I suspect that one of the reasons why certain plants have declined has been that their stocks have gradually accumulated viruses and other disease problems during their time in cultivation. It may well be that we need to turn to specialists with modern techniques to develop "clean" stocks which we can re-introduce to general circulation. Here I am thinking particularly of certain hardy plant groups such as primrose cultivars, Russell lupins, etc. The re-establishment of healthy stocks may be essential for the survival of such plants.

I mentioned our local groups earlier. We are trying to encourage them to help with the propagation and distribution of plants which might otherwise run the risk of being lost. For this purpose we are to hold a conference on propagation for them next month at Pershore College, to which I intend later today to invite official representatives from the IPPS. The NCCPG is very keen not to compete directly with the trade — indeed I am sure it would mostly warmly encourage any nurserymen prepared to add new items to their commercial list; the greatest safeguard for unusual plants is that they do remain commercially available. However, initially, we shall certainly encourage our local groups to propagate items that the Trade is unwilling or unable to produce. They will need your expertise and advice, whether as amateurs or professionals, and I sincerely hope that some of you may be prepared to join your local groups and share your knowledge with them.

ETIOLATION OF STOCK PLANTS FOR IMPROVED ROOTING OF CUTTINGS: I. OPPORTUNITIES SUGGESTED BY WORK WITH APPLE

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Abstract. The percentage rooting of leafy cuttings of the apple rootstock, M 9, was increased on average from 11% to 78% by prior etiolation A period of exposure to light before taking pre-etiolated shoots as cuttings was essential and it was not necessary to continue to exclude light from the future rooting zone The only limitation to the practical application of the technique appears to be that the conditions under the black polythene covers used to exclude light from the stock plants are favourable for *Botrytis* infection Because complete darkness is not essential, this problem can probably be overcome by effective ventilation of the covers

Terminology. There are many reports of stimulating adventitious rooting by various treatments involving the exclusion of light. Treatments range from excluding light from the base of the cutting during rooting, as is normal for cuttings

planted in conventional rooting media, to growth of stock plants in complete darkness. All have been referred to as "etiolation". Definitions of the term are correspondingly variable. Most, e.g. (8) refer specifically to the typical appearance of plants *grown* in complete darkness (i.e. elongated internodes, no chlorophyll and small leaves). Etiolation has also been defined as the exclusion of light, without any clear limitation as to stage of development or to the effects it may have (17). However, both Hartmann and Kester (7), and Garner (6) clearly favour the first of these definitions, reserving the term etiolation for *growth* of shoots in darkness as distinct from exclusion of light from initially light-grown tissue which, in time, may lead to loss of colour, and may be described as blanching. This more restricted definition is used here to distinguish between the various types of treatment that have been used in the study of the effects of light on rooting at East Malling and elsewhere.

Exclusion of light from the base of cuttings during rooting. Illumination of the base of the cutting during rooting completely prevented rooting of *Chrysanthemum* (1), reduced rooting of *Picea abies* from about 50% to about 5% (15), and greatly reduced root numbers in *Salix alba*, and in mung bean (12). Although an inhibitory effect is not always observed, e.g. (16), I am not aware of any reports of the stimulation of rooting by light.

Blanching treatments applied to shoots on stock plants. Herman and Hess (9), and more recently Kawase and Matsui (13) reported that root primordia develop rapidly under black polythene or paper wrapped around the stem of plants of *Phaseolus vulgaris*. With *Hibiscus rosa-sinensis* no root primordia were visible after 5 weeks but rooting of cuttings was improved (9). Recent unpublished work at East Malling has demonstrated increased rooting of cuttings following blanching in a wide range of plants including *Acer platanoides* 'Crimson King', *Tilia cordata*, *T.* × *vulgaris*, *T. platyphyllos*, *Corylus avellana*, and several apple scion cultivars and rootstocks. For example, the effect of black tape applied to non-etiolated shoots on the rooting of leafy cuttings of apple rootstock M9 is shown in Table 1.

Etiolation. There are few reports of the effect of true etiolation other than with hypocotyl cuttings made from young seedlings, e.g. (4). Gardner (5), and more recently Delargy and Wright (3), reported large increases in rooting percentage of cuttings of difficult-to-root apple scion cultivars as a result of etiolation followed by continued exclusion of light from a short basal section of each shoot.

