SATURDAY AFTERNOON SESSION

December 1, 1956

The final session convened at 2:00 p.m., President Scanlon presiding.

PRESIDENT SCANLON: The first speaker this afternoon will be Dr. J. P. Nitsch, Department of Floriculture and Ornamental Horticulture, Cornell University, Ithaca, New York. His subject is "Light and Plant Propagation."

DR. J. P. NITSCH: May I first say how pleased I am to be with you again this year. I enjoyed my first meeting with you last year and am quite pleased to come again. Secondly, I feel quite honored to have become a member of this Society.

Dr. Nitsch presented his paper entitled "Light and Plant Propagation." (Applause).

LIGHT AND PLANT PROPAGATION

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The subject of "Light and Plant Propagation" is a very broad one, as you well realize, so I will have to limit myself to some aspects only of the effect of light on plants.

Every one of us knows, of course, that plants need light in order to grow. We should also be aware of the fact that plants are much smarter than we are, in that they capture light energy and use it to synthesize many complicated chemicals which the best chemist can possibly obtain only with high temperatures and very complicated apparatus. As a matter of fact, we should realize that, without the plant and without the energy it receives from the sun, life on this planet would be impossible.

I — PHOTOSYNTHESIS

The process by which green plants use light energy in order to synthesize chemicals from water and the carbon dioxide of the air is called "photosynthesis." This process requires a relatively high level of light energy. This energy, which normaly comes from the sun, can be replaced by artificial light. Plants have been grown to flower and fruit in rooms without any sunlight whatsoever.

There are three major difficulties in using artificial light for adequate photosynthesis in higher plants at the present time Firstly, it is difficult to manufacture light sources of intensities approaching that of sunlight. Carbon arc and mercury vapor lamps are among the sources which can give the most intense light. However, and this is the second difficulty, the composition of the light which they produce does not match exactly that of sunlight. This is an important point, as we will see later. It is, necessary, therefore, to use a combination of different types of artificial light to obtain a somewhat balanced "spectrum." Thirdly, the cost of growing plants under completely artificial light is prohibitive One of the cheapest combinations, published in 1937 by Arthur and Harvill of the Boyce Thompson Institute (2), consisted of four 10,000 lumen sodium vapor lamps, mounted in the form of a square, 2 feet on a side, with a small 85-watt capillary mercury arc lamp placed in the center of the square. Good results were obtained when the sodium vapor lamps were left on 24 hours and the mercury lamp turned on 2 hours each day. Such a combination was estimated to cost at that time 3c a square foot a day Other installations, involving banks of fluorescent tubes supplemented by a few incandescent bulbs are in use in the "Phytotron" at the California Institute of Technology, Pasadena, California, but only for research purposes.

For all these reasons, I will not talk today on artificial illumination as a substitute for sunlight. Rather, I will limit this exposé to the use of artificial light as a *supplement* to normal sunlight. For the action of light is manvfold. Light does not only provide the bulk of the energy necessary for plant growth. It also acts in a more subtle manner to regulate this growth. It is in this connection that, I think, nurserymen can use light to advantage.

II — REGULATORY EFFECTS OF LIGHT

In contrast to photosynthesis, the regulatory effects of light are obtained with low intensities, that is intensities which are barely above that given by the full moon on a bright night Let us review briefly the various types of these light effects.

