to the relevant bed. The bed could also be changed immediately for any given load of plants.

Having decided to continue with trailers, we reassessed the prototypes towed by the Bonsers and improved their design. As we were unable to find a suitable trailer on the market at what we considered to be a reasonable price, we decided to fabricate it ourselves.

We worked out overall dimensions suitable for all sizes of pot and Empot trays that we thought we would be using. A prototype was built and tested and this was used as a model for the others. They have since proved sufficiently versatile to be used for transport and as mobile benches for the staff when packing or knocking out.

4. **Improvement of practical management techniques.** The basic idea behind all of these projects was to create a cohesive base from which we could expand production. The successful operation of most systems in horticulture rely upon the people who are involved in their day to day use. Staff motivation is therefore important. Making the potting operation easier and faster with the use of rigid pots for all saleable plants has helped to motivate staff. This was reinforced with the introduction of a bonus scheme which rewards the staff individually for their personal performance whilst potting.

In conclusion, our main aim has been to make the physical side of container nursery stock production less arduous by combining good nursery layout and mechanisation where possible. In order to achieve this we have invested the maximum amount possible each year. Although I have described the creation of our nursery in terms of individual problems and solutions, I am sure you will appreciate that, in reality, it is never that simple.

IMPROVING THE ROOTING OF *SYRINGA VULGARIS* CUTTINGS BY ETIOLATION

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Abstract. An increase in the rooting percentage of cuttings of *Syringa vulgaris* 'Madame Lemoine' was observed in response to an etiolation treatment in the field in 1983. This result was not supported by data in 1984, possibly due to the disturbances of cuttings in an attempt to assess the time of root development. Variation in the rooting of shoots within treatments was associated with their stock plant origin.

Shoots grown in light and dark in controlled temperature environments developed at the same rate Consequently differences in the striking date and also in the rooting environment between treatments were avoided Cuttings which developed at 25°C rooted earlier than cuttings developed at 15°C High temperatures alone may account for rapid shoot extension whereas improved rooting was, in general, associated with the combination of high temperatures and low light levels The value of studying etiolation in systems facilitating more precise control of the shoot environment during treatment is discussed.

REVIEW OF LITERATURE

Etiolation as a process involves the development of shoots in a dark environment and, for a range of woody ornamental plants, a period of approximately four weeks is required for the development of suitable cutting material. Recent reviews of the literature covering early research in etiolation are presented by Delargy and Wright (2) and Harrison-Murray (4).

Extensive work on apple rootstocks, e.g. Malling 9, and some ornamentals has been carried out at East Malling Research Station (6). A number of physiological and environmental stimuli may be involved in the root initiation process (11) which means that the design of covers used for etiolating shoots is of primary concern. High temperatures and high humidities associated with completely enclosed etiolation covers can result in major disease problems. Work with the apple rootstock, Malling 9, using covers with minimal ventilation has shown that a low irradiance of up to 2.5% of available daylight was as effective as complete darkness for stimulating rooting (5). Subsequently, to avoid disease problems, covers were ventilated either by splitting and partly patching the polythene or by cutting away a section at the base of the cover. The observation that a high level of ventilation, during the etiolation of Malling 9 shoots, reduced rooting indicated that high temperatures were more important than high humidity in promoting rooting of cuttings (6).

Etiolation studies have been carried out on a range of hardy ornamental nursery stock (HONS) including *Syringa* species (12). Based on field studies using non-ventilated black covers it was concluded that the response to etiolation is species specific and can be variable between successive years.

The propagation of a range of cultivars of *S. vulgaris* using nodal and tip cuttings has been studied in Poland (1). High rooting percentages and root numbers were associated with young shoots being taken as cuttings early in the growing season when the flowers were at the beginning of anthesis or at full anthesis

This paper reports the results obtained from etiolation experiments in the field and in controlled environment cabinets for *Syringa vulgaris* 'Madame Lemoine'. This study torms part of a wider programme to improve the rooting of shoots of HONS by treatments applied to the stock plants.

