B. C. M. VAN ELK: We find it effective as a diluted quick-dip.

JIM WELLS: We have abandoned Jiffy Grow as we cannot get consistent results. However the material does, I believe, contain boron. We have used boron at 50 ppm, which has given good results when added to a hormone; it seems to increase the potency of the hormone.

B. C. M. VAN ELK: We have used boron widely without finding any significant results. But then we use cow manure at 70 tons per hectare every 2 or 3 years, so obviously our boron level is well maintained in the soil.

A. D. WEGUELIN: In France they are using CO_2 to hasten the rooting of cuttings. Has any work been done on this at Boskoop?

B. C. M. VAN ELK: Yes, but a 0.06% concentration gave no results. In the peat in which we place our azaleas we have CO_2 concentrations approaching 0.11%. We have not tried higher concentrations.

JAMES KELLY: At Kinsealy, a pilot trial has suggested that the illumination of cuttings in winter may give very good results. With *Chamaecyparis lawsoniana* 'Fraseri' and *Juniperus chinensis* 'Pfitzeriana', rooting occurred more quickly and thoroughly where the natural daylight was supplemented by mercury vapour lamps. We hope to continue our experiments and collect more substantial evidence.

LIGHTING — ITS EFFECT ON ROOTING AND ESTABLISHMENT OF CUTTINGS (A SHORT REVIEW)

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Searching through the literature, one finds that a considerable amount of research and experimentation has been carried out relative to this subject, particularly in the United States, U.S.S.R. and some European countries. Lighting has three main roles. These are —

1. *Rooting of cuttings.* This can be subdivided into —
   a) treatment of the stock plant;
   b) application to the cutting in the actual rooting bench.

2. *Establishment of rooted cuttings.* This can be interpreted as the continuation of growth to delay or prevent dormancy, with the aim of reducing losses of specific deciduous subjects during the winter.

3. *Breeding.* To speed up a breeding programme when plant breeders are anxious to see the results of their crosses earlier, e.g. *Rhododendron,* which has flowered after 3 years instead of 6 years. It may be practical with some subjects to

cause plants of early and late varieties to bloom simultaneously so that they can be hybridized.

I have purposely used the term "lighting" in this paper, as supplementary light has been used both to give photoperiodic and photosynthetic effects. It is most important to establish the difference between photoperiodic (daylength) and photosynthetic effects. Some of the literature can be misleading where supplementary light is discussed, as in most cases it is used mainly to control daylength.

Definition's to distinguish between the two are as follows:

Photoperiodic use — Extended daylength where low intensities of light are required; 5 to 50 foot candles. Here the light is at non-photosynthetic intensity.

Photosynthetic use — Actually supplementing the natural daylight, with the aim of increasing photosynthesis (building up carbohydrate reserves); approximately 400 foot candles or more are required. It is important to bear in mind, however, depending on the length of period it is given, that daylength can also be increased.

PHOTOPERIOD (daylength)

In the early 1920's Garner and Allard (1) showed the reason why some plants flower only in winter and not at all in summer. They found that this was dependent on the number of hours of daylight and darkness the plants received each day. The term given to this phenomenon was photoperiodism. This can be defined as a phenomenon in which relative lengths of light and darkness influence the development of plants, or alternatively, as the controlling action of the daily duration of light or dark on the flowering of some kinds of plants. They subsequently classified plants into three groups depending on their response. They are —

1. *Short-Day plants* — these only flower when the daily light period is less than a critical value; e.g. chrysanthemum.
2. *Long-Day plants* — these only flower when the daily light period is above a critical value; e.g. *Hibiscus syriacus*.
3. *Day-Neutral plants* — flowering of these plants shows no photoperiodic response; e.g. *Buddleia*.

This early work on photoperiodism was concerned entirely with flowering, but daylength can also control other plant processes. For example, dahlias — where a fibrous root system develops under long days and thicked storage organs in short days. Photoperiodism can also provide a survival mechanism. Plants which do not cease growing long before the arrival of early frost may be injured or killed outright. An example is the sycamore-maple, *Acer pseudo-platanus,* where new growth ceases by early July, immediately after the commencement of short days, thus helping to "condition" the plant for the winter.

Since the early 1920's, the physiologists' knowledge of photoperiodism has developed considerably. This knowledge has been applied to commericial horticulture, for what can best be described as "precision growing"; chrysanthemums, poinsettias and kalanchoes can be flowered at any time of the year by regulating the duration of the "light" and "dark" periods. Chrysanthemum "stools" naturally produce cuttings at specific times during the autumn and winter, but by controlling the daylength. they can be maintained in a vegetative condition throughout the year. This illustrates how one's knowledge of photoperiodism can improve management of a nursery.

STOCK PLANTS

In some species of woody plants the development of roots in cuttings has been found to be sensitive to daylength. Rooting is nearly always inhibited by S.D.; thus it has been found practical to produce artificial L.D. to encourage rooting in certain species.