At East Malling Research Station, etiolation studies have centred on M9, a commercially important apple roostock which roots poorly from cuttings (11). Results obtained over 4 years show that etiolation transforms the rootability of M9 cuttings (Table 1) with rooting percentage increased from, on average, 11% to 78%. The response was consistent despite a change of site, different ventilation of the polythene covers, occasional *Botrytis* infection, different rooting media, and, in 1981, covering being delayed by three weeks. Maintaining localised darkness with black tape was always advantageous but the average further increase in rooting percentage was only 7%.

Table 1. Effects of etiolation and of blanching on rooting of leafy summer cuttings of apple rootstock M9 observed over 4 years All cuttings were treated with 2500 ppm IBA (Roots per rooted cuttings in brackets)

Date Covered	Rooting Percentage			
	Etiolated		Non-Etiolated	
	+ Tape	− Tape	+ Tape	− Tape
May 12, 1978	92 (25 3)	70 (12 9)	** 36 (3 6)	8 (2 3)
May 18, 1979	88 (41 0)	83 (22 0)	—	15 (1 7)
May 9, 1980	95 (45 0)	90 (37 7)	30 (4 2)	10 (4 0)
May 7, 1981	76 (38 8)	73 (18 3)	25 (6 0)	15 (4 8)
May 27, 1981	*76 (16 1)	*75 (8 7)	30 (5 1)	6 (1 0)

* cuttings prepared from dark-grown part of shoots

** tapes applied 2 weeks prior to collection, in later years applied as shoots reached about 40 mm in length

Effects of low light intensity. Using stock plants grown at a range of light intensities in growth cabinets, stimulation of rooting at low irradiance has been reported for apple rootstock M26 (2), *Chrysanthemum* (1), and *Pinus sylvestris* (16). In general, effects were small but this may only reflect the narrow range of irradiance used (generally 8 to 40 Wm^{-2}).

Results of experiments with field-grown stock plants of M9 covered with polythene of different light transmission characteristics, show that very large responses can be obtained without complete exclusion of light (Table 2).

Table 2. Percentage rooting of apple rootstock M9 cuttings from stock plants covered with polythene of different light transmission characteristics (Roots per rooted cutting in brackets)

	Light transmission through cover			Uncovered control
	0 00%	0 25%	2 5%	
+ Tape	70 (40 8)	86 (37 0)	88 (41 2)	25 (6 0)
− Tape	65 (15 4)	82 (18 6)	79 (21.8)	15 (4.8)

Mechanism of responses. Despite the numerous reports of improvements in rooting through the exclusion of light, there

is little clear evidence as to the mechanism involved nor is it clear whether this is the same for the various treatments referred to above.

Since the effect of auxins in promoting rooting is well established, as is also the destructive effect of light on IAA *in vitro*, effects of light on endogenous auxin concentrations have frequently been suggested. Kawase (12) reported that the rate of decline in endogenous auxin in mung bean cuttings during rooting was reduced by about half when light was excluded. However other reports, e.g. (13) have failed to demonstrate a convincing effect on auxin concentration. Furthermore, there are many reports of dark treatments which, far from making auxin treatment unnecessary, greatly increased the responsiveness to auxin treatment (2,3,9,13). Pre-etiolated M9 cuttings behaved in this way (Table 3) but if etiolation was followed by the application of black tape to maintain darkness over a short basal section of the shoot, preformed roots eventually developed and, long before roots were visible, the need for auxin treatment was much reduced. One possible explanation of the enhanced effectiveness of auxin in dark treated tissues might be higher levels of rooting cofactors but Herman and Hess (9) were unable to demonstrate convincing differences in cofactor levels using a mung bean bioassay and concluded that a complex of many factors was probably involved.

Table 3. Interaction between the effects of IBA (2500 ppm), etiolation, and black tape treatments on percentage rooting of apple rootstock M9 cuttings (Roots per rooted cutting in brackets)

	Etiolated		Non-Etiolated	
	+ Tape	− Tape	+ Tape*	− Tape
− IBA	85 (8 4)	45 (7 9)	0 (−)	0 (−)
+ IBA	95 (45 0)	90 (37 7)	30 (4 7)	10 (4 0)

* Tapes applied as soon as shoots were sufficiently long (ca 40 mm)

Pre-etiolation as practised at East Malling. Etiolated shoots are produced by covering sections of hard-pruned hedges with black polythene (500 gauge) stretched over a wooden frame and buried at the edges. Very limited ventilation is provided by small slits in each end wall, covered by a further piece of polythene arranged to exclude light but not air. Covers are generally erected as bud-break commences. As a further protection against loss of etiolated shoots through *Botrytis* infection, hedges are sprayed with a systemic fungicide before covering and again if infection is seen. After four weeks, when shoots are about 100 mm long, a panel is removed from the north side to admit some light and thus allow the development of a few green leaves before cuttings are taken two weeks later. This is essential to the subsequent survival of the cuttings. The dark treatment may be maintained around the basal

2.5 cm of a sample of the etiolated shoots by wrapping with self-adhesive black plastic tape. Cuttings are propagated under mist, generally following treatment with 2500 ppm IBA applied as a 50% acetone quick-dip. Rooting is assessed after four weeks.