MATERIALS AND METHODS

Field Etiolation 1983. Thirty 2-year-old field-grown plants of *Syringa vulgaris* 'Madame Lemoine' (clone 1) grafted on *S. vulgaris* were obtained from Coles Nurseries, Leicester and replanted 0.6 m apart in the field in April, 1982. In early March, 1983, these stock plants were pruned to leave approximately six buds per main stem.

Four wood-framed covers were constructed with gaps at the base and the top overhung by flaps of polythene to permit ventilation. Two of the frames were covered with clear and two with black polythene (500 gauge). Light levels under the covers and in the open were monitored using a scanning spectroradiometer (Licor LI 1800). Temperatures were monitored with a Grant recorder and humidity measured with an Assman Hygrometer. In addition, weather station data was available.

The stock plants were sprayed with Rovral (iprodione) at bud break and the covers placed over them to provide the 3 treatments, viz. black cover (etiolation), clear cover, and no cover (control). Seven plants received each treatment, with groups of 3 and 4 under the treatment covers. At the end of the period of each treatment (Table 1) the basal section of one side of the polythene covers was removed 3 days prior to striking the cuttings to permit "regreening" of the shoots.

Table 1. Environmental data and the dates of treatments for field etiolation and controlled environment etiolation of *Syringa vulgaris* 'Madame Lemoine'

	1983 Field			1984 Field		1984 Controlled Environment			
	Control	Clear cover	Black cover	Control	Black cover	Light 15°C	Light 25°C	Dark 15°C	Dark 25°C
Date covers on 'bud break'	—	3 May	3 May	—	21 April	6 April	6 April	6 April	6 April
Date cuttings struck	7 June	27 May	31 May	28 May	24 May	21 April	15 April	21 April	15 April
Duration of treatment (days)	—	21	25	—	30	14	8	14	8
Regreening (days)	—	3	3	—	3	1	1	1	1
Mean minimum temp °C	7 2	6 6	6 7	4 2	4 0	14	24	14	24
Mean maximum temp °C	14 8	25 0	18 0	14 8	18 5	16	26	16	26
% Daylight	100	70	0 2	100	0 2	—	—	—	—
Humidity % RH	*	*	*	35-85	34-87	73-88	65-76	72-83	67-76

* Recordings not taken

When the shoots in the different treatments were between 6 and 11 cm in length they were prepared as basal cuttings without removing any leaves to reduce wounding. Cuttings remained in groups (according to stock plant) and half of them were given a 5 sec. dip in a 0.2% solution of indolebutyric acid (IBA) in 50% acetone. The cuttings were inserted in a moss peat: perlite (1:1, v/v) rooting medium in lines radiating from mist nozzles. The mist bench was enclosed with a polythene tent and the irradiance at cutting level was 159.3 Wm^{-2} (677 $\mu Em^{-2}s^{-1}$). Compost temperature was set at 20°C, although temperatures up to 28°C were occasionally recorded. Fungicides, Rovral and Ronilan (vinclozolin) used alternatively, were applied at intervals of 14 days. The rooting of cuttings was recorded as percent cuttings rooted, number of roots per cutting, and root length per cutting 42 days after sticking.

Field Etiolation 1984. The clonal stock plants used in 1983 were divided into 8 groups with half of the plants receiving an etiolation treatment under 4 black polythene ventilated covers. As in 1983, the etiolated shoots were regreened for 3 days (Table 1). Cuttings received the same handling except that no IBA treatment was used and a shade screen was installed over the mist benches to reduce temperature extremes. The irradiance at the height of the cuttings was reduced to 80.6 Wm^{-2} (342.6 $\mu Em^{-2}s^{-1}$). The rooting of cuttings was recorded on days 14, 24, 32 and 42 post striking.

