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SECURITY LIGHTING AND ITS IMPACT ON THE LANDSCAPE

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Recent programs of installing security lighting in our urban areas may have a major impact on mankind and on all the other organisms that share the landscape. Artificial lights have been designed for one primary function—to give mankind visibility in the dark. Good visibility is a basic requisite for public safety; it also permits prolonged periods of activity during each day. Although the motivation for the installation of artificial light has always been the comfort and security of mankind, the same sources of illumination can alter the activity of all organisms on the landscape. We have only to step outside on a summer night and view the extensive collection of night-flying insects that have been attracted by the porch lights. The same light—with a yellow coating—becomes a bug lamp. Bug lamps emit much less blue light and thus are much less attractive than ordinary lights. These same lamps have also been the basis for the technology that permits ornamental plant growers to shift and regulate the growth and flowering times of many kinds of plants.

All advances in vision lighting have been concerned primarily with lamp efficiency, thus reducing the cost of producing light. Color rendering of the people, animals, plants, and buildings that have been illuminated is considered less frequently, except in areas where appearance is critical for sales or aesthetics.

Light Sources for Vision Lighting

Sunlight emits light in the visible region . . . from blue to green to yellow to red. The red region of the spectrum regulates the photoperiod responses of plants. The red and the blue regions activate chlorophyll for photosynthesis. The blue region attracts night-flying insects.

Before 1950, electric incandescent filaments and gas lights were used for outdoor lighting. Levels of illumination were below 1 foot-candle except in concentrated urban areas. Nightflying insects were attracted to the lamps.

Between 1950 and 1965, mercury lamps, which use one-third to one-fifth the electricity of incandescent lamps, permitted better visibility. The use of outdoor lighting subsequently increased. These lamps emitted blue light but little red and were attractive to night-flying insects. No effects of light were reported except for extremely light-sensitive plants such as poinsettias in greenhouses.

Metal halide lamps, which have better color emission and greater efficiency, were an improvement over mercury. Recent improvements in mercury with phosphers, however, have resulted in color rendition similar to metal halide.

About 1965, the introduction of high-pressure sodium (HPS) lamps gave street lighting a yellow-colored lamp with approximately double the efficiency of mercury lamps. These lamps emit less blue light with more yellow and red light.

Present use of high-intensity discharge lamps in malls, parks, and residential areas varies from 1 to 5 footcandles, depending on distance between lamps. Urban areas would normally be expected to have higher levels than sparcely settled regions.

Three questions that arise are: Do these lamps have more effect on altering the growth of plants than the ones that they replaced? What is the effect of increasing the intensity of light throughout urban areas? What kinds of changes in plant growth should be expected from the new security lighting.

To answer these and related questions, we should first summarize how photoperiod regulates the growth of plants.

Photoperiod

Day-length effect on plants has been identified for more than 50 years as the major signal from the environment that regulates plant response. From these observations, we now know that light-dark cycles during the 24-hour day trigger the flowering, branching, dormancy, bulbing, and many other growth responses of plants. Studies of artificial light sources enabled USDA research scientists to discover that the red part of the visible spectrum was the triggering light. Artificial light helped them to identify and isolate "phytochrome"—a blue, photoreversible pigment whose red (580-700nm) and far-red (700-850 nm) absorbing forms regulate plant responses. Any light source that affects the photoperiod responses of plants acts through its red content. Incandescent-filament lamps, whose radiation is primarily in the red region, are the standard source for adjusting the photoperiod of plants.

1. Short-day plants continue in vegetative growth or in flower only when the length of the daily light period is less than a critical number of hours. Daily light periods shorter than the critical number promote vegetative growth or flowering. Daily light periods longer than the critical number inhibit vegetative growth or flowering.
2. Long-day plants continue in vegetative growth or flower only when the daily light period is longer than the critical number of hours. They become dormant or form rosetting plants when the daily light peiod is shorter than the critical length.
3. Day-neutral plants continue in vegetative growth or flower regardless of the day's length.

