cause them to grow as if they received continuous light.

Substances that accumulate in the leaves during darkness become ineffective by the frequent exposures to light. For example, Weigela grows at a constant rate of approximately 1/4" per day when exposed to continuous light. Similar plants given light for only one second out of each minute during a 16-hour dark period, grew equally as well. (See Figures 1 and 2).

With the cost of lighting cut to such a low figure, the use of such intermittent lighting should certainly be considered. It might be pertinent to mention at this time that not all photoperiod sensitive plants respond in the same degree to flash-lighting. Some species respond very slowly and would perhaps best be given continuous light to avoid a long delay between periods of growth.

Intensity

To get the plants to respond to night lighting there are several requirements to be met, all of which are important. The first is the intensity of artificial light. Although there are many plants that are sensitive to very weak light, say one to 10 footcandles, I would recommend that you use 15 to 30 footcandles to be on the safe side.

You'll find that different species of plants may have different light requirements, some need more than others. The critical intensity for each species can be learned with experience. Although growth may occur under a range of say 5 - 30 footcandles, it will most likely be more rapid at 25 footcandles than at 5 footcandles.

Temperature

As a rule, growth of plants given light at night is influenced by temperature. Experiments conducted outdoors in Connecticut during the summers of 1958 and 1959 have shown that the relatively low night temperatures prevalent there delayed the plants' response to both flashlighting for 1 sec/min as well as to continuous light.

The mean night temperatures for June, July, and August were 52°, 61°, and 59° f. The increased growth of the lighted plants over those not lighted did not occur until October - a rather unfortunate time to get new growth. Of course, many of the varieties that were lighted were killed during early winter.

It appears then, that the application of night lighting should be restricted to the greenhouse unless it is done in an area where night temperatures do not go below 65° F. Experiments in greenhouses with a controlled minimum temperature showed a good response at a minimum temperature of 65° F. but a more rapid response at 70° F. Plants lighted in greenhouses with a minimum temperature of 50° F. produced little or no growth.

Of course there are exceptions to all rules; there are many varieties of plants that ordinarily grow well at temperatures of 55° to 60° F. *Undoubtedly, they would respond to night lighting at those* temperatures.

What Parts of the Plants Are Sensitive to Photoperiod?

The leaves most sensitive to photoperiod treatment are those nearest the growing points of each branch. The newly developing leaves are extremely responsive, whereas the older leaves that are located further down the stem do not respond as well. This is fortunate because it requires us to illuminate only the tops of the plants rather than the entire plant structure.

Type of Growth

A major difference between plants grown under natural conditions and those grown with supplemental lighting is in the development of the lateral buds. Let us use the Japanese maple as an example. A seedling that had been grown outdoors for three years to a height of about two feet would be fairly well-branched. A similar seedling Japanese maple, given supplemental light, could be grown to that height in six months except that it would not be well-branched but would be a single whip.

The type of growth that occurs with night lighting can be compared favorably to the normal growth of an individual terminal shoot.

The only difference is in the length of time of active growth. The shoot on the outdoor-grown plant will reach a length of approximately six inches; the lighted plant will, with time, be considerably longer and have many more leaves, but neither shoot will have any lateral branches.

It would be necessary in both cases to expose the lateral buds to winter temperatures to break their dormant condition before they can develop into branches.

Therefore we shouldn't expect a plant grown continuously, under long photoperiods for several months or more, to have the same ratio of height to spread, as a plant of the same height that was grown outdoors and has had its buds overwintered two or more times. After the whip is removed from the light treatment, and subjected to natural outdoor conditions, its normal branching habit will eventually prevail. Incidentally, not all species produce a whip-like growth. Some will develop lateral branching while being subjected to night lighting. A good example of this can be found with Cornus kousa.

Perhaps those plants that normally develop lateral branches on the current year's wood will also do so while being subjected to lighting at night.

Purposes For Which Night Lighting May Be Used In Nursery Practices

(A) To extend the normal period of growth for the purpose of:

1. Hastening the growth of seedlings of species that normally require a year or two of close watching and careful handling, before they can be lined out. Rhododendron, azalea and umbrella pine seedlings would fit into this category.

2. Hastening the flowering of those species that normally require three to four or more years growth before flowering occurs. This would be of benefit for the plant breeders among you.

3. Increasing in size seedlings of those species that are difficult to overwinter the first year. The point being that a larger seedling would stand a better chance of survival than a small one, provided it has hardened off sufficiently.

4. For the rapid production of understocks for grafting.

5. Having a constant source of cuttings. By this means a large number of plants could be propagated from only a few original stock plants in a relatively short span of time. New or rare varieties could be multiplied considerably by the constant illumination of the rooted cuttings as well as the stock plants from which they were taken. While under constant growth cuttings can be taken from cuttings, etc. This was actually accomplished with a dwarfed variety of arborvitae. With only two cuttings at the start, it was possible to produce 1200 rooted plants in two years.

(B) To renew the growth of plants that have become dormant.

1. When it is desired to obtain additional growth on plants that have completed their natural period of growth, illumination of such plants during the night will break the dormancy of the terminal and perhaps some of the lateral buds without having to expose them to low temperatures.

For the foliage to respond to light at night, it is necessary that they should not have been dormant for too long a time. If the foliage has started to begin to take on fall color, it would be extremely difficult to break the dormancy of the buds. The deeper the dormancy; the more difficult it is to overcome.

Although flashing light for one second each minute has been found to be effective in breaking dormancy for some species, I would recommend that continuous light be applied until new growth is produced.

The new growth should be evident within four weeks from the date the plants are first lighted. The flashing light treatment may be used after new growth has started.

2. The lighting of dormant winter grafts of evergreens to get an extra spurt of growth early enough to allow time for them to harden before setting out in the spring.

3. To obtain a flush of growth on cuttings that are difficult to over-winter after being rooted. Some plants that might fit into this category are Cornus florida rubra and some of the deciduous azaleas.

I've tried to give you briefly an idea of what you might expect when lighting plants at night. You'll find if you try lighting, that your timing will be quite different from what you ordinarily expect. Some varieties will be in constant growth and will become pot-bound in a short time. Also, you may have to fertilize sooner than you expected to. You'll observe some varieties producing extremely large leaves. Unless you are careful and remove the lights in time, you'll have plants that are too tender to over-winter.

Using a proper timing sequence is one of the main things to take into consideration, especially before lighting plants that are to be set out in late summer and fall.

There is much to be learned concerning the use of supplemental lighting for the nursery industry. I would, therefore, suggest that if you want to try it, do so on a small scale at first and play it safe.

(Editor's Note: The following paper was not presented during the Speaker-Exhibitor Symposium, but was submitted for inclusion in the proceedings by Mr. Roy Nordine.)