Controlled Environment Etiolation 1984. Twenty-four 2-year-old field-grown plants (clone 2) grafted on *S. vulgaris* were obtained from Notcutts, Suffolk and planted in March, 1983, in a peat-based compost with Osmocote in 30-litre containers. On 8th March, 1984, they were lightly pruned. At the time of bud break the plants were transferred to 6 controlled environment cabinets to be grown at either 15°C or 25°C with and without light (70.6 Wm^{-2} [300 $\mu Em^{-2}s^{-1}$]) provided from warm white fluorescent lamps. Black polythene with small slits was used to black out half of each cabinet. Three cabinets were run at 15 ± 1°C and three at 25 ± 1°C, with two plants in each environment in each cabinet. All of the plants were sprayed with Rovral prior to placing in treatment. Regreening of etiolated shoots was limited to one day (Table 1). The preparation and handling of cuttings and the recording of rooting was carried out as noted above.

RESULTS

Over any 24-hour period considerable variation in temperature was noted for the different treatments, as shown in Figure 1 for a moderately sunny day. The temperature under ventilated black covers was 1 to 4°C higher than the control. By contrast, non-ventilated covers were 4 to 10°C higher than the control (Figure 1A). The temperature under ventilated clear covers used in the 1983 field experiment was 1 to 5°C higher than the ventilated black covers (Figure 1B).