Opportunities for practical application. It seems reasonable to assume that the effect of blanching on rooting already operates in practical propagation systems, such as stoolbeds, in which soil excludes light from the base of shoots. It is hard to envisage widespread adoption of alternative more labour-intensive methods of blanching, such as the application of polythene tapes to individual shoots. For large scale operation, etiolation, achieved by covering stock plants with black polythene for a few weeks, is more feasible.

The only practical difficulty emerging from our experiments with M9 is that of possible *Botrytis* infection during the period of growth under the black polythene covers. Although this had no effect on rooting of cuttings, infection of shoots on the stock plants reduced the number of cuttings available in 1979 and 1981. Fungicides helped to counter this problem but effective ventilation of the covers would probably be better. Without ventilation the plants are continuously wet from condensation except on very hot days. Effective ventilation is difficult to provide without allowing some light to penetrate. However the results shown in Table 2 clearly indicate that complete darkness is unnecessary and may actually be undesirable because cuttings from the low light treatments were larger and stronger than those grown in complete darkness. Further work will be required to determine the highest light intensity that can be used without reduction of rooting. Also, it remains to be seen whether the presence of water on the plants contributes to the rooting response observed with poorly ventilated covers. However, observations of the effect of placing wet cotton wool underneath the black tape used for blanching light grown shoots suggest that any such effect is likely to be small.

Amongst those features of the response of M9 to etiolation that favour its practical development, the most important are the size of the response and the fact that application of black tapes to maintain localised darkness after the covers are opened is not essential. Furthermore, the pre-etiolated cuttings are not so delicate as to require special handling and stock plants recover rapidly. It is impossible to predict how many other difficult-to-root plants may also meet these criteria. This will be determined from trials with a range of species such as those reported by Rowell (14).

The technique has proved effective also for the difficult-

to-root apple scion cultivars, Cox and Golden Delicious, but only when followed by a black tape for the remainder of the growing season. Similar treatments have been successful with other apple scion cultivars (3,5). If a light absorbing or reflecting material could be found which was suitable for spraying onto plants after etiolation and also had the necessary elasticity and resilience to substitute effectively for black tape, the technique could become attractive.

Alternatively, practical application of etiolation to such difficult subjects may come indirectly through elucidation of the basic physiological mechanisms involved, leading eventually to the development of novel chemical aids to rooting. This is the primary objective of current work at East Malling.

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ETIOLATION OF STOCK PLANTS FOR THE IMPROVED ROOTING OF CUTTINGS II. INITIAL EXPERIENCES WITH HARDY ORNAMENTAL NURSERY STOCK

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Work at East Malling Research Station has shown that the etiolation of stock plants of apple rootstock M9 can result in an increased rooting percentage of softwood cuttings. An observation was carried out to see if there was a similar response on ornamental species, and in 1980 and 1981 a range of species was tested in cooperation with Mr. J. Watts, propagator for Darby Nursery Stock Ltd. Results to date have been variable. In 1980 a number of species, especially lilacs, showed a marked response to etiolation but in 1981 results have been disappointing.

1980 TRIALS

At bud burst in spring stock plants of the following species were covered with a black polythene tent supported over and around the plants on a simple wooden frame. Immediately prior to covering, the plants were sprayed with benomyl as a precaution against *Botrytis* infection.

		Covering date
Species covered	*Polygonum baldschuanicum*	April 4
	Cotinus coggygria 'Royal Purple'	April 4
	Corylus maxima 'Purpurea'	April 1
	Corylus avellana 'Contorta'	April 1
	Syringa vulgaris 'Charles Joly'	April 8
	S vulgaris 'Madame Lemoine'	April 8
	S vulgaris 'Ludwig Spaeth'	April 8

In the 2 to 3 weeks after covering, the growth rate of the buds was monitored and when the shoots had grown approximately 8 cm the black polythene was raised on the north side of the tent about 30 to 45 cm to allow the shoots to green up. After a further week cuttings were taken and placed in a mist house for rooting.

RESULTS

Effects on Growth. The effect of the blackout treatment