Light throughout the 24-hour day inhibits flowering and promotes vegetative growth of short-day plants, encourages continued vegetative growth and early flowering of long-day plants, and increases stem lengths of day-neutral plants. Plants vary greatly in their responsiveness to light source, duration, and intensity. Since the new light source, HPS, provides illumination from dusk to dawn at intensities seldom before used for street lighting, many questions have been received from florists and nurserymen concerning what effect these lights would have on their fields and greenhouses adjacent to the brightly lighted areas. Poinsettia, chrysanthemum, and orchid growers learned the first year that their plants had to be covered nightly in order to avoid altering their scheduling of flowering. Into the fall season young plane trees (sycamores) in the nursery grew more rapidly and much later than plants of similar age that had been screened from the night lighting. Winter dieback was severe on the lighted trees during the following spring.

Experiments on Relative Effectiveness

Experiments were conducted at the Beltsville Agricultural Research Center, Beltsville, Md., to determine the relative effectiveness of five light sources on photoregulation of 22 species of ornamental plants. An abstract of the research was published in HortScience for the August 1973 meeting of the American Society for Horticultural Science:

"*Abstract.* When compared at a level of 1 ft-c. for 16 hrs at a night temperature of 68°F the 5 light sources delayed flowering of short day plants (chrysanthemum, marigold, rieger begonia), promoted vegetative growth of woody plants (2 species of *Ulmus,* 2 species of *Acer, Koelreuteria, Rhododendron, Rhus* and *Zelkova*), and promoted flowering of long day plants (marguerite, carnation, petunia) in the order from most to least effective: Incandescent (INC) > High Pressure Sodium (HPS)> > Metal Halide = Cool White Fluorescent Clear Mercury. Poinsettia, *Betula, Catalpa, Platanus and Tilia* continued to grow vegetatively in response to all sources. *Ilex* and two species of *Pinus* did not response to any of the light sources. Lighting with HPS lamps had to be increased at least 4- to 8-fold (on a ft-c basis) to regulate vegetative growth of long day plants and delay the flowering of short day plants in comparison to INC lamps. HPS lamps were ineffective in promoting early flowering of long day plants, regardless of intensity or duration."

Based on this abstract and subsequent interviews, we have received numerous requests to clarify the impact of the new street lighting technology on plants in the landscape.

1. *Is there a combination of factors involved, all of which must be eliminated, or is there a single key factor at the root of the problem?*

Light exerts its growth-controlling effects only when the environmental and cultural conditions are properly combined to permit rapid growth. Any factor that would limit growth—cold, heat, drought, standing water—could override the effects of the security lighting. Light alone, at the intensities used for street lighting, is insufficient to sustain growth. Its effects come into force only when the natural day is adequate to permit growth. Thus, night temperatures below 55° or above 90°F limit the effectiveness of the night lighting. Periods of extra dry or wet weather would limit growth and thus reduce the sensitivity of the plants to the night lighting.

2. *Wouldn't mercury lamps (or any light source) produce the same result with higher than normal light levels?*

The lamp types used in the experiments and the intensity of radiant energy at plant height per foot-candle

Lamp	Watts	Total lamp lumens	Microwatts per square centimeter perlumlen 400-700 white	580-700 red	700-850 far-red
Incandescent filament (standard frosted)	60	810	4.4	2.9	5.6
Flourescent (cool white)	215	12,400	3.2	1.1	.1
Mercury (clear)	250	11,600	3.0	.2	.2
Metal halide	175	12,000	3.0	1.5	.6
High-pressure sodium	275a	25,000	2.6	1.7	1.0

a. Now manufactured as 250 watt with no change in spectral output per lumen.