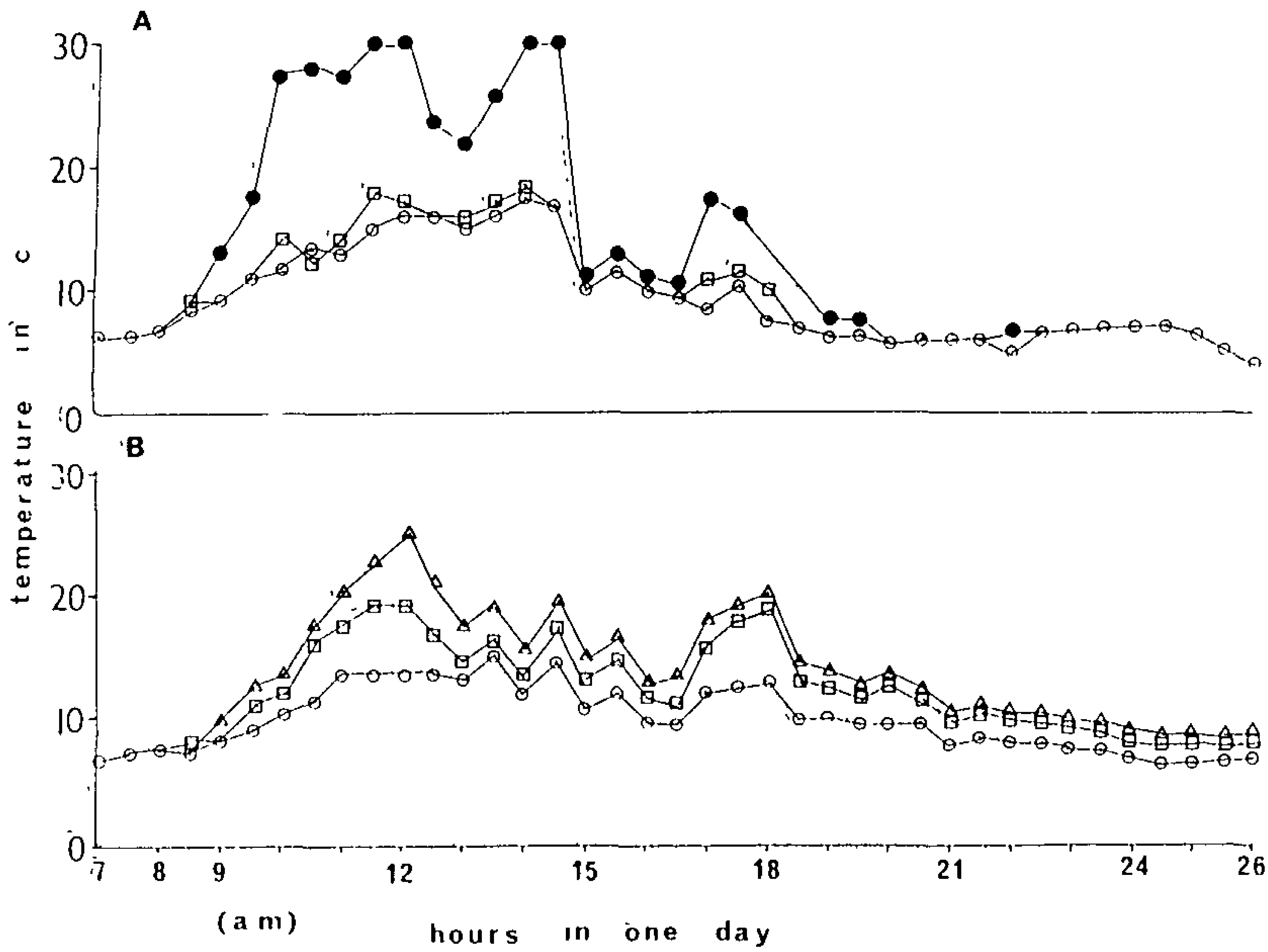

Figure 1. Temperature variations over a period of 24 hours during the field etiolation in 1984
A Ventilated (□) and non-ventilated (●) black polythene covers compared to the control (O)
B Ventilated black (□) and clear (▷) polythene covers compared to the control (O)

In the 1983 field experiment the etiolation treatment significantly increased ($P < 0.001$) the number of cuttings which rooted and the rooting percentage (Figure 2A). However, the mean root number per rooted cuttings was not significantly different (Figure 2B).

Etiolation of shoots in the 1984 field experiment did not increase the number of cuttings which rooted. Eight cuttings rooted from the etiolation treatment, and 9 from the control, representing 6.5 and 7.5% rooting, respectively.

The number of cuttings which rooted and the rooting percentages for the controlled environment experiment are shown in Figure 3. Data are presented for days 32 and 60 from the time of striking the cuttings.