1) *Light and seed germination.* We are accustomed to bury slightly seeds into the soil in order to germinate them and, therefore, think that seeds do not need light for germination. Now we have heard this morning that seeds of various trees and shrubs, including conifers, need a preliminary cold treatment. This treatment is of the order of two months duration. I may astonish you by saying that this treatment may, sometimes, be completely omitted, and that two hours of light may replace two months of stratification Let us take three examples. The first one concerns birch seeds. Both Black and Wareing in England (3) and Vaartaja in Canada (13) have reported that *Betula pubescens* and *B. verrucosa* can germinate at 20° C (68° F) if they are given light (about 300 ft. c.). Continuous light seems to yield the best results. These same seeds, when germinated in the dark, need about a month of pre-chilling at 1-4° C. Recently, Toole and co-workers (12) have shown that unchilled seeds of Virginia pine (*Pinus virginiana*) do not germinate in total darkness. When these same seeds are first moistened, left for one day in darkness at 5° C (41° F), then exposed to red light, and returned to complete darkness, they will germinate very well at 25° C (77° F), poorly, however, at either 20° C (68° F) or 30° C (86° F). The third example is taken from the work done at Cornell University by Mr. S Waxman (16) on the germination of *Sciadopitys verticillata,* the umbrella pine. These seeds are difficult to germinate and take

many months to come up. It was found that daylength markedly influenced the germination of these seeds left uncovered, under mist. However, the effect was inverse to that reported for birch seeds, in that the short daylengths (about 9 hours of light) promoted germination, whereas long days (18 hours or more of light) or continuous light inhibited it. In fact, Mr Waxman found that if about one hour of incandescent light was given around midnight to cut the dark period into two moieties, germination was delayed. If these preliminary results can be confirmed and extended, they will constitute the first case of seeds acting like "short-day plants," that is, in which germination is promoted by short days but inhibited by long days.

2) *Light and rooting*: After seed germination, the second item of interest to the plant propagator is the rooting of cuttings. Several people have studied the regulatory effect light can have in this case Recently, Snyder (10) published the results he has obtained with *Taxus*. Sarting with dormant cuttings taken from November to January, he found that daylength had no effect upon rooting itself, but had a clear-cut influence upon bud break. An 8-hour day kept buds dormancy, whereas an 18-hour day caused them to grow out. In this case, the retardation of bud break was beneficial, because the cuttings without new growth survived better transplantation into the field. On the contrary when using softwood cutings taken from dogwoods in full growth in June, Mr Waxman (16) obtained a very beneficial effect of long days upon rooting. All the cuttings rooted under mist, but the number of roots per cutting was larger under long days than under short days These results may be of general interest to nurserymen because they emphasize the importance of timing, which many speakers have stressed, in preparing softwood cuttings Cuttings made in June will root faster and more abundantly than cuttings taken when days are shorter Of course, other factors may modify the validity of this statement in the practice For example, it may not be feasible to root certain softwood cuttings in June because they are too soft. On the question of the quality of the additional light that may be best to increase rooting, I may refer you to the studies of Stoutemyer and Close (11) who found that, in the case of *Ligustrum ovalifolium*, for example, pink light was better than white light, and white light better than blue light, when equal intensities were used

3) *Light and flowering*: One of the best-known regulatory effects of light is the control of flowering in certain herbaceous plants. In the case of woody materials, much research has yet to be done Experiments at Cornell on *Weigela* showed that flowers appear first on plants grown from cuttings under 24 hours of light, then on those under 21 hours, then under 18 hours, then under 15 hours, finally on plants grown under 9 hours plus one hour of light in the middle of the night. On large pink flowering dogwoods, flower buds were produced eventually on slow-growing side-shoots under all treatments. Long days (18 hours) given during flower initiation produced leaf-like bracts, they caused elongation of the peduncle when given during flower opening (16).

4) *Light and vegetative growth*: Most striking was the effect of daylength on the vegetative growth of certain species. As reported last year, long days stimulated certain species such as *Weigela, Cornus florida* and *Viburnum opulus* to grow continuously, whereas short days (less than 13 hours) brought growth to a stop and induced dormancy There seem to be several ways in which dormancy is brought about. In all cases, growth in length of each shoot stops This is apparently all that happens in *Weigela*. But in *Populus* or in *Viburnum opulus,* for example, the young leaf primordia, instead of developing into leaves, become scales which enclose and protect the terminal meristem. In other cases, such as that of catalpa which was reported by Downs and Borthwick (8), and that of the staghorn sumac (*Rhus typhina*) which I have observed this year, the onset of dormancy is accompanied by the abscission of the very tip of the shoot.