The effectiveness of a light source is dependent on its radiation in the red region. Mercury lamps emit little radiation in the red region; thus, any increase in the intensity of light from this source would not be expected to have any more effect than a less intense lighting level. Color-improved mercruy lamps are essentially the ordinary mercury lamp with a fluorescent powder covering the inside surface. Since little red radiation is produced, again the improved lamps would have no detectable effect on most plants.

3. *Do mercury vapor and metal halide lamps cause the same response in plants as does the high-pressure sodium lamp?*

All lighting that produces long-day effect on plants exerts the same growth control of promoting the formation of new leaves and the elongation of the distances between the leaves. Mercury vapor and metal halide lamps emit so little red light that they delay flowering only on a greenhouse crop such as poinsettia and promote continuous vegetative growth only on highly responsive trees such as birch, elm, and sycamore. Only 7 of the 22 species tested exhibited any growth responses to the mercury vapor and metal halide lamps. However, HPS lamps altered the growth responses of 16 of the 22 species tested, only one less than the number of plant species that were responsive to night lighting with incandescent-filament lamps.

4. *We would like to know whether the increased plant growth is due to light quality or intensity or to a combination of both?*

The increased growth is in response to a combination of light quality, intensity, and duration interacting with the environment. The significant change from the older street lighting systems to the HPS lamps is the change in the intensity of lighting at street level and plant height. It is probably two to four times higher than was formerly used, as measured on a footcandle scale.

5. *Are trees affected because of the sodium source itself?*

The light emmission of sodium at 589 nm, so-called sodium line, produces its growth effects on plants. Since the lamp is operated at high pressure, the light spectrum that is emitted broadens into green on one side and red on the other side of the yellow line. Phytochrome, the blue pigment that is present in the leaves and that perceives the light, responds to the red part of the light. To the plant, the yellow source acts as if it were a red source. Thus, what appears to our eye is viewed quite differently by the plant.

6. *What could be the side effects on the plants exposed to security lighting?*

Nighttime lighting has one primary effect, to promote continous growth or elongation of plants when the natural environment is signaling a stopping of growth. This is the major concern, that lighting could alter the way that plants receive their signals from the environment and how they adjust their growth characteristics according to the season. If growth continues, the plants may still be growing when the first killing frosts of fall come. This would mean increased winter injury to plants during the following spring. It would be obvious during the spring when the tips of the limbs of the plants nearest the lamps would not leaf. Only one side of the plant or part of a limb may be affected by the light. Photoregulation because of artificial light is not translocated from one limb of the plant to another. One can observe directly the effects of the lighting in relation to the distance of the plant to the light and the effects of the position of the various limbs of the plant to the light source.

7. *Are trees affected because of the continuation if a minimum level of light, daylight and artificial, on a 24-hour basis with no opportunity to rest?*

Growth responses that are due to photoperiod have no relationship to the concept of rest. This is a concept that mankind brings from its own way of living to the plant world. Plants live out-of-doors throughout 12 months and adjust their growth patterns in response to the light-dark signal from the environment. Their actions are modified by temperature, carbon dioxide, nutrition, water, and many other factors. Continuous lighting depresses the formation and maintenance of chlorophyll in leaves and promotes lengthening of the internodes of the branches and expansiion of leaf area.

All of these changes increase the likelihood that the leaves will be more sensitive to air pollution during the growing season. Most daily newspapers report the concentration of oxidants in the atmosphere based on the standards of measurement established by the Council of Government's Air Quality Index. Air pollution alerts are called when the level of oxidants in the atmosphere exceeds 100 parts per 100 million (by definition). Plants in a state of more rapid growth face a greater risk of being injured by the increasing levels and frequencies of air pollution than plants growing without security lighting. One can detect air pollution injury on the recently matured leaves, as they will initially have a glistening, oil appearance. The tissues between the veins of the leaves may turn pale green or white. The margins of some leaves may dry to tan and may eventually rupture. The oldest leaves may progressively die and drop from the plants.