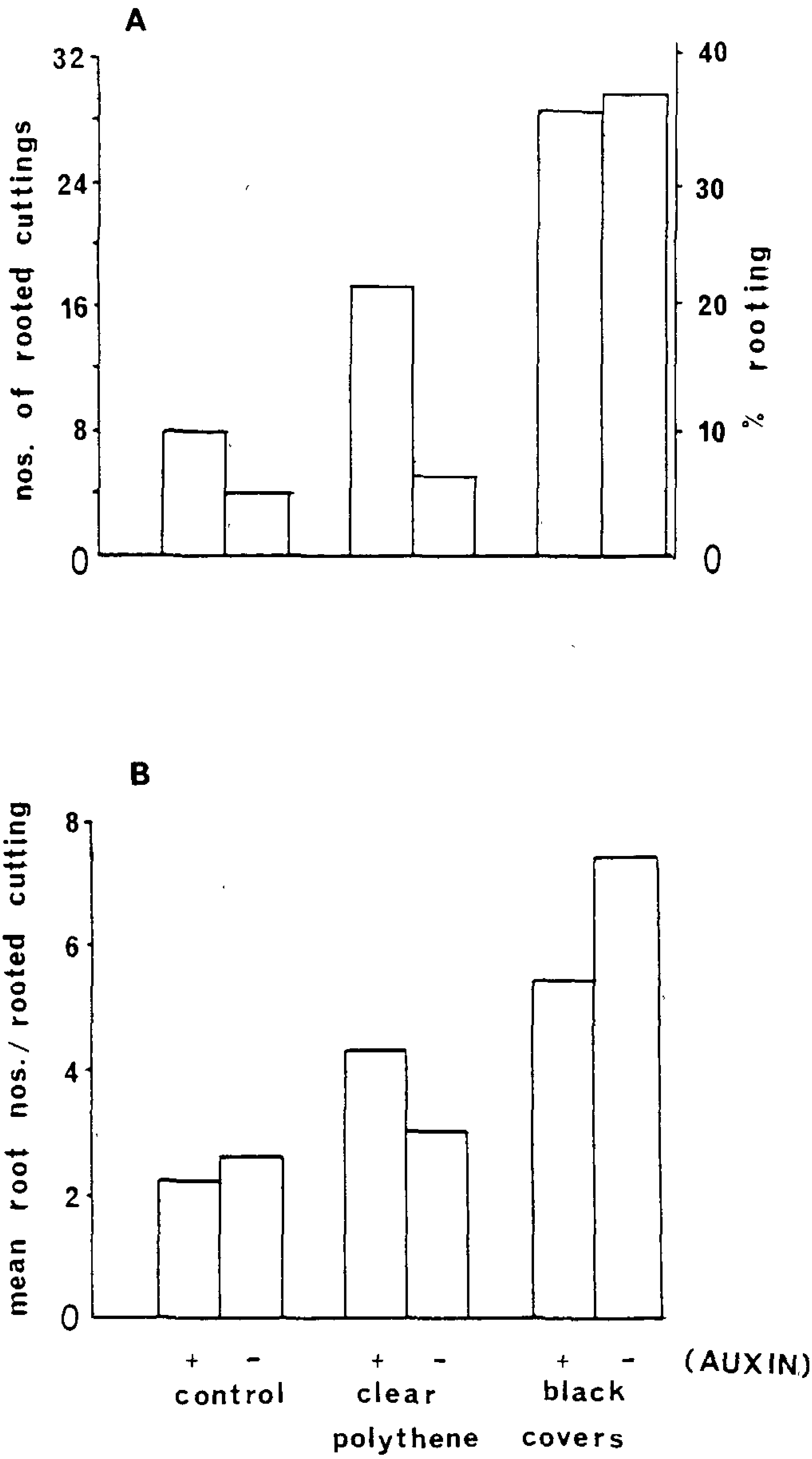

Figure 2. The rooting of cuttings of *Syringa vulgaris* 'Madame Lemoine', 42 days post striking, from the 1983 field etiolation experiment, 75 cuttings per treatment.
A The number and percentage of cuttings rooted
B The number of roots per rooted cutting
Note auxin treatment = ±0 2% IBA in 50% acetone, 5 sec dip

