Improved Rooting in Woody Species by Reducing Stock Plant Irradiance

Ole Billing Hansen
Department of Horticulture and Crop Sciences, Agricultural University of Norway, P.O. Box 5022, N-1432 Aas, Norway

In two experiments the benefits of reducing the irradiance to stock plants on the rooting of woody plant cuttings were demonstrated in the apple rootstocks *Malus* Ottawa 3 and Malling 26, *Rhododendron* 'Britannia' and 'Unknown Warrior', and in *Juniperus horizontalis* 'Andorra Compact'. In cuttings of *R.* 'Purple Splendour' and *Kalmia* 'Ostbo Red', and seedlings of *Kalmia* no positive effect of etiolation was found. The temperature during etiolation did not seem to have a significant effect on the rooting response.

INTRODUCTION

The effects on root formation of manipulating the irradiance during stock plant growth and development seem to vary between species (Moe and Andersen, 1989). If one considers the carbohydrate level of the cuttings as the decisive factor, it would seem correct to provide high irradiances, e.g. by using supplemental light in a greenhouse. However, especially in the case of trees and shrubs, it has been shown that high irradiances to stock plants can reduce the rooting percentage. In such cases it would be reasonable to reduce the stock plant irradiance. Maynard and Bassuk (1987, 1989) demonstrated that several species of herbaceous and woody plants respond positively to different kinds of etiolation and shading.

The irradiance can be reduced in several ways:

- Excluding light from developing shoots from bud break (etiolation);
- Etiolating the shoot, but letting part of it adjust to light before taking the cutting (localized etiolation);
- Letting the shoot develop in light, but subsequently exclude light from the part of the shoot that will become the base of the cutting (blanching);
- Reducing the irradiance to the whole stock plant (shading).

In experiments at the Horticultural Crops Research Laboratory in Corvallis, Oregon and at our department at the Agricultural University of Norway we have studied how some of these methods of reducing the irradiance affect the rootability of cuttings in some woody species.

EXPERIMENT 1

Stock plants of the apple rootstock *Malus* Malling 26 (syn. 'M26') and Ottawa 3; *Rhododendron* 'Britannia', 'Purple Splendour', and 'Unknown Warrior'; and *Kalmia* 'Ostbo Red' as well as *Kalmia* seedlings were etiolated from bud break at two temperatures (18 or 28C) (Hansen and Potter, 1997). After 2 to 4 weeks of etiolation the stock plants were moved to a greenhouse under ambient light conditions. The etiolated plants were divided into two equally sized groups. In one group the base of each shoot was wrapped with aluminum foil to exclude light and thus provide a localized etiolation. Shoots on the remaining plants were allowed to develop in light. Control plants were grown in a growth chamber at a constant photon flux density of 250 μmol m^{-2} s^{-1} at the two temperatures and subsequently moved to the greenhouse along with the etiolated plants. During a period of 6 to 10 weeks of light acclimation the plants developed new, normal leaves and pigmentation on previously etiolated stems. The aluminum wraps were then removed, and cuttings were obtained. The base of each cutting was dipped in 0.8% IBA talc, wounded by removing strips of bark on opposite sides of the cutting base (*Rhododendron* and *Kalmia*), inserted in flats containing a peat and perlite mixture (1 : 1, v/v) and placed under intermittent mist in a polythene tunnel in a greenhouse. Each cutting was scored for rooting twice; after 6 and 14 weeks for apple rootstocks and after 12 and 20 weeks for *Rhododendron* and *Kalmia*. The rooting percentage and the quality of rooting, assessed by number of roots in apple rootstock cuttings and rootball diameter in *Rhododendron* and *Kalmia* cuttings, were scored.

In apple rootstocks the localized etiolation (wrapped cuttings) produced a higher rooting percentage than the nonwrapped cuttings and the control (Table 1). The same was observed for *Rhododendron* 'Britannia'. In 'Unknown Warrior' both etiolation treatments were effective in producing a higher rooting percentage. In 'Purple Splendour' and *Kalmia* there was no difference between rooting of cuttings from the etiolated plants and from the control plants, irrespective of assessing rooting percentage or root quality (Table 2).

Temperature generally had only a minor influence on rooting (Table 1). Cuttings of Ottawa 3 rooted better when the stock plants were grown at 18 than at 28C. An interaction was observed between temperature and stock plant etiolation in *Kalmia*. Control cuttings rooted better when the stock plants had grown at 28C, while etiolated cuttings generally rooted better when stock plants had grown at 18C.

EXPERIMENT 2

Stock plants of *Juniperus horizontalis* 'Andorra Compact' were grown on a raised bed in a polythene covered greenhouse from 29 May to the first week of November (Thorvaldsdóttir, 1990). The irradiance in the greenhouse was set to be 100%, and shading was 70% or 50% of this level. The shaded stock plants were fertilized in four different ways providing 12 possibly different C/N (carbohydrate/nitrogen) ratios within the stock plants at the end of the growing season. Cuttings were obtained 3 and 10 November. The base of each cutting was dipped in 2% IBA talc, inserted in flats containing perlite, and placed in a fog chamber. During rooting supplemental light was given to provide equal irradiance for all the cuttings during rooting. Rooting was scored twice, 11 and 16 weeks after sticking.

A significantly improved rooting (both percentage and number of roots) was observed after shading the stock plants (Table 3). On average the number of roots increased from about 4 in non-shaded stock plants to almost 6 in cuttings from 50% shaded stock plants.