8. *Are any figures available on how many footcandles are required to make trees grow faster and/or longer?*

Footcandles are a measure of the amount of visible light, based on the sensitivity of the human eye. The curve is bell-shaped, and the maximum sensitivity occurs in yellow green. The blue and red regions, on opposite ends of the visible spectrum, are not detected readily by the eye as is the yellow region. The red region of the spectrum regulates the photoperiod responses of plants. In this region, a footcandle meter can measure the intensity of the light, but only with diminished sensitivity and possible inaccuracy. We do not know the footcandle sensitivity for continued vegetative growth of most landscape plants when one uses HPS lamps as the light source. They do give high footcandle readings, but the red region is considerably lower than that emited by incandescent-filament lamps. The intensity of light from HPS lamps should be increased at least fourfold to create a lighting system with photoregulation similar to a response produced by an incandescent-filament lamp.

9. *We are currently building a massive development where high-pressure sodium street lamps are going to be used for security purposes. We plan to plant trees 4 inches or larger in caliper (stem diameter). Will the lamps 40 feet high have an effect on these new trees?*

The effects of the lighting will depend on the type of tree selected for the area and on how close the lamps will be to the trees. For example, a 400-watt HPS lamp on a 30-foot pole emits about 1 footcandle of light 20 to 30 feet horizontally on the ground. The light level increases as one moves closer to the light source.

Sycamores and elms, for example, should be expected to respond to the lighting during their first years by continuing to grow for a longer period in the fall. Other species would exhibit intermediate or low growth responses to the security lighting.

Sensitivity of 40 plants to security lighting:

High

Acer ginnala, Amur maple
Acer platanoides, Norway maple
Betula papyrifera, Paper birch
Betula pendula, European white birch
Betula populifolia, White birch
Catalpa bignonioides, Catalpa
Cornus alba, Tatarian dogwood
Cornus florida, Dogwood
Cornus stolonifera, Red-osier dogwood
Platanus acerifolia, Sycamore
Ulmus americana, American elm
Ulmus pumila, Siberian elm
Zelkova serrata, Zelkova

Intermediate

Acer rubrum, Red maple
Acer palmatum, Japanese maple
Cercis canadensis, Redbud
Cornus controversa, Giant dogwood
Cornus sanquinea, Bloodtwig dogwood
Gleditsia triacanthos, Honeylocust
Halesia carolina, Silver-bell
Koelreuteria paniculata, Goldenrain-tree
Ostrya virginicana, Ironwood
Phellodendron amurense, Cork-tree
Sophora japonica, Japanese pagoda-tree
Tilia cordata, Littleleaf linden

Low

Carpinus japonica, Hornbeam
Fagus sylvatica, European beech
Ginkgo bilola, Ginkgo
Ilex opaca, American holly
Liquidamber styraciflua, Sweetgum
Magnolia grandiflora, Bull bay
Malus boccata, Siberian crabapple
Malus sargenti, Sargent's crabapple
Pinus nigra, Austrian pine
Pyrus calleryana, Bradford pear
Quercus palustris, Pin oak
Quercus phellos, Willow oak
Quercus robur, English oak
Quercus shumardi, Shumard oak
Tilia x europaea, European linden

Plants have been listed alphabetically and are not grouped in descending order of sensitivity. A high, intermediate, or low rating identifies the relative responsiveness of the plants to security lighting. Plants with low sensitivity would be preferred in areas with security lighting.

10. *Would shutting off the light source for a given period of time each night reduce the effects of the lights?*

The response of the trees is based on continuous illumination from the time of intense sunlight and continued by the artificial light. The maximum effectiveness of the light is dependent on the fact that the light continues uninterrupted throughout the 24 hours. Continuous lighting permits the minimum intensity of light to exert its effects in creating a long-day effect on plants. One simple method to reduce the effectiveness of the lights in regulating plant growth is to shut off the lamps for 2 to 4 hours during the early part of the evening. This dark period permits the plants to reset their timing system. From a security viewpoint, however, darkened areas during the early evening would defeat the purpose of the lighting, to permit continued surveillance throughout the night.