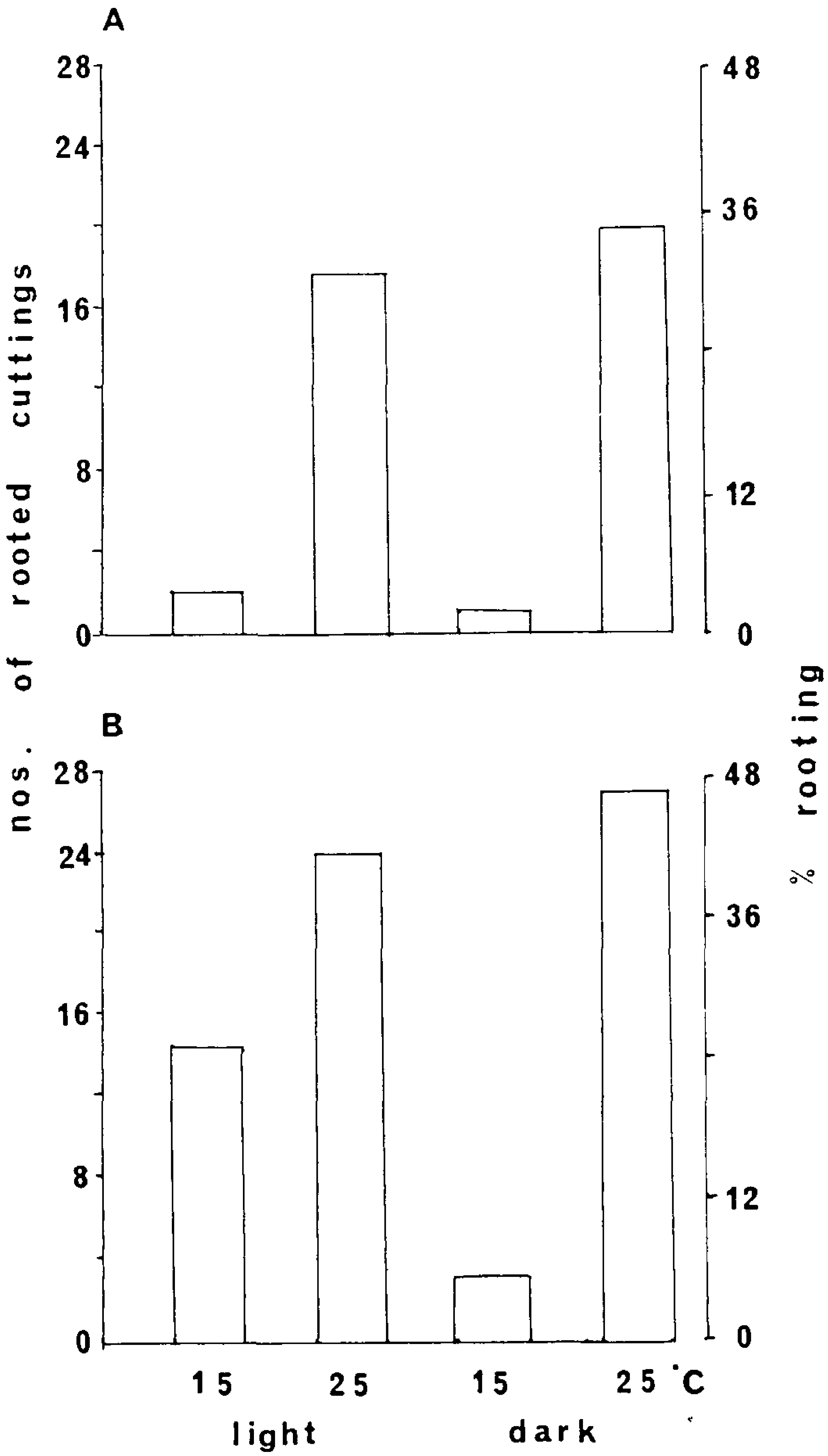

Figure 3. *The effect of light and temperature on the rooting of cuttings of Syringa vulgaris* 'Madame Lemoine', in the 1984 controlled environment etiolation experiment, 54 cuttings per treatment No auxin treatment.
A 32 days post striking
B 60 days post striking

Table 2 shows the rooting performance of cuttings (42 days from striking) taken from individual stock plants. The plants selected represent the limits of the range of rooting performance within the treatments in the 1983 field experiment and the 1984 controlled environment experiment.

Table 2. Rooting performance of cuttings from individual stock plants of *Syringa vulgaris* 'Madame Lemoine' 1983 field experiment (clone 1) and 1984 controlled environment experiment (clone 2) Mean rooting percentage based on cuttings taken from 7 stock plants

	1983 Field						1984 Controlled Environment							
			Polythene covers				Light				Dark			
	Control		Clear		Black		15°C		25°C		15°C		25°C	
Stock plant number	24	23	12	2	19	21	15	6	23	20	4	8	29	16
No of cuttings taken	29	27	25	21	21	11	9	18	10	22	16	10	11	10
No of cuttings rooted	1	7	2	4	1	7	0	5	1	8	0	2	1	8
Rooting %	3	26	8	19	5	64	0	28	10	36	0	20	9	80
Mean rooting %	9		14		40		*		*		*		43	

* insufficient rooting percentages were obtained to enable the mean rooting percentage to be calculated

DISCUSSION

In the 1983 field experiment the increased percentage rooting of cuttings achieved with the ventilated black covers (38% versus 5% for the control) was comparable to the enhanced rooting reported by Rowell (12), when non-ventilated covers were used (28% versus 6% for the control). Percentage rooting increased from 11% (control) to 37% (etiolated) when cuttings were treated with IBA; however IBA did not increase the rooting percentage of etiolated shoots.