An interaction between irradiance and fertilization of the stock plants was observed. The reason for this interaction was thought to be differences in the C/N ratio. The C/N ratio was, as expected, higher at the highest irradiance (Table 4). However, rooting was better at the lower irradiance. This is not in agreement with the theory advocated by others that a high rooting percentage is positively correlated with a high C/N ratio.

Table 1. Rooting percentages of stem cuttings from plants forced to grow in darkness (etiolated, E) or in diurnal light (control, C) at two temperatures. Etiolated stems were either left nonwrapped (NW) or wrapped (W) with aluminum foil. F-test nonsignificant (NS) or significant (*) at P≤0.05.

		Control		Etiolated nonwrapped		Etoliated and wrapped		F-test		
		Temperature (C)						C vs. E NW	C vs. E W	Temp.
Species/cultivar	Total no. cuttings	18	28	18	28	18	28			
Malus										
Malling 26	331	56	63	56	54	83	82	NS	*	NS
Ottawa 3	192	91	71	86	58	100	94	NS	*	*
Rhododendron										
'Britannia'	275	75	77	78	79	90	91	NS	*	NS
'Purple Splendour'	441	91	94	88	85	92	94	NS	NS	NS
'Unknown Warrior'	288	76	84	91	89	92	91	*	*	NS
Kalmia										
'Ostbo Red'	255	53	71	67	38	69	61	NS	NS	NS
seedlings	203	19	38	51	27	55	33	NS	NS	NS

Table 2. Roots per cutting (*Malus*) and rootball diameter (*Rhododendron* and *Kalmia*) in stem cuttings from plants forced to grow in darkness (etiolated) or diurnal light (control). Data pooled from the two temperature treatments. Means separation within rows by multiple range test at $P \leq 0.05$.

Species/cultivar	No. of cuttings	Control	Etiolated nonwrapped	Etiolated wrapped
		No. of roots per cutting		
Malus				
Malling 26	109	4 b	4 b	11 a
Ottawa 3	106	7 b	10 b	13 a
		Rootball diameter (mm)		
Rhododendron				
'Britannia'	134	56 b	67 a	66 a
'Purple Splendour'	305	72 NS	72	75
'Unknown Warrior'	164	68 b	72 b	83 a
Kalmia				
'Ostbo Red'	41	34 NS	39	41
seedlings	33	43 NS	46	36

Table 3. Effect of irradiance to stock plants of *Juniperus horizontalis* 'Andorra Compact' on rooting of winter stem cuttings. Means separation within columns by multiple range test at $P \leq 0.05$.

Irradiance (%)	Rooting (%)	Roots per cutting
100	66 b	3.8 c
70	84 a	4.8 b
50	85 a	5.6 a

Table 4. The C/N ratio [(ratio between content of carbohydrates (g per 100 g dry matter) and content of nitrogen (g per 100 g dry matter)] in stock plants of *Juniperus horizontalis* 'Andorra Compact' after combinations of fertilizer programs and irradiances. Rooting (%) in brackets (After: Thorvaldsdóttir, 1990).

	Irradiance (%)		
	50	70	100
Osmocote®* 2.5 kg m^{-3}	2.60 (83)	2.41 (86)	3.30 (74)
Id. + supplement**	2.99 (83)	3.87 (83)	4.31 (71)
Humusan®*** 5.0 kg m^{-3}	1.92 (82)	2.77 (74)	3.27 (57)
Id. + supplement**	2.48 (92)	2.34 (89)	3.61 (61)

* = Osmocote® Plus 3-4 months (15N-5K-12P);
** = 600 ppm $Ca(NO_3)_2$ 3 times; 14, 17, and 18 weeks after planting;
*** = Humusan® dried poultry manure (4.1% N).

DISCUSSION

The cultivars in Experiment 1 were chosen to represent both easy-to-root taxa (Malling 26 and 'Purple Splendour') and difficult-to-root taxa (Ottawa 3, 'Britannia', 'Unknown Warrior', and *Kalmia*). However, there was no real relationship between the supposed ease of rooting and the actual rooting. Even some of the difficult-to-root cultivars rooted quite easily.

It is well documented that etiolation and blanching of stems can improve adventitious rooting. However, the response to such treatments differs among species and cultivars. For example, etiolation improved rooting in the *Rhododendron* cultivars 'Britannia' and 'Unknown Warrior', while it did not improve rooting in 'Purple Splendour' (which rooted excellently after all treatments).

The time period for light acclimating *Rhododendron* shoots is several weeks, because the shoots should be somewhat mature before taking them as cuttings. This means that the shoots will get an extended time in light. One would think that such a long light period would nullify the positive effect of etiolation on rooting. But even after a light acclimation period of 10 weeks the positive effect of etiolation on rooting remained. The effect of temperature during etiolation remains obscure. Patience and Alderson (1984) found better rooting after stock plant growth at 25 than at 15C in *Syringa vulgaris*, while our experiment only showed small differences between etiolation at 18 or 28C. In those instances where we found a significant effect, the lower temperature gave the best result.

Several theories have been put forward to explain the positive effect of light exclusion from (part of) the stock plants on rooting of cuttings (Maynard and Bassuk, 1989). These theories include changes in stem anatomy, sensitivity to auxin, and changes in the content of phenols. In addition, etiolation starting from bud break results in reduced thickness of the stem, which in turn may reduce the demand for carbohydrates and increase the survival as a cutting (Howard, personal comm.).

The proposed theories do not fully explain why a limited irradiance reduction (shading) can have positive effects on rooting in several woody species. A suggested explanation for such results has been a reduction in the break-down of auxin, and that the resulting higher auxin content then improves rooting. The C/N ratio does not seem to be helpful in indicating rootability of conifer cuttings.

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