11. *Could you indicate certain tree species that might be more tolerant to high-intensity lighting than others?*

Many types of trees are used to decorate the landscape. They possess varying sensitivity to high-intensity lighting. One would expect the recently planted trees to be particularly responsive to the lighting; older, slower-growing trees tend to become dormant by midsummer in most growing areas. Thus, the lighting would exert no measurable effects on the plants. In our tests, using pines as an example of a conifer and Japanese holly as an example of a broadleaf evergreen these plants did not visibly respond to night lighting from any source when the intensity was 1 footcandle. Deciduous trees were more responsive to the lighting. Red maple, for example, was less responsive to the lighting than was Norway maple (see list following question 9).

12. *Are plants in our tropical regions affected by high-pressure sodium lamps?*

Most plant growth in our tropical areas is less obviously controlled by photoperiod than plant growth in the more temperate climates. The photoperiod in these areas is seldom more than 13 or 14 hours and is seldom less than 11 hours. Since the effects of the lighting is to override the natural regulatory system of photoperiod, it would be expected that plants in tropical regions would have growth throughout the year, shifts in the time of flowering or leaf drop, and eventually plants radically different looking from those growing without the lighting. The response will depend on the light level, on the ambient temperatures, and on the cultural conditions.

Alternatives

We can expect the continued installation of security lighting throughout the United States in order to maintain good visibility. Each of us can influence this trend by considering the following alternatives.

Selection of lamp type.—HPS could be used where high visibility on streets or freeways is required and where only light-tolerant plants would be used. Although less effecient than HPS lamps, metal halide lamps would be preferred in malls, parks, and residential areas where dense plantings are made and where color rendering of plants, people, and buildings is desired.

Shielding.—The least expensive fixtures (luminaries) often emit light in 180 radiance under the lamp. Covering lenses or shields can sometimes be used to direct the light to the street and away from the plants. More expensive fixtures have additiional built-in shielding to aid in controlling light.

Selection of plants.—Cooperative work of urban planners, landscape architects, and horticulturists should be started to identify which plants are suited to the environment of security lighting. Some commonly used street trees such as elm and sycamore may have to be avoided in future plantings. With the great variety of plant material available and often not considered, environmentally adapted plantings can be planned.

Installation and maintenance programs.—New plantings could be installed in the fall months of the year to permit a full-year cycle of growth and adjustment prior to the following summer and fall, when the major impact of the lighting is expected to occur. To slow growth during this period and during subsequent years, the frequency of watering and the level of fertilizers should be reduced. Maintenance programs during the first years of growth can greatly help to decrease the sensitivity of the plants to security lighting, as well as to heat, cold, drought, air pollution, and salt injury. However, the majority of plants brought into urban areas die, because there is no maintenance following their installatiion into the landscape.

The Ornamentals Laboratory plans to continue research in its greenhouses and in cooperative projects with urban planners and horticulturists.

Sources of Additional Information

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ABSTRACT

Payne, B. R. 1974. **The twenty-nine tree home improvement plan.** Nature History 82(9): 74-75.

The economic importance of trees near homes is often overlooked. When decisions affecting land use and value are made, there is a tendency to place much greater weight on measurable dollar costs than on so-called intangible factors such as trees. The value of such trees has to be measured by their contribution to property values. To do this, a research team from the United States Forest Service selected land suitable for building and constructed a scale model of it. After photographing both the actual site and the scale model, they "planted" varying numbers of trees on the model and rephotographed it. The photographs were shown to real-estate appraisers. On the average, the results showed that trees contributed as much as 27 percent of the appraised land value. A related study of lots and houses was conducted with real-estate appraisers and homeowners. The results showed that trees contributed 7 percent to the value of the average property and as much as 15 percent to some lots.