Shoots from plants covered with clear polythene, although developing the earliest, were slower to root than etiolated shoots. The rooting percentages follow a similar pattern to those reported for the apple rootstock Malling 9 when non-ventilated black covers, clear covers, and controls gave 50, 28, and 4% respectively. Similarly, for Malling 9, root numbers per rooted cutting were 33.5, 4, and 1.5, respectively (6).

Variation within treatments (Table 2) prevents the observations on root numbers (Figure 2B) being significantly different between treatments. Rooting percentages of cuttings from individual plants in clone 1 varied within treatments by 5% to as much as 64%. Similarly in clone 2, used in the controlled environment experiment, where sufficient rooting percentages were available for comparison, a range of 2% to 80% was noted.

The absence of any response to the etiolation treatment in the 1984 field experiment will be discussed in terms of (i) treatment, (ii) plant material, and (iii) the rooting environment.

Treatment. Differences in field results between successive years are usually attributed to variation in climatic factors. For a study of etiolation in the field the design of the covers will have direct effects on the shoot environment and therefore on the treatment. The covers used in 1983 and 1984 were identical in design, therefore differences in climatic factors between the two years can be discussed in relation to the treatment results. The major differences between the two years were the lower relative humidity (41% versus 52%) and lower mean minimum temperatures (4.2°C versus 7.2°C) in 1984 as compared to 1983. In both years the mean maximum temperature was 14.8°C. Humidity is not regarded to be as significant as temperature in causing enhanced rooting following an etiolation treatment (5,6), and differences in the maximum temperatures under different treatments are likely to be more important. However, in this study it is not possible to explain the differences in rooting performance between the two years in terms of temperature since the maximum temperatures were comparable (Table 1). Likewise, the ventilation of the covers probably did not vary greatly between the two years as the run of wind for 1983 and 1984 was comparable (8.8 and 9.1 km h^{-1} respectively).

Plant Material. The same stock plants were used in both the 1983 and 1984 field experiments. Difficulties were encountered in re-arranging plants between treatments in 1984 to achieve an equal distribution of plants which had been etiolated or which exhibited a known level of rooting ability in 1983 (Table 2). Rowell (pers. comm.) also noted variation among stock plants in etiolation studies with *S. vulgaris*. An attempt was made to apply the etiolation treatment to one half of individual stock plants using black polythene bags, leaving the other half of each plant as a control. However, difficulties in disease management and mechanical damage to the shoots prevented the study being completed.

Rooting Environment. In the 1984 field experiment an attempt was made to identify the period in which roots were initiated. Inadequate replication prevented sequential harvesting of cuttings and the low percentage rooting made selection of random sub-samples hazardous in terms of missing the result. Cuttings were therefore examined on 3 occasions with both control and etiolated cuttings subjected to the same degree of disturbance. As a result of this attempt to monitor rooting the water status of cuttings in 1984 may have been significantly altered. Drops of moisture were removed from leaf surfaces during the inspection of cuttings and water stress may have occurred (3), although the capacity of *Syringa* cuttings to take up water from the leaf surface is not known. The etiolated cuttings may have been more susceptible to water loss during handling due to a potential reduction in the thickness of cell walls and the cuticle following the etiolation treatment, as reported for cuttings of the apple rootstock, Malling 9 (7). It is well known that the successful rooting of cuttings is dependent on the maintenance of a high leaf water potential and a positive water balance in cuttings (8,9).