5) *Light, fall colors and leaf drop*: Long days retard the development of fall colors and also leaf abscission, keeping the leaves green You may have noticed this on trees growing near street lights. At Cornell, I have observed it during this warm fall on elm (*Ulmus americana*), red oak (*Quercus borealis*) and maple In each case, branches under street lights had still green leaves on November 5 The other branches of the same trees had no more leaves (in the case of the elm) or yellow leaves that were falling (in the case of the maple). This effect can be obtained experimentally, as shown by the dogwoods grown by Mr Waxman (16), the leaves of which turned red and dropped much earlier under short days than under long days, even when the night temperature was lowered to 40° F.

All the above-mentioned examples show how varied the regulatory effects of light can be. Let us now examine in somewhat greater detail the effect of light on vegetative growth in woody ornamentals.

III — SPECIAL STUDY OF THE REGULATION OF GROWTH BY LIGHT

By "growth" is meant here the increase in size of the plant by both an increase in the number of nodes and leaves produced, and a lengthening of the internodes

1) *Timing and quality of illumination*. The effects on growth which I have described are all obtained with a light of relatively low intensity which supplements a day of normal sunlight. In this situation, two points are of particular importance: the time at which this supplementary light is given and its quality.

a) *Timing*: One can get just about the same growth in height by subjecting a *Weigela* plant to a natural day of 16 hours or by giving it 8 hours of sunlight plus 8 hous of artificial light of much lower intensity. This indicates that it is the length of the day and not the intensity of the light which is the decisive factor in this case. Also, if we supplement a basic 8 hour day of sunlight with 7, 10, 13 hours of artificial light, we can observe that the height of *Weigela,* dogwood or *Viburnum opulus* plants progressively increases with the length of these light periods. There is a limit to this, however. In several cases, it was found that giving no night at all was detriemental, that is a 24-hour light period gives less growth than a 20-hour light period (at least when using incandescent light). Actually, it is not so much the length of the day than the length of the uninterrupted dark period which is the decisive factor. This can be demonstrated by cutting a long night in its middle by a short period of light Thus, a *Weigela* plant does not grow under a 9-hour day, but, if the night is interrupted in its middle by an hour of light, then it will grow as well as if it had received about 15 hours of light In both cases, the periods of *uninterrupted* darkness are similar (7 and 9 hours). On the contrary, if the extra hour is given immediately following the 9 hours of light, so as to make 10 hours of light and 14 hours of straight darkness, then the *Weigela* will not grow. Any uninterrupted dark period longer than 12 hours will cause it to become dormant. Physiologists try to interpret these observations by assuming that a sort of chain-reaction, ending in the formation of a growth-inhibitory principle, takes place during the long night During the first part of the night, the first links of this chain are made. These are sensitive to light and can be destroyed by it. Towards the end of the dark period, the first compounds are transformed into different ones which are not destroyed by light any more The first steps of the chain-reaction must be very sensitive to light for a very short light-break can offset the effect of a long night. In the case of shrubs, we have found that 30 minutes of light to 20 ft. c were just as effective as 1 hour. One could probably go much below this value. *Viburnum opulus* did not seem to respond well to a one-hour light-break when the night temperature was 50° F, but did respond when it was 70° F. (16). This indicates that temperature may modify the effectiveness of the light-break treatment.

b) Light quality: The type of light used is important also. Following Dr. Borthwick's experiments on the flowering of the cocklebur (4), red and far-red lights have been tried in a light-break studies What I call "far-red" is a light which is beyond the bright red in the light spectrum, towards the infra-red region. It has a wavelength of about 7,200 angstroms It was found that red light interrupting a long night caused growth and flowering in *Abelia grandiflora;* far-red light did not cause any flowermig and supported only a small amount of vegetative growth. In addition, ½ hour of far-red light reversed completely the promotion of flowering caused by ½ hour of red light, provided the far-red light was given immediately after the red light (16).