A number of workers have found that the daylength to which the stock plant is subjected has an effect on subsequent rooting responses of cutting. Some of the earlier work was carried out in Russia by Moshkov and Kocherzenko (2) which showed that the photoperiodic treatment given the stock plant can affect the rooting of cuttings taken from it, as well as having a direct effect on the cuttings themselves. They found that when cuttings of *Salix undulata* were taken from stock plants in long-day conditions, they all rooted. At the same time, rooting did not occur with cuttings taken from stock plants which were held under short-day conditions. A rather similar response was found with other species of *Salix*. The importance of this is that it helps to explain seasonal variation in rooting and emphasies the importance of the time of year cuttings are taken.

This response was confirmed later by Waxman (3), working with *Cornus florida* 'Rubra.' He found that cuttings from plants held in short-day conditions for 45 days rooted only half as readily as those from plants in long-day conditions for the same period. The cuttings did not root if the short-days were extended for 125 days.

A rather different effect was found by Kelly (4) using *Ilex crenato* 'Hetzi'. Cuttings taken from plants receiving 30 and 40 short days rooted best, while cuttings from stock plants grown entirely in long days rooted least. A possible explanation given was that more growth regulating substances were produced under short days with this particular plant.

As short-day conditions bring about the cessation of extension growth and the formation of resting buds, the question arises whether buds which are dormant can be induced to resume growth by exposure to long-day conditions. Long-day treatment showed that resting buds of *Fagus sylvatica, Robinia pseudacacia* and *Larix decidua* could be induced to growth by exposure to long-days. It may be that this treatment could be used in rooting a number of important plants, so that the cuttings could be taken earlier in the year.

DIRECT RESPONSE OF CUTTINGS TO PHOTOPERIOD

This can best be described as the response of cuttings to the photoperiod in which they are rooted and only a limited number of investigations have been carried out in this field. In some species the development of roots on cuttings has been found to be sensitive to differing photoperiods, but it is apparent that a considerable variation in results has been obtained. Perhaps the plant which has been investigated the most is holly. Downs (5) undertook some experiments where terminal cuttings from male and female plants, using single clones, of 10 *Ilex* species and varieties, were rooted under mist in natural (winter) daylength and in L.D. conditions (obtained by interrupting the natural night for 3 hours with tungsten-filament bulbs). The results showed that long days encouraged earlier and better rooting; clones of *Ilex crenata* were the most responsive, while these of *Ilex aquifolium* and *Ilex opaca* were the least. He noticed that roots under long days were larger; there was also a marked difference in response by clones within the species.

Lanphear & Meahl (6) carried out some trials using 13 species of evergreen and semi-evergreen ornamental shrubs. They were rooted under 18-hour, 24-hour, and natural daylength. The results obtained were quite varied but they did show that with particular subjects there was a difference when rooting in long photoperiods in the autumn, compared with rooting in long photoperiods during the winter. During the winter, long photoperiods had no effect on rooting ability, although the number of cuttings rooted was reduced in the case of *J. horizontalis* 'Plumosa.' In autumn, however, only *Juniperus horizontalis* 'Plumosa' showed improved rooting percentages in long photoperiod, although the rooting quality of *Juniperus horizontalis, Ilex opaca* and *Rhododendron mucronatum* was improved.

Some investigations by Kamp and Van Drunen (7), working with *Taxus cuspidata* (*T. c. capitata*) were interesting. During October they took tip cuttings of the current season's growth, 8-10 inches long; subsequently some cuttings were placed under short days (natural daylength) and some were given a 4½-hour night break to provide a long-day effect. They found that rooting under short days was better than under long-day conditions.

ESTABLISHMENT

The primary objective here is to avoid "wastage" of valuable plant material. Some important deciduous subjects which are recorded as being difficult to overwinter, are *Cornus florida* 'Rubra', *Magnolia, Viburnum carlesii* and *Acer palma-*

tum cultivars. The propagator has no doubt gone to great lengths to root these subjects successfully in early summer, only to find after the winter that there have been serious losses. A reason given why *Viburnum carlesii* does not successfully over-winter is, firstly, because the young cutting has had insufficient time to build up a carbohydrate reserve and, secondly, the tissues have not hardened up sufficiently. Many propagators no doubt have their own methods of successfully over-wintering these subjects, but some experiments have been carried out to show that in many cases extension of daylength can assist.

Some early work has shown that under long-day conditions extra vegetative growth can be achieved on a number of woody plants after they have been rooted, for example, *Rhus typhina, Cornus nuttallii* and *Acer palmatum,* but this growth was only achieved when the surrounding temperature was in the region of 60°-65°F. In addition, considerable investigations have been carried out at the Experimental Station in Boskoop, Holland.