Shading of the mist benches in 1984 reduced the irradiance level at the height of the cuttings to 80 Wm^{-2}. However, quantum irradiance figures of 100 Wm^{-2} (3) and radiant energies of 1.5 MJ (10) have been shown to provide sufficient light for photosynthesis in the mist bench. Although these figures are not directly comparable to the 80 Wm^{-2} recorded, low irradiance is unlikely to have been a major factor in the low rooting percentage observed in 1984.

From the results of the controlled environment experiment it is evident that early rooting is linked to high temperatures. The 15°C and 25°C temperature regimes were selected as they represent the range of temperatures recorded under the different covers in the field.

The difference in rooting percentage between cuttings from clear covers (6.5%, Figure 2) and the light 25°C controlled environment (31.5%, Figure 3) is unlikely to be related to temperature. Irradiances of 244.7 Wm^{-2} (1040 $\mu Em^{-2}s^{-1}$) and 70.6 Wm^{-2} (300 $\mu Em^{-2}s^{-1}$) were recorded, respectively. A further difference, however, was in light quality with recorded spectra of 400-1100 nm under the clear covers and 405-700 nm in the controlled environment. The latter environment was artificially high in red light and this may have influenced rooting.

Shoots in both light and dark treatments within the controlled environment temperature regimes developed together. This has major advantages for the study of etiolation since it ensures that the early environment for the control and etiolated cuttings is identical. In view of this the rooting of cuttings associated with the 15°C dark-treated plants can be directly regarded as a treatment effect. Furthermore, the death of the apex and upper leaves of *Syringa* cuttings, which has led to the tradition on some nurseries of removing the shoot tip at the time of striking cuttings, is associated with exposure of the cuttings to high temperatures and water stress. Over the two years of the present study it was noted that a period of cool, cloudy days following striking of the cuttings may permit the apices to remain intact or "functioning" for a longer time.

Whether high temperatures hasten or cause the death of shoot apices has yet to be ascertained.

The equal rates of shoot development in the light and dark at 15°C and similarly at 25°C further establish temperature as an important factor in the etiolation process. A comparable observation has been made from controlled environment etiolation studies with *Cotinus coggygria* 'Royal Purple'.

The value of studying etiolation in both the field and in controlled environments is apparent and to take this control of variable factors a step further an *in vitro* culture system for etiolating shoots is being developed. Treatments will be applied to clonal shoots to avoid the variation among stock plants reported in this paper. The production of shoots in culture will also give access to a large population of shoots in a similar physiological state throughout the year. By studying etiolation at these three levels in parallel it is hoped that a greater understanding of the rooting process in woody plants will be obtained.

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EXPERIENCES WITH HERBICIDES ON CONTAINERS

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INTRODUCTION

It has been established for some time that labour is the highest cost when producing nursery stock. Therefore there is a need to ensure the highest proportion of those labour costs should go into production. Despatching and aftercare are the other high labour areas. Aftercare sometimes implies afterthought, or the time we have left between potting and despatching.

There is a neglected argument of forethought with herbicides, as this should be the first rule of growing. Good weed control, like early propagation, comes down to timing. The criteria is to apply a herbicide seal to the compost as soon after potting as possible and follow it up at regular intervals, not allowing an infestation to take place. With labour costs high you cannot afford to delay a routine spray, as problem weeds germinate all too quickly and hand weeding is labour intensive and costly.

To my surprise I have found few species of problem weeds, but these few are not to be underestimated. They include, especially in the propagation stage *Cardamine hirsuta*, which if controlled at this stage, would not lead to problems once the plants are on the container beds, and *Epilobium spp.* which has an extreme ability to produce vast numbers of seed and then remain as a perennial weed over the winter period. Also *Poa annua* which builds up mainly due to the overuse of one herbicide (Tenoran).

We shall, firstly, look at the chemicals which have given the most success in preventing germination of weed seeds: