the cutting at bench level as if the density had been decreased.

Most of the cultivars rooted better as unstripped cuttings, when all the conditions were the same. I mentioned earlier that all cultivars except T. 'Densiformis' were stuck unstripped. We kept trying different variables and finally found that decreasing the hormone level from that of our normal program for T. 'Densiformis' brought the rooting percentage back up to our previous level.

Sticking the cuttings has been a little slower but not enough to change our rates. It has been trickier to space the cuttings more evenly and it takes a lot more supervision to be sure the depth of sticking is consistent.

In summary, about 10% of this year's crop was harvested with a machine, due primarily to a shortage of cutting wood. We are sticking all cultivars as unstripped 4-in. cuttings. We are still working on perfecting the band saw and hedge trimmer method but this year it will remain R&D. The cuttings will be made individually, screening out the branched cuttings that will require stripping. Hormone treatment will be done by bundle instead of lug and the sticking will be paced to finish in 15 days.

STOCKPLANT ETIOLATION AND BANDING FOR SOFTWOOD CUTTING PROPAGATION: WORKING TOWARDS COMMERCIAL APPLICATION

NINA BASSUK, BRIAN MAYNARD, AND JOHN CREEDON

Dept. of Floriculture and Ornamental Horticulture
Cornell University, 20 Plant Science Bldg.
Ithaca, New York 14853

Abstract. The technique of stockplant etiolation has made it possible to root cuttings of plants which previously could only be propagated by budding or grown from seed. The cost of producing rooted cuttings from etiolated stockplants is approximately $0.05 to 0.10 more per cutting than traditional cutting procedures. The practice of field etiolation can produce a finished plant in the same time as field budding. Greenhouse etiolation substantially decreases the time required to produce a finished plant.

REVIEW OF BASIC TECHNIQUE

The technique of etiolating stockplants prior to cutting propagation has been shown to yield markedly improved rooting percentages for plants previously considered difficult-to-root (1). Etiolation means growing plants in the absence of light or in very heavy shade as the term is commonly used in cutting propagation. The basic method involves covering dormant stockplants with black shade cloth when the buds are beginning to swell. Typically, greater than 90% shade is used because it is not necessary to achieve

100% darkness. In fact, a totally enclosed shading structure is detrimental as it would allow too much heat to build up under the shade on sunny days. Some ventilation, such as opening the corners or making cuts in the fabric near the top, is necessary to reduce heat build-up.

After the new growth has reached approximately 2 to 3 in. (5 to 7 cm), a 1-in. (2.5-cm) square band of black velcro whose "wool" and "hooks" have been dipped in an 0.8% indole butyric acid (IBA) talc preparation (Hormodin No. 3) is pressed onto the base of the new growth (the future cutting base), so that the velcro band cannot slide up or down the stem. The new stem is in fact sandwiched between the wool and hooks of the velcro. At this time, the shade cloth is removed gradually over the period of one week so as not to burn the tender etiolated shoots. The band remains on the new shoot for 4 weeks while the top of the shoot is allowed to turn green. After 4 weeks, the shoot is cut right below the band, and the band is removed revealing a still etiolated cutting base which has swollen in response to the IBA treatment. The cutting is then stripped of lower leaves, if necessary, treated again with the same hormone preparation (Hormodin No. 3) and rooted under mist. All deciduous cuttings treated in this way rooted in 4 weeks; some as early as two. Pines, however, took 12 weeks to root. With *Betula* and *Carpinus* species, roots had already begun to form under the velcro bands while shoots were still attached to the stockplant.

Banding on its own without prior etiolation has also proved to be a very effective root promoting treatment. With this treatment, stockplants are allowed to produce 2 to 3 in. shoots and then velcro bands with hormone are applied to the bases of the new shoots in exactly the same manner as described for the etiolation and banding process. The area under the band loses chlorophyll after banding and so is said to be blanched. Those plants which responded more to etiolation or to banding alone are listed in Table 1.

RESULTS AND DISCUSSION

Etiolation trials with several new species proved successful this year. Shoots from *Chionanthus virginicus* seedlings rooted at 80% while shoots from mature *Pyrus calleryana* plants rooted at 87%, when banded alone. *Carpinus betulus* 'Fastigiata' cuttings from mature trees rooted at 100% when etiolated. *Fagus sylvatica* cvs. rooted between 25% and 84% when etiolated.

Further experimentation with the technique suggests that shoots can be banded at the base (as has been described) or in mid-stem with equal success (2). Using *Betula papyrifera*, stockplant age also interacted with the etiolation effect (Table 2).

Shoots from older stockplants were more difficult to root but responded positively to an etiolation pre-treatment, whereas shoots

Table 1. The best rooting percentages obtained from either etiolated or banded cuttings.

Species	Best rooting %	Treatment type
Acer griseum	50	E*
A. saccharum	86	E
A. platanoides	75	E
Betula papyrifera	100	E
Carpinus betulus	96	E
C. betulus 'Fastigiata'	100	E
Castanea mollissima	100	E
Chionanthus virginicus	80	B
Corylus americana 'Rush'	87	E
Fagus sylvatica	64	E
F. sylvatica 'Atropunicea'	25	B
F. sylvatica 'Laciniata'	84	E
F. sylvatica 'Fastigiata'	44	E
Pinus mugo	64	B
P. sylvestris	92	B
P. strobus	83	B
P. thunbergii	92	B
Pyrus calleryana	87	B
Quercus coccinea	46	E
Q. palustris	64	E
Q. robur	70	B
Q. rubra	50	B
Syringa vulgaris 'Belle de Nancy'	65	E
S. vulgaris 'Charles Joly'	63	E
S. vulgaris 'Charles X'	79	E
S. vulgaris 'Michel Buchner'	83	E
S. vulgaris 'Mme. Lemoine'	83	E
S. vulgaris 'Pres. Grevy'	48	E
Taxus × *media*	100	E

E = etiolation plus banding; B = light-grown, banded shoots.

Table 2. The effect of etiolation, banding, and age of stockplant on percent rooting of *Betula papyrifera* cuttings.[1]

Age of stockplant	Etiolated − band	Etiolated + band	Light grown − band	Light grown + band
1-year old seedlings	71%	100%	51%	65%
4-year old trees	63%	68%	10%	15%

[1]Thirty cuttings per treatment

obtained from seedling stockplants also showed a positive if less dramatic response to the pre-treatment.

COMMERCIAL APPLICATION

If this technique is to become commercially viable, it must be compared with current propagation practices. For shade tree production, budding is the method generally used. Trials are underway in cooperation with Schichtel's Nursery, Orchard Park, N.Y.

which seek to compare production schedules, costs, and plant quality of budded and etiolated plants in a commercial nursery.

Initial comparisons of production schedules shows that etiolation may be as fast or faster at producing the same sized plant as budding (Table 3).

Table 3. Comparing production schedules for field budding and greenhouse etiolation

Time of year	Budding	Field etiolation	Greenhouse etiolation
1987			
January			bring in dormant stockplants
February			etiolate stockplants
March			
April	plant out seedling understock	etiolate stockplants	take cuttings
May			cuttings rooted ↙ ↘
June		take cuttings	
July	bud understock	cuttings rooted ↙ ↘	grow on plant out
August			in
September		grow on in greenhouse plant out	greenhouse
November			finished plant
1988			
Spring	cut back understock	grow on for another season	
Fall	finished plant	finished plant	

Budded plants are produced by planting out the understock in the spring, budding in mid to late summer, cutting back the understock the next spring, and then growing on the new scion bud for one growing season before sale.

Field etiolated plants can be produced by etiolating stockplants right before bud burst in spring, uncovering and banding the new shoots a few weeks later, leaving the bands on for 4 weeks, taking cuttings by late June or July, and then rooting them in a mist bench for another month. After another season's growth they should be comparable to budded plants in size and quality. Greenhouse etiolation considerably lessens the time it takes to produce a plant of comparable size. Dormant stockplants can be potted up and forced in the greenhouse during January and February thereby producing rooted cuttings by May or June of that same year. The rooted cuttings can then be grown on in the same growing season to produce a finished plant by the end of that year. The cost of producing plants by these three methods is summarized in Table 4.

Table 4. Costs of producing budded liners compared with etiolated field or greenhouse grown cuttings

Budding		Field etiolation		Greenhouse etiolation	
1 year old seedling understock	$0.30	Stockplant maintenance	$0.05	Stockplant maintenance	$0.10
Budding	0.08	Standard cutting production	0.137	Standard cutting production	0.137
Materials	0.01	Etiolation labor	0.03	Etiolation labor	0.03
Maintenance	0.25	Etiolation materials	0.012	Etiolation materials	0.012
Land	0.01	Land and greenhouse fixed costs	0.05	Land and greenhouse fixed costs	0.05
Overhead	0.15	Overhead	0.15	Overhead	0.15
Total cost/plant	$0.80	Total cost/cutting	$0.43	Total cost/cutting	$0.48
Assume 15% loss	$0.92	Assume 15% loss	$0.49	15% loss	$0.55
		Assume 50% loss	$0.65	50% loss	$0.72

Costs of budding were compiled by George Schichtel of Schichtel's Nursery, Orchard Park, New York. To compare etiolation costs the following method was used.

Stockplant maintenance. An assumption of 20 cuttings/stockplant/year was made. Schichtel's Nursery maintenance cost ($0.25/plant) was divided by 20 which gave a cost of ($0.25/20) $0.013. Added on to this was the original cost of the stockplant spread over a 30-year life span assuming 20 cuttings/year. We can assume a $20 cost for the stockplant. Therefore, 30 years × 20 cuttings/year = 600 cuttings which yields a stockplant cost of $0.03/cutting ($20/600). Stockplant costs ($0.03) plus maintenance ($0.013) equals $0.043 per cutting, rounded up to $.05.

Standard cutting production. The Ohio State University publication, "Costs of Establishing and Operating Field Nurseries", (3) was used to develop a per cutting cost of $0.137 based on 11,869 viburnum cuttings produced. Cutting cost included rooting medium, collecting, stripping and sticking, maintenance, harvest, and hormone powder.

Additional etiolation costs. Additional etiolation costs were computed as follows. At $6.00/hr one person can band 240 shoots which equals $0.025/shoot ($6.00/240). With the addition of labor for shading the stockplants initially this figure can be rounded up to $0.03. Materials for etiolation (shade cloth, velcro, hormone powder) added another $0.012 per cutting.

Fixed costs. Fixed costs were calculated from the same bulletin (3) and overhead was supplied by Schichtel's Nursery.

The only difference in these figures with greenhouse etiolation procedures comes in the 10 to 12 weeks when stockplants are brought into the greenhouse for forcing in winter. Based on a \$1.00/ft^2/year greenhouse production cost, 12 weeks of heating a 2 ft^2 area for the stockplant would equal \$0.025/cutting [\$2.00 × .25 year = \$.50/20 cuttings). Additional media based on 6.50/yd^3 = \$0.005. Stockplant containers (5-gal containers/stockplant) for 5 years at \$0.01 per cutting, and labor for potting up at \$6.00/hr, potting up 30 plants/hour = \$0.01. Greenhouse costs (\$0.025) plus media (\$0.005) plus cost of container (\$0.01) plus labor (\$0.01) equals = \$0.05 additional cost per rooted cutting of bringing stockplants into the greenhouse in winter.

Initial plant quality appears very good; however, further work comparing rooted cuttings with field-budded liners will be undertaken next year.

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