Waxman (8) carried out some interesting work with *Cornus florida* 'Rubra.' Cuttings were rooted under mist in early summer and were then subsequently exposed to 18-24 hour photoperiods. Significant extra growth was achieved when compared with the controls. Chances of survival were increased as leaf fall was delayed and additional buds were allowed to develop. He makes two very interesting and important remarks. Before the young plants can be over-wintered in a cold frame, they must be hardened off. This can be achieved by transferring the plants to short days from long days. However, if one wishes, one can keep the plants in long days throughout winter to produce new growth until the following spring and then they are placed outdoors. This can be expensive, due to the glasshouse space involved.

Deciduous azaleas have received some considerable attention where a major problem in their culture has been the losses which occur over the winter. Some investigations were carried out by March (9) at the U.S. National Arboretum with Ghent and Mollis type azaleas. He noticed that over-wintering proved difficult because the cuttings tended to become dormant after rooting and to die the following spring. He found that the use of articicial light from 8 p.m. to 6 p.m., given from the time of potting (around the 3rd week in July) until the 1st week in September, induced shoot growth immediately after rooting and enabled the plants to be over-wintered satisfactorily in a cold frame or cold greenhouse. Weiser (10) reported that the growth of young rooted plants of deciduous azaleas and dwarf rhododendrons was stimulated by being grown in continous light, using intensities of 35-50 foot candles.

SOURCES OF LIGHT

The cheapest and simplest source of light is the ordinary electric light bulb (tungsten-filament bulb). These are available in various forms. A point to remember is that ideally one should use reflectors around the bulb. There are three possible ways of applying this form of light; viz. by night-break, cyclic, or continuous over the 24- hour period. The method used largely depends on economics and the actual plant material.

When applying extended daylength to cuttings in the bench, Waxman (8) used for some of his work 75-watt bulbs with reflectors, which were spaced 3 feet apart and 3 feet above the cuttings. He suggests that the light intensity should be no lower than 30 foot-candles, with a minimum air temperature of 60°F. Elsewhere it is reported that for rooting *Rhododendron molle* (*Azalea molle*) 60-watt bulbs were spaced 3 feet apart and 20 inches above the cutting.

Lamps used for supplying supplementary light (e.g. mercury discharge lamps) have generally been found unsuitable for extended daylength purpose. They can provide light up to an intensity of 400 foot-candles, thus giving both a photosynthetic and a photoperiodic effect. They usually have a narrow spectral range, however, which is not so suited to photoperiodic control; their control gear is costly and also there is a "fall off" of intensity between the lamps. They could be useful when one wishes to rapidly build up carbohydrates as well as to give a photoperiodic effect.

CONCLUSIONS

On reflection, one could say that the knowledge of photoperiodic effects in trees is much less complete than that of herbaceous and annual plants which is, no doubt, due to the fact that such work with tree species is slow and sometimes difficult. One is dealing with a very wide range of clones and species whose responses are often totally different. Nitsch (11) illustrates this point very well. He gives three examples of the response of woody plants to long days:

a) A continuous growth response; e.g. *Viburnum carlesii, Cornus florida, Thuja occidentalis* and *Weigela.*

b) Growth in flushes; e.g. Scotch Pine, Red Oak.

c) Where the onset of dormancy cannot be prevented, but just slightly retarded; e.g. Lilac, *Viburnum prunifolium.*

Thus anyone wishing to use extended daylength must be prepared to experiment himself and a set of conditions suited to one subject will not necessarily suit another. The use of extended daylength does not seem practical for those plants which do not present any difficulty in their rooting or subsequent establishment. Also the propagator must be prepared to alter the subsequent management of his plants as indicated earlier.

Finally, the information the propagator requires is whether or not it is economically feasible to apply extended daylength to a particular subject. Also are there methods other than altering daylength which would more easily overcome the difficulty encountered in propagation and subsequent establishment? The propagator wants to know which plants respond to a given photoperiod, and what other factors, such as how much extended daylength, do particular subjects require.

It is known that a number of propagators in the U. K. used photoperiodic lighting with varying degrees of success; the aim of this short review is to give some background on the work already out in this field in different parts of the world. It is hoped that this will stimulate further interest in the U. K. and subsequently result in a lively session devoted to this topic at a future conference.

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MY APPROACH TO TEACHING PLANT PROPAGATION

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The teaching of plant propagation by any one person is, in essence, a personal philosophy of that particular individual, developed as a result of his experience in that field. It may well differ radically from the views of other teachers but I offer no apologies for this — my own approach. Basically this philosophy is a synthesis of three components. Firsthly, there is the influence of one's original teachers who must necessarily have the major effect for they are able to mould one's thinking; this component is thus the most telling as it is, perhaps, the most difficult to disregard. Secondly, the effect of the work and thinking of other teachers, researchers and practical propagators must have marked influences in developing one's