Light quality is important not only in the case of the light-break I have said that supplementing with artificial light an 8-hour day of sunlight is as effective, as far as growth in height is concerned, as subjecting the same plant to 16 hours of pure sunlight. This depends on the quality of the supplementary light In this respect, incandescent light is much more effective than mercury light, in fact, it is even more effective than sunlight itself as shown by Roodenburg in Holland (9). This effect of incandescent light has been traced down to its content of far-red light. Thus, Downs (6) at Beltsville caused bush beans to elongate like pole beans by supplementing long normal days with far-red light. On the other hand, the Dutch workers Wassink and Stolwijk (15) have observed that 4 hours of violet, blue or far-red light added to 8 hours of sunlight caused lettuce plants to elongate as if they were going to flower. Green, yellow or red supplementary light was inactive. The opposite was found in the case of spinach in which violet, blue and far-red light inhibited flowering and kept the plants in the rosette stage. No doubt, one will have to do much more work in the field of light quality in order to understand all these effects.

2) *Types of plant responses*: This last example brings up the fact that different species respond differently. I think that we could avoid confusion by trying to classify the plant responses into different types, such as the following ones (which are, of course, very tentative):

a) The response to long days is continuous growth: This seems to be the case of various dogwoods (*Cornus florida, C. kousa*), of *Weigela, Viburnum opulus, V. Carlesi, Populus, Salix repens, Thuja occidentalis,* etc. In these cases, an 18-21 hour day seems to be better than no night at all, except for *Salix* and *Populus, V. opulus* and *Thuja* which grow well under vontinuous light. With Professor Chouard in France (5), we might distinguish in this group two sub-sections according to their reactions to short days, namely: that of plants which stop growing completely under short days (all of the above-named species, except, *Thuja,* and that of the plants which grow continuously, although at a very much reduced rate, even under short days, such as *Junipers horizontalis* and *Thuja occidentalis* (16)

b) The response to long days is growth in spurts: We have observed this sort of growth on red oak seedlings. The plants seemed to beome dormant after having produced the first leaves. A few months later, however, a second flush of growth occurred, under long days only Three such flushes of growth could be obtained on some of the seedlings in one year (16). Similar results have been reported by Downs and Borthwick with the Scotch pine (8).

c) Long days cannot prevent the onset of dormancy Lilac, boxwood, *Viburnum prunifolium* do not seem to grow much more under long days than under short days. Long days may somewhat retard the onset of dormancy in lilac but, sooner or later, the shoots stop growing, bud scales are formed. Only a cold treatment will start the buds growing again.

d) Long days are detrimental to growth· If you try to grow a tomato plant under continuous light, it will die (1). It is not quite clear if this is an effect of the length of the day as such or if it is due to the type of artificial light used to supplement the normal day. In any event, certain plants do not thrive when the lights are left on continuously at night. *Weigela*, for example, grew less under 24 hours of light than under 18 hours (16).

3) *The locus of light perception*: Which is the part of the plant through which light exerts its regulatory effects? An obvious possibility is the foliage. As I have indicated, a *Weigela* plant does not

grow whatsoever under 9-hour days. Now if one removes all the leaves, one will observe that the tip of the shoot will start growing, producing new leaves. When these leaves reach about their full size, growth stops again. By removing the leaves as soon as they reach about ¾ of their mature size, Mr. Waxman was able to keep *Weigela* plants growing for over two months under short days. After the plants had exhausted all their food reserves, however, they suddenly collapsed. It is interesting to remark that old leaves have a very reduced effect and that a *Weigela* can be kept growing for a few months under short days by removing only the young leaves when they are ½ - ¾ of their full size (16.) These young leaves, therefore, seem to be the active receptors through which light exerts its effect on growth. Another experiment also illustrates the controlling effect of leaves. It deals with the growth of axillary buds when the terminal of a dogwood is removed. You know very well that, when the tip of a shoot is broken, the nearest lateral buds develop This is true with dogwoods grown under long days, but not under short days. In fact, when the whole plant is kept under long days, if short days are given to a single top leaf, this one leaf may be sufficient to inhibit the growth of the nearby axillary buds (16). Not all plants respond in this manner. In *Betula pubescens*, for example, the light-sensitive organ of the plant may be the terminal bud itself (14).

III — POSSIBLE PRACTICAL USES

As you can see, the mechanisms through which light works are rather complicated and may vary from species to species in their details. You will also realize that much more fundamental study on the basic mechanisms involved is necessary. May I merely point out certain problems which may be of direct interest to you.

1) *How to keep growing a plant that is growing*: If you make a dogwood cutting in June or July and leave it exposed to the natural daylight conditions, it may make a few inches of growth possibly but, rapidly, it will stop growing and stay in a dormant condition until May of the following year. If you want to keep it growing, you may supplement the normal daylength with incandescent light, so as to give a total daylength of 18 hours throughout the fall, winter and spring. Of course, this necessitates the use of a greenhouse kept around 70° F. The following August, you will have a tree five to six feet tall, whereas the cutting left under natural days will be only one foot tall.

2) *How to cause a dormant plant to grow*: The previous example concerns plants that are actively growing. If you have plants that have already stopped growing, the story is different and varies according to various factors, such as the presence of reasonably young leaves. Let us distinguish two main cases:

a) The plant has good leaves on: You can get it to grow again, even under short days, by defoliating it. I very well remember horse-chestnut trees in my home town, Mulhouse, France As a boy, I used to go to the out-of-doors market with my mother. After a hot and dry summer, most of these horsechestnut trees would have yellow leaves or practically no leaves at all. In late September, after a rain, these trees would grow green leaves and bloom, as if it would be spring. Of course, if you defoliate the plant and leave it under short days, it will soon stop growing again. It is necessary to give it long days to keep it growing. If you place a leafy dogwood which has become dormant under long days, it takes about two weeks, as found by Mr. Waxman, to get it to grow again.

b) If the plant has no more reasonably young leaves on, or if it has shed all its leaves in the fall, then two cases might happen In the first one, which seems more general, only an appropriate cold treatment will bring this plant out of dormancy This is the case for lilac and catalpa, at least in the fall. Other species, such as the European beech (*Fagus sylvatica*) will break buds and start growing without any cold treatment, if they are subjected to continuous light

3) *How to induce dormancy*: In the practice, we do not grow trees indoors, but out-of-doors, and the winter would soon kill tender growth. It is necessary to know when to stop the long-day treatments in order to induce hardening and dormancy This study has barely begun. In the case of the pink dogwood, it was found that already two weeks after having shifted the plants from long days to short days (9 hours of light), growth had completely stopped (16). But defoliation and the formation of good scales to protect the buds in various species would take longer. Experiments are in progress at Cornell along this line.

CONCLUSION

Do not mind the chaotic situation in which the study of regulatory effects of light seems to be today. So many new facts are discovered each year that it is difficult, sometimes, to understand why a given treatment works in one case, but does not in another It is simply a new field which is growing up. It is an exciting one, and I hope that you will share the enthusiasm of the research men who are working in it.

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PRESIDENT SCANLON: I think we will proceed with the report of the activities of the Field Trials Committee. This report will be made by the chairman, Dr John Mahlstede, Department of Horticulture, Iowa State College, Ames, Iowa.

REPORT OF FIELD TRIALS COMMITTEE FOR 1956 — PHOTPERIOD STUDIES

JOHN P MAHLSTEDE
Chairman

During the meetings last year, as well as on the questionnaire circulated this spring by our program chairman, Mr. Louis Vanderbrook, considerable interest was expressed on the effect of light on plant growth, as it in turn is related to plant propagation. It was because of this interest that your Field Trials Committee, composed of Vincent Bailey, John Roller, Harvey Templeton, John Vermeulen and myself