# **Propagation**

Cecil Pounders
Section Editor and Moderator

## Control of Tomato Seedling Hypocotyl Elongation Using a Pre-plant Paclobutrazol Seed Soak

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Index Words: Tomato, Hypocotyl, Paclobutrazol, Seedling Height Control, Seed Soak

**Nature of the work:** The present study was conducted at Mississippi State University to investigate the use of placlobutrazol as a seed soak to reduced the hypocotyl height and total height of tomato [*Lycopersicon esculentum* (L.)] seedlings.

Success in automated transplanting is limited to the quality of the plugs. Excessive elongation of the hypocotyl is especially a problem with automated transplanting. Seedlings with long hypocotyls are more likely to suffer mechanical damage from which the seedlings cannot recover. Early control using chemicals is difficult to achieve since PGRs are not labeled for use before the first true leaves have expanded.

Pasian and Bennett (2001) soaked seeds of Tagetes patula 'Bonanza Gold' and Pelargonium spp. 'Cherry Orbit' in solutions of paclobutrazol (PB) at 0, 500, or 1000 mg•L-¹ a.i. They found that by increasing the concentration and soaking time, height was reduced. Hypocotyl height was not reported. There was a reduction of emergence in geraniums. Pill and Gunter (2001) found that priming seeds of *Tagetes* in a solution of 1000 mg•L-¹ a.i. PB was more effective than either a drench or a foliar application. They concluded that the residual effect on seedling growth was minor when seeds were primed versus the drench or the foliar spray. The effects of a pre-planting seed soak with paclobutrazol on seed germination and seedling growth was studied using tomato.

Seed Material: Batches of fifty seeds were counted from a lot of 10000 seeds of hybrid tomato [Lycopersicon esculentum (L)] Better Boy. Each seed batch was weighed before and after treatment. A factorial complete randomized design with two factors was used. Seed batches were soaked in a solution of 0, 250, 500, 750, or 1000 mg·L<sup>-1</sup> of paclobutrazol (PB) for 1 to 12 hours with 3 replications. For soaking, the seeds were placed in sealed assay tubes containing 5 ml of PB solution. The tubes containing the seed were placed on a shaker table for aeration while the treatment was applied. Treated seeds were removed from the tubes, surfaced dried on blotting paper, and the weight recorded. The electrical conductivity of the PB solution was measured before adding the seeds and after the seeds were removed. The seeds were dried at 30 °C for 3 days and weighed again.

Seedling Growth: Ten treated seeds from each of the treatments described were sown in 288 cell plug flats. The 288 cell plug flats were divided with tape to create 10 cell divisions. The treatments were randomly assigned to a division in the flats. The flats were placed in the greenhouse on capillary matt

for the first 15 days. After 15 days the flats were moved off the capillary matt and irrigated overhead. Germination counts were made at 7 and 14 days after sowing. At 35 days after sowing, three seedlings were destructively harvested for measurements. The seedlings harvested were measured for hypocotyl height, total height, and dry weight. Dry weight was measured as an average of the three seedlings measured. Data collected was analyzed using the Regression procedure of SAS (SAS institute, Cary , N.C.)

Results and Discussion: Seed Treatment: There were no treatment effects on seed dry weight or seed wet weight. As PB concentration increased the solution electrical conductivity (EC) increased. EC also increased the longer the seed soaked. Subtracting the initial EC value for each of the concentrations of PB from the final EC (EC after seed soaked) resulted in the change in EC ( $\Delta$ EC) due to seed electrolyte leakage as affected by PB concentration and time (Data not shown). The  $\Delta$ EC of the soaking solution did not change between 1 and 12 hours at 0 mg/L-1 of PB. As PB concentration increased, the value of  $\Delta$ EC decreased indicating, the electrolyte leakage from the seed decreased. The increase in  $\Delta$ EC over time was greater at higher PB concentrations than at lower PB concentrations. This was likely due to the amount of solutes present in the solution that increased as concentration increased.

Seedlings: Pasian and Bennet (2001), found that germination was reduced as PB concentration increased. However, in the current study, neither PB concentration nor soaking time affected germination of Better Boy tomato seed. Groot and Karssen (1987), found that the main action of gibberellins in germination of tomato seeds was the weakening of the endosperm allowing the radicle to protrude. In addition, the development of the embryo was not dependent on gibberellins. Since PB was applied to the seed, the inhibition of gibberellin biosynthesis would affect gibberellin production after germination and not before. Therefore, endogenous gibberellins in the embryo and endosperm should be sufficient to allow germination.

Paclobutrazol applied to tomato seeds as a pre-plant soak at between 0 and 250 mg•L-¹ of PB reduced the hypocotyl length of the seedlings (Fig.1). At 500 mg•L-¹ or greater there was no further reduction in hypocotyl height (Fig.2). At between 0 and 250 mg•L-¹ of PB effectively reduced the total seedling height. The additional reduction in height from PB at 500 mg•L-¹ or greater was not significant. This indicates that between 0 and 250 mg•L-¹ PB was most effective to control height in tomato seedlings using a pre-plant seed soak. There was no effect on hypocotyl length nor seedling height due to soaking time. Seedling dry weight decreased as PB concentration increased (Data not shown).

**Significance to the industry:** The application of this technique results in smaller amounts of PB that can be applied as a seed treatment by seed companies to ensure grower success. This result in a more effective control of hypocotyl elongation that will ensure high quality plugs.

- Britten, A. (2000). PGRs at Seedling Reduce Early Stretch, pp 44-46.
   In: Jayne VanderVelde (ed.). GrowerTalks on Plugs 3. Ball, Batavia, Illinois.
- 2. Groot SPC, Kieliszewska-Rokicka B, Vermeer E, Karssen CM (1988) Gibberellin-induce Hydrolysis of endosper cell walls in gibberellin-deficient tomamto seeds prior to redicle protrusion. Planta 174:500-504
- Passian C.C. and M.A. Bennett, 2001. Paclobutrazol Soaked Marigold, Geranium, and Tomato Seeds Produce Short Seedlings. HortScience 36(4):721-723.
- Pill W.G. and Gunter J.A. Jr. (2001) Emmergence and Shoot Growth of Cosmos and Marigold From Paclobutrazol-treated Seed. J. Environ. Hort. 19:11-14.

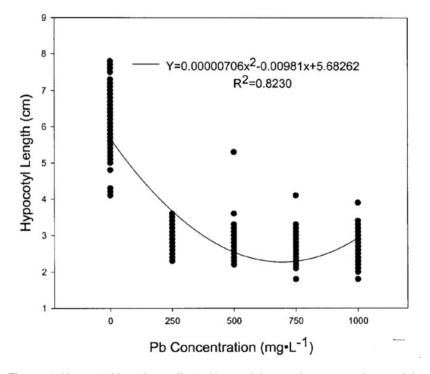
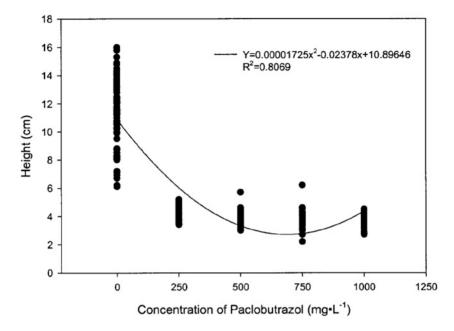


Figure 1. Hypocotyl length as affected by paclobutrazol concentration mg·L-1.



**Figure 2.** Seedling total height (cm) as affected by paclobutrazol concentration  $(mg \cdot L^{-1})$ .

### Improving Rooting of Ludisia discolor (K.G.)

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Index Words: Jewel Orchid. Ludisia discolor. Bottom Heat. Auxin

**Nature of Work:** A study was conducted to determine the effects of rooting substrate, auxin concentration, and bottom heat on propagation of *L. discolor* (Jewel Orchid) stem cuttings.

This experiment was performed using a split-split-plot arrangement in a completely randomized design. The first split was bottom heat using temperature treatments of 20, 25, and 30°C. The 20°C treatment was used as the control. The second split plot was rooting substrate using BM1 (Berger Peat Moss, St. Modeste, Quebec, Canada) and unmilled sphagnum moss. Flats were filled with substrate so that three 6-cell packs were filled with unmilled sphagnum moss and three 6-cell packs were filled with BM1 potting mix, for ease of watering. There were four IBA concentration treatments: 0% IBA, 0.1% IBA (Hormodin 1), 0.3% IBA (Hormodin 2), and 0.8% IBA (Hormodin 3) (Olympic Horticultural Products, Bradenton, FL).

Terminal cuttings averaging 6cm in length with an average of three leaves were taken from stock plants. Each cutting had no visible roots, and the cut was made below the node closest to the 6cm mark. Treated cuttings were placed in the mist house at 55% shading, 70% humidity, and an average air temperature of 21°C. Venting was set at 24°C, with a result of almost constant ventilation during the summer in Mississippi. Using destructive harvest, sampling was done weekly for twelve weeks, with three replications per treatment. Observations recorded included root number, root length, and node where the roots originated.

**Results and Discussion:** Although bottom heat temperatures of 35°C combined with wounding and IBA treatment significantly increased rooting percentages in Mango (Majumder and Prasad, 1988), no significant difference was found between the bottom heat treatments in this study. (Fig. 1.) These results are similar to those found for kiwi cuttings in a study by Testolin and Vitagliano (1987). They reported bottom heat by itself had no significant affect on root formation. However, they did find that bottom heat, when combined with auxin treatment, resulted in optimal rooting conditions for kiwi cuttings.

Auxin concentration, independent of type or form, resulted in an increase in rooting of *Arbutus andrachne* cuttings (Al-Salem and Karam, 2001). In fact, they reported that rooting increased up to 72% for basal cuttings. Ofori et al (1996) reported that addition of IBA increased root number in *Milicia excelsa* cuttings by 80%.

Shiembo et al (1996) theorized that propagation substrate may play a role in rooting of *Irvingia gabonensis* cuttings. Developing roots require the diffusion

of oxygen which is dependant on the porosity of the substrate (Shiembo et al, 1996). Their study found that of six different substrates tested, cuttings planted in sawdust resulted in a greater percentage of roots than any of the other five substrates.

An interaction was found between IBA concentration and rooting substrate in this study. All treatments using BM1 performed better than those using unmilled sphagnum moss (Fig. 2). Optimal results were obtained using BM1 with 0.1% IBA, which resulted in a mean of 22.17 roots. Acceptable rooting was observed from treatments of BM1 and either no IBA or 0.3% IBA. BM1 combined with0.8% IBA had a decreased root number. This could possibly be due to too great an auxin concentration inhibiting root growth. Ofori et al (1996) reported rooting percentages in *Milicia excelsa* cuttings decreased when treated with IBA at concentrations greater than 0.2%.

There was no difference in rooting between the sphagnum moss treatments, although all treatments had fewer roots than the cuttings rooted in BM1. The sphagnum moss stayed wetter than the BM1 under the mist conditions and has a much greater porosity than BM1.

This interaction in hormone and substrate is similar to that found by Al-Saqri and Alderson (1996) in a study of *Rosa centifolia*. They found that application of IBA increased rooting, but rooting substrate also played a role in the cutting root number. Cuttings treated with the same concentration of IBA had a higher mean root number when grown in peat:perlite versus those grown in vermiculite.

The optimal conditions derived from this study for propagation of *L. discolor* stem cuttings include use of BM1 substrate and 0.1% IBA (Hormodin 1). Placed under mist, rooted cuttings were produced in four weeks.

**Significance to Industry:** According to growers of *L. discolor*, there is a delay of up to twelve weeks between sticking cuttings and sufficient root growth. This delay is possibly due to slow root initiation, delayed root growth, or delayed shoot growth or branching. In this study, we were able to produce rooted cuttings in four weeks instead of twelve, using BM1 rooting substrate in combination with 0.1% auxin.

- Al-Salem, M.M. and N.S. Karam, 2001. Auxin, wounding, and propagation medium affect rooting response of stem cuttings of Arbutus andrachne. HortScience. 36:976-978.
- 2. Al-Saqri, F. and P.G. Alderson. 1996. Effects of IBA, cutting type, and rooting media on rooting of Rosa centifolia. J. Hort. Sci. 71:729-737.
- 3. Majumder, P.K., and J. Prasad. 1988. Rooting of hardwood cuttings of mango through bottom heat. Acta. Hort. 231:198-202.
- Ofori, D.A., A.C. Newton, R.R.B. Leaky, and J. Grace. 1996. Vegetative propagation of Milicia excelsa by leafy stem cuttings: effects of auxin concentration, leaf area, and rooting medium. For. Eco. Mgmt. 84:39-48.

- Shiembo, P.N., A.C. Newton, and R.R.B. Leakey. 1996. Vegetative propagation of Irvingia gabonensis, a west african fruit tree. For. Eco. Mgmt. 87:185-192.
- 6. Testolin, R. and C. Vitagliano. 1987. Influence of temperature and applied auxins during winter propagation of kiwifruit. HortScience 22:573-574.

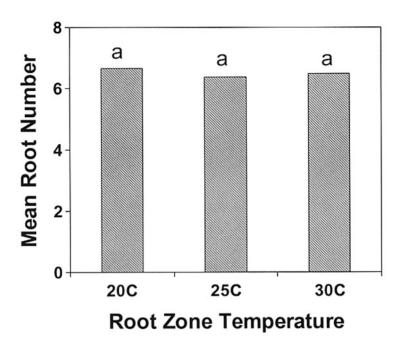
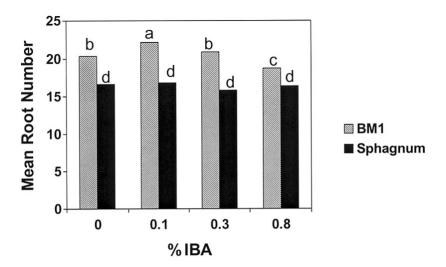


Fig. 1: The effect of bottom heat on rooting of Ludisia discolor.



**Fig. 2:** The effects of IBA concentration and rooting substrate on rooting of Ludisia discolor.

## Cutting Propagation of *Ilex vomitoria* 'Nana' Using a Foliar Application of Auxin

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**Index Words:** Dwarf Yaupon Holly, Rooting Hormones, Cutting Propagation, Spray Application

Nature of Work: Auxins as rooting hormones are typically applied to stem cuttings of woody ornamentals as a quick basal dip using liquid or talc formulations, and occasionally using other techniques such as an extended basal soak using liquid formulations (Hartmann et al., 2002). Under EPA Worker Protection Standards, employees who work with rooting hormones must receive specific safety training and wear personal protective equipment (protective gloves, eyewear, and appropriate clothing). Employees often note that the equipment is uncomfortable, and may also be concerned about their exposure to the chemicals. If an alternative means of auxin application were available that could reduce the number of nursery employees who must handle the auxins or reduce the amount of time that each employee must work with the chemicals, nursery safety could be enhanced. Spray applications of auxins after sticking cuttings may be an alternative for some crops.

A single spray application of auxin has been shown to be as effective as a basal dip for rooting cuttings of *Chrysanthemum pacificum*, but not for *Rosa* 'Red Cascade' (Blythe et al., 2002). Chadwick and Kiplinger (1938) noted that chrysanthemum cuttings rooted better with a 24-hour basal dip than with a foliar spray using very low concentrations of IBA, but provided no data. Van Bragt et al. (1976) determined that cuttings of various woody species rooted better when immersed in a solution of auxin for two minutes in comparison to a basal dip in an auxin powder.

The objective of this experiment was to determine whether no rooting hormone treatment or one or more foliar spray applications of the auxins indole-3-butyric acid (IBA) and 1-naphthaleneacetic acid (NAA) as a dilution of Dip 'N Grow® rooting hormone (Dip 'N Grow, Inc., Clackamas, OR) would be as effective as a quick basal dip application for rooting hardwood, terminal cuttings of *Ilex vomitoria* 'Nana'.

Terminal 2.5-inch cuttings of *Ilex* vomitoria 'Nana' were stuck into Fafard 3B mix (peat/perlite/vermiculite/pine bark) (Conrad Fafard, Inc., Agawam, MA) in bedding packs. Cuttings were placed inside a polyethylene-covered enclosure within a greenhouse with overhead mist applied once daily to maintain high humidity. Cuttings in the control treatment were basally dipped for one second in a solution of 2,500 ppm IBA + 1,250 ppm NAA prior to sticking. Cuttings in a second treatment received no auxin application. Cuttings in all other treatments were sprayed once daily with Dip 'N Grow diluted with water at either 1 ppm IBA + 0.5 ppm NAA or 10 ppm IBA + 5 ppm NAA, for one, three, five, or seven

consecutive days (beginning the day the cuttings were stuck) in a  $2 \times 4$  factorial arrangement. Kinetic surfactant (Helena Chemical Company, Memphis, TN) at 1.0 ml/L was included in all spray treatments. Overhead mist was not applied to the cuttings in the high-humidity enclosure until the eighth day. Three replicates per treatment were prepared on Feb. 23, 2002 and evaluated after 145 days. A completely randomized design was utilized in all experiments, with cuttings in each pack regarded as subsamples. All cuttings were evaluated for rooting percentage, root number, total root length, percent of cuttings with shoot growth, and shoot length at the end of the rooting period. Regression analysis was used to look for trends in response to the spray treatments at each level of auxin and Dunnett's Test was used to compare spray treatments with the basal dip control treatment

Results and Discussion: Cuttings receiving no auxin treatment and cuttings in all spray application treatments exhibited higher rooting percentages than cuttings treated with the basal dip. Cuttings receiving this same basal dip treatment in other rooting trials conducted during the same season (data not presented) rooted no higher than 63%. The low rooting percentage in the basal dip treatment may have been due to sensitivity of the cuttings to the alcohol in the rooting hormone solution, as has previously been reported by Berry (1994). Number of roots per rooted cutting was greater for cuttings sprayed once with 1 ppm IBA + 0.5 ppm NAA compared to the basal dip, and was similar for other treatments. Cuttings sprayed one or five times with 1 ppm IBA + 0.5 ppm NAA produced greater total root length compared to the basal dip, while results with other treatments were similar to the basal dip.

Percent of rooted cuttings with new shoots was lower for cuttings treated with 1 ppm IBA + 0.5 ppm NAA for all number of applications compared to the basal dip treatment. Spray treatments with three applications of 10 ppm IBA + 5 ppm NAA produced a lower percent of rooted cuttings with new shoots compared to the basal dip, while results were similar for other spray treatments at the same auxin concentration compared to the basal dip. Results suggest that spray applications of auxin at the lower rate may inhibit bud break, but inhibition appeared to be overcome (at least in part) on cuttings in treatments that produced larger root systems. Shoot length per rooted cutting was similar among all treatments compared to the basal dip treatment.

Overall, results suggest that one or five foliar spray applications of 10 ppm IBA + 5 ppm NAA improves the rooting of cuttings in comparison to the basal dip control. Acceptable results can also be obtained without the use of an auxin treatment.

**Significance to the Industry:** Experimental results indicate that hardwood cuttings of *llex vomitoria* 'Nana' may be rooted successfully with no rooting hormone treatment and with a dilute foliar spray application of auxin after sticking. While a spray application may not be more effective than a basal dip on all crops, it serves as an additional tool for the commercial propagator who wishes to reduce chemical use and maximize rooting response on specific crops, such as *llex vomitoria* 'Nana'.

- Berry, J. 1994. Propagation and production of *llex* species in the southeastern United States. Comb. Proc. Intl. Plant Prop. Soc. 44: 425-429.
- Blythe, E.K., J.L. Sibley, K.M. Tilt, and J.M. Ruter. 2002. Evaluation of an alternative method of auxin application in cutting propagation. Proc. South. Nurs. Assoc. Res. Conf. 47:348-351.
- 3. Chadwick, L.C. and D.C. Kiplinger. 1938. The effect of synthetic growth substances on the rooting and subsequent growth of ornamental plants. Proc. Amer. Soc. Hortic. Sci. 36:809-816.
- Hartmann, H.T., D.E. Kessler, F.T. Davies, Jr., and R.L. Geneve. 2002. Plant Propagation Principles and Practices. 7th edition. Prentice Hall, Upper Saddle River, NJ.
- 5. Van Bragt, J., H. Van Gelder, and R.L.M. Pierik. 1976. Rooting of shoot cuttings of ornamental shrubs after immersion in auxin-containing solutions. Scientia Hort. 4:91-94.

**Table 1.** Root and shoot development on cuttings of *llex vomitoria* 'Nana' in response to single and multiple applications of Dip 'N Grow (IBA + NAA) applied as a foliar spray (with Kinetic surfactant), a single basal dip, and no auxin treatment.

Number of applications	Rooting Percentage		<b>Root Length</b>		Mean Shoot Length per Cutting (mm) <sup>2</sup>		
Basal Dip with 2500 ppm IBA + 1250 ppm NAA							
1	20.0%	4.3	110	83.3%	6.7		
	No Auxin Treatment						
0	66.7% ‡ <sup>y</sup>	6.8	218	55.6%	6.5		
Foliar Spray with 1.0 ppm IBA + 0.5 ppm NAA							
1	80.0% ‡	5.6	135	7.4% *x	0.7		
3	96.7% ‡	5.4	171	31.5% *	4.0		
5	93.3% ‡	6.8	146	35.9% *	3.6		
7	90.0% ‡	5.1	160	40.7% *	5.7		
Significance w	NS	NS	NS	L	L		
Foliar Spray with 10.0 ppm IBA + 5.0 ppm NAA							
1	90.0% ‡	8.8 ‡	265 ‡	59.8%	9.7		
3	83.3% ‡	5.7	206	48.1% *	6.7		
5	93.3% ‡	7.1	289 ‡	78.9%	11.2		
7	90.0% ‡	6.3	174	55.7%	6.2		
Significance	NS	NS	NS	NS	NS		

<sup>&</sup>lt;sup>z</sup>Least squares means calculated using rooted cuttings only.

 $<sup>^{</sup>y}$ Means followed by '‡' within a column and auxin rate are significantly greater than the mean for the basal dip treatment according to Dunnett's Test (upper-tailed test); P = 0.05.

<sup>\*</sup>Means followed by '\*' within a column and auxin rate are significantly less than the mean for the basal dip treatment according to Dunnett's Test (lower-tailed test); *P* = 0.05.

wNonsignificant (NS), linear (L), or quadratic (Q) regression response by auxin formulation (P≤0.05). Untreated cuttings were included in the regression analyses.

## Propagation of Ulmus parvifolia 'Emerald Prairie' by Semi-hardwood Cuttings

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Index Words: lacebark elm, asexual propagation, IBA

Nature of Work: Lacebark elm (*Ulmus parvifolia* Jacq.) is grown widely across the United States and recently has become a popular landscape tree. The genetic diversity in seedling populations has lead to an increase in the number of cultivars released. Ornamental characteristics of lacebark elm include lustrous dark-green foliage and mottled orange and brown bark on some selections (1). Other attributes include adaptability to a diverse range of landscape environments and superior pest resistance; including Dutch elm disease [Ophiostoma ulmi (Buism.) Nannf. and O. novo-ulmi Brasier], black leaf spot [Stegophora ulmea (Schweinitz: Fries) Sydow & P. Sydow], Japanese beetle (Popillia japonica Newman) and elm leaf beetle (Xanthogaleruca luteola Mueller). Resistance to black leaf spot appears to vary by genotype, however, 'Emerald Prairie' lacebark elm appears to be completely resistant. While preliminary reports suggested this clone could be propagated asexually by stem cuttings (2, 3), some growers have resorted to grafting due to cutting propagation difficulties. This study was conducted to evaluate the influence of IBA (indole-3butvric acid) on adventitious root formation in semi-hardwood stem cuttings of 'Emerald Prairie' lacebark elm.

Approximately 200 cuttings were collected from the original clone on the grounds of the John C. Pair Horticultural Center on the morning of July 14, 2002. Terminal shoots were harvested from the middle to upper canopy of the tree, which is now 15 years old and 29 ft (8.8 m) in height. From the initial material, cuttings of current season's growth were trimmed to 3 to 4 in (7.5 to 10 cm) in length and the basal 0.4 in (1 cm) was dipped in one of five IBA solutions and allowed to air dry for 5 min. Treatments consisted of 0, 5000 (0.5%), 10000 (1.0%), 15000 (1.5%), or 20000 (2.0%) ppm IBA dissolved in 50% isopropanol. Cuttings were then inserted into flats containing a rooting substrate of 3 perlite: 1 peat moss (by vol.) and placed under intermittent mist in a greenhouse with ambient temperatures 75°F day / 70°F night (24°C day / 21°C night). Mist operated for 5 sec every 6 min during daylight hours. Cuttings were maintained under natural daylight and photoperiod. The experiment was a randomized complete block design with 6 blocks and 6 cuttings per treatment per block. Three weeks after the initiation of the experiment, a mechanical error resulted in mist failure for an entire weekend. Once repairs were made, another set of cuttings were taken on the morning of August 15 and treated identically to the previous experiment. Cuttings collected in August were from 10 different clonally propagated plants of 'Emerald Prairie' approximately 8 years of age and 12 ft (3.6 m) in height, also located on the grounds of the John C. Pair Horticultural Center. For comparison, both sets of

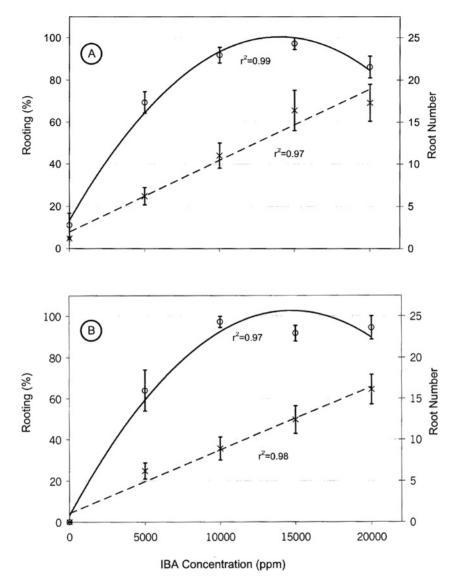
data are presented here. Cuttings were harvest after 6 weeks and data were recorded. Rooting percentage and the number of primary roots ≥ 1 mm (0.04 in) were recorded. Data were subjected to ANOVA and regression analysis.

Results and Discussion: Rooting percentages were high for both July and August cuttings (Fig 1), and were significantly influenced by increasing IBA concentration. Cuttings treated with IBA rooted well, whereas untreated cuttings taken in August did not root, and only 11% of untreated cuttings in July rooted. Maximum rooting was achieved between 10000 and 20000 ppm IBA and was generally greater than 90%, indicating a strong rooting response to IBA application. July cuttings treated with 15000 ppm IBA rooted 97%, whereas August cuttings rooted at 97% when treated with 10000 ppm IBA. In both cases the response to increasing IBA concentration was quadratic with a predicted maximum at 15000 ppm IBA. The results suggest that rooting was not compromised by the failure of the mist system, and that successful rooting of 'Emerald Prairie' lacebark elm can be realized over a fairly extended period of time in late summer. Additionally, rooting did not appear to be influenced by the age of the stock plants.

IBA concentration also significantly affected the number of roots produced per rooted cutting. In this instance, the response was linear with increasing IBA concentrations producing greater root numbers (Fig 1). Untreated cuttings taken in August produced no roots, and only one root per rooted cutting was produced on the untreated cuttings collected in July. However, when 10000 to 20000 ppm IBA was applied to the cuttings, approximately 10 to 17 roots per rooted cutting was observed.

Significance to Industry: This study suggests that semi-hardwood cuttings of the current season's growth can be rooted in high percentages using standard mist propagation procedures and 10000 to 20000 ppm (1.0 to 2.0%) IBA. While grafting may be successful, stem cuttings appear to root rapidly regardless of stock plant maturity, and over an extended period of the summer. Additionally, stem cuttings are less laborious than grafting procedures and the chances of graft union failure are eliminated. This highly disease resistant cultivar of lacebark elm can be cloned in large numbers using relatively simple cutting techniques.

- Dirr, M.A. 1998. Manual of Woody Landscape Plants: Their identification, ornamental characteristics, culture, propagation and uses. Stipes Pub. Champaign, III.
- Pair, J.C. 1993. Evaluation and propagation of lacebark elm selections. 1993 Woody Ornamental Evaluations, Report of Progress 693, Wichita Horticulture Research Center, Agricultural Experiment Station, Kansas State University.
- Pair, J.C. and M. Shelton. 1994. Evaluation and propagation of lacebark elm selections. 1994 Woody Ornamental Evaluations, Report of Progress 715, Wichita Horticulture Research Center, Agricultural Experiment Station, Kansas State University.



**Fig. 1.** Effect of increasing IBA concentration on adventitious root production (solid line) and the number of roots produced (broken line) on stem cuttings of *Ulmus parvifolia* 'Emerald Prairie' collected on (A) July 14, or (B) August 15. Error bars represent ±1 standard error of the mean.

## Evaluation of Auxin Application to Cuttings Via an Organic Substrate

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**Index Words:** Hedera helix, Rosa 'Red Cascade', Rooting Hormones, Cutting Propagation

Nature of Work: The use of auxins as rooting hormones in cutting propagation has traditionally focused on their application to stem cuttings as a basal dip using liquid or talc formulations or an extended basal soak using liquid formulations (Hartmann et al., 2002). Current Worker Protection Standards mandate that employees using these chemicals receive specific safety training and wear personal protective safety equipment (gloves, eyewear, and appropriate clothing). With a focus on improving employee safety, while simultaneously reducing production costs, nursery managers may look for alternative rooting hormone delivery methods that permit reduced exposure and use of lower chemical concentrations. Incorporation of auxins directly into the rooting substrate may be one means of accomplishing this goal.

Microcuttings produced in tissue culture are often rooted in a Stage III medium containing auxin (Kyte, 1987). Auxin may also be incorporated into the rooting substrate used for air layering (Wells, 1986). Various retail products used as a post-transplant soil drench contain low concentrations of auxin. However, scientific literature contains no mention of auxin application to conventional stem cuttings by way of the rooting substrate. The objective of this experiment was to determine whether an application the potassium salt of indole-3-butyric acid (KIBA) or a combination of KIBA and the potassium salt of 1-naphthaleneacetic acid (KNAA) would be as effective as a quick basal dip application (standard industry technique) for rooting single-node cuttings of *Hedera helix* and *Rosa* 'Red Cascade'.

Q Plug™ rooting plugs (International Horticultural Technologies, Hollister, CA), stabilized organic substrate units containing peat moss and a polymer binder, were used to provide uniform, easily handled rooting substrate elements.

1-inch x 0.625-inch oval plugs (4 cc vol.) were dried for 24 hours at 115F and then soaked by submergence for 24 hours in water; aqueous solutions of KIBA at 15, 30, 45, 60, and 75 ppm; and aqueous solutions of KIBA + KNAA at 15 + 7.5, 30 + 15, 45 + 22.5, and 60 + 30 ppm. Plugs were placed into alternate cells of a 384-cell polyethylene tray in a completely randomized design.

Single-node, 1.5-inch cuttings of *Hedera helix* and single-node, 0.75-inch cuttings of *Rosa* 'Red Cascade' were prepared from greenhouse-grown stock plants. Cuttings in treatment 1 received no auxin treatment, while cuttings in treatments 2 and 3 received a 1-second basal dip to a depth of 0.25-inch in 1000 ppm KIBA or 1000 ppm KIBA + 500 ppm KNAA, respectively; these cuttings were stuck to a depth of 0.25-inch into plugs that had been soaked in water. Cuttings

in the remaining treatments were stuck to the same depth into plugs that had been soaked with the nine auxin solutions. Cuttings of the two species were stuck in separate trays with 15 replicates of each species per treatment and placed under a greenhouse mist system providing overhead mist for 6 seconds every 16 minutes during daylight hours for a rooting period of 30 days. Rooting percentages were evaluated with logistic regression. Mean number of roots, total root length and shoot length (initial growth during the rooting period) were evaluated with regression analysis and compared with the basal dip control treatments using Dunnett's Test.

Results and Discussion: Cuttings of *Hedera helix* rooted at or near 100% in all treatments (Table 1). Cuttings in plugs treated in KIBA alone exhibited a linear increase in number of roots with increasing auxin concentration. Cuttings in plugs treated with 45, 60, and 75 ppm KIBA produced more roots than cuttings receiving a basal dip in 1000 ppm KIBA. Total root length also increased linearly with increasing KIBA concentration, and was greater with cuttings in plugs treated with 45 and 60 ppm KIBA compared to the basal dip. Shoot length on cuttings in plugs treated with KIBA alone was similar to cuttings receiving the basal dip. Number of roots and total root length on cuttings in plugs treated with KIBA + KNAA were similar to those in the basal dip treatment. Shoot length on cuttings in plugs treated with KIBA + KNAA was lower compared to the basal dip, and decreased linearly with increasing auxin concentration.

Cuttings of *Rosa* 'Red Cascade' in plugs treated with 0 to 60 ppm KIBA rooted similarly to cuttings in the KIBA basal dip treatment; the highest concentration (75 ppm KIBA) produced a lower rooting percentage than the control (Table 2). Cuttings in plugs treated with KIBA exhibited a linearly decreasing and quadratic response in number of roots and total root length with increasing auxin concentration, while shoot length exhibited a linear decrease. Number of roots, total root length, and shoot length on cuttings in plugs treated with up to 45 ppm KIBA was similar to the KIBA basal dip treatment, and lower on cuttings in plugs treated with 60 and 75 ppm KIBA. All root and shoot development measures on cuttings in plugs treated with KIBA + KNAA decreased linearly with increasing auxin concentration. Rooting percentage and number of roots was lower on cuttings in plugs treated with the two highest concentrations of KIBA + KNAA, while total root length was lower with the three highest concentrations, compared with the basal dip in 1000 ppm KIBA + 500 ppm KNAA. Shoot length on cuttings in plugs treated with KIBA + KNAA was similar to cuttings receiving the basal dip.

Overall, KIBA alone was preferable to KIBA + KNAA for cuttings of these two species. In several cases, equal or better root and shoot development was obtained on cuttings in auxin-treated plugs compared to the basal dip treatments, and occurred using auxin concentrations substantially below those employed with the basal dip treatments.

**Significance to the Industry:** Experimental results indicate that cuttings of *Hedera helix* and *Rosa* 'Red Cascade' may be rooted successfully in a stabilized organic substrate that has been pretreated with auxin. With the selection of an optimal auxin formulation and concentration, root development can equal, and sometimes exceed, that of cuttings receiving a conventional basal dip, without

an adverse effect on subsequent shoot development. This technique can help to enhance employee safety and nursery productivity, and is compatible with mechanized production systems.

- Hartmann, H.T., D.E. Kester, F.T. Davies, Jr., and R.L. Geneve. 2002. Plant Propagation Principles and Practices. 7th edition. Prentice Hall, Upper Saddle River. NJ.
- 2. Kyte, L. 1987. Plants from Test Tubes. Timber Press, Portland, OR.
- 3. Wells, R. 1986. Air layering: an alternative method for the propagation of *Mahonia aguifolium* 'Compacta'. Comb. Proc. Intl. Plant Prop. Soc. 36:97-99.

**Table 1.** Rooting and initial shoot growth response of *Hedera helix* cuttings to KIBA or KIBA + KNAA applied via a treated plug or a basal dip.

Auxin Treatment (ppm)	Rooting Percentage	Mean Number	Mean Total Root Length	Mean Shoot Length
	r crocmage	of Roots <sup>z</sup>	(mm) <sup>z</sup>	(mm) <sup>z</sup>
Untreated	100.0%	10.5	260	9.3
15 KIBA Treated Plug	100.0%	11.5	236	8.7
30 KIBA Treated Plug	100.0%	11.9	262	7.1
45 KIBA Treated Plug	100.0%	13.4 ‡ <sup>y</sup>	301 ‡	8.5
60 KIBA Treated Plug	100.0%	14.0 ‡	314 ‡	8.3
75 KIBA Treated Plug	100.0%	13.4 ‡	260	6.3
Responsex	NS	L	L	NS
1000 KIBA Basal Dip	100.0%	9.9	227	10.0
15 KIBA + 7.5 NAA Treated Plug	100.0%	11.6	261	6.3 *w
30 KIBA + 15 NAA Treated Plug	93.3%	9.4	183	4.6 *
45 KIBA + 22.5 NAA Treated Plug	100.0%	9.6	195	1.6 *
60 KIBA + 30 NAA Treated Plug	100.0%	11.7	210	0.7 *
Response	NS	NS	NS	L
1000 KIBA + 500 NAA Basal Dip	100.0%	9.7	246	11.1

<sup>&</sup>lt;sup>2</sup>Least squares means calculated using rooted cuttings only.

 $<sup>^{</sup>y}$ Means followed by  $\ddagger$  within a column and auxin formulation are significantly lower than the mean for their corresponding basal dip treatment according to Dunnett's Test ( $\alpha$ =0.05).

<sup>&</sup>lt;sup>x</sup>Nonsignificant (NS), linear (L), or quadratic (Q) regression response by auxin formulation (*P*≤0.05). Untreated cuttings were included in the regression analyses.

<sup>\*</sup>Means followed by \* within a column and auxin formulation are significantly lower than the mean for their corresponding basal dip treatment according to Dunnett's Test ( $\alpha$ =0.05).

**Table 2.** Rooting and initial shoot growth response of *Rosa* 'Red Cascade' cuttings to KIBA or KIBA + KNAA applied via a treated plug or a basal dip.

Auxin Treatment (ppm)	Rooting	Mean	Mean Total	Mean Shoot
	Percentage	Number	Root Length	Length
		of Roots <sup>z</sup>	(mm) <sup>z</sup>	(mm) <sup>z</sup>
Untreated	100.0%	4.6	174	4.7
15 KIBA Treated Plug	100.0%	5.3	202	4.8
30 KIBA Treated Plug	86.7%	6.6	204	4.0
45 KIBA Treated Plug	93.3%	6.6	173	3.8
60 KIBA Treated Plug	100.0%	3.6 *	86 *	2.3 *
75 KIBA Treated Plug	60.0%* <sup>y</sup>	2.1 *	33 *	1.9 *
Responsex	NS	L,Q	L,Q	L
1000 KIBA Basal Dip	100.0%	5.5	209	4.1
15 KIBA + 7.5 NAA Treated Plug	100.0%	4.7	155	3.6
30 KIBA + 15 NAA Treated Plug	93.3%	3.4	72 *	2.8
45 KIBA + 22.5 NAA Treated Plug	80.0% *	2.8 *	59 *	2.8
60 KIBA + 30 NAA Treated Plug	66.7% *	2.5 *	52 *	2.3
Response	L	Ĺ	L	L
1000 KIBA + 500 NAA Basal Dip	100.0%	4.9	182	3.4

<sup>&</sup>lt;sup>z</sup>Least squares means calculated using rooted cuttings only.

yMeans followed by \* within a column and auxin formulation are significantly lower than the mean for their corresponding basal dip treatment according to single degree of freedom orthogonal contrasts for rooting percentage and Dunnett's Test for all other measures (α=0.05).

<sup>\*</sup>Nonsignificant (NS), linear (L), or quadratic (Q) regression response by auxin formulation (P≤0.05). Untreated cuttings were included in the regression analyses.

## Effect of Mist and Cutting Water Potential on Rooting Stem Cuttings of Loblolly Pine

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Index Words: Vegetative Propagation, Water Deficit, Clonal Forestry

Nature of Work: Vegetative propagation of loblolly pine (*Pinus taeda* L.) by stem cuttings can be used to multiply superior full-sib families and elite clones within superior families for reforestation (2). Producing high quality rooted cuttings on a large scale, however, creates the challenge of maintaining a suitable rooting environment. Because rooting environments can vary from polyethylene-covered greenhouses, to semi-shaded structures, and to direct field setting of stem cuttings, specific propagation protocols may not be applicable to all rooting environments (1). Thus, a more comprehensive understanding of water relations of stem cuttings during the rooting period may guide the design and implementation of suitable propagation conditions for different types of rooting environments.

In many propagation systems involving rooting of stem cuttings, intermittent mist application minimizes water deficit by lowering leaf temperatures and transpiration while increasing the humidity surrounding the cuttings (8). Thus, the water potential of stem cuttings  $(\psi_{\text{cut}})$  is a physiological indicator of plant water deficit (5) and has been suggested to be related linearly to rooting percentage (4). The implication is that the less water deficit cuttings experience during the period of adventitious root formation, the greater the likelihood of root initiation and development. On the other hand, it has been shown that supra-optimal mist application decreases rooting (3). However, the degree of water deficit that a stem cutting can withstand during the rooting period and still produce adventitious roots has not been defined for any species.

It was determined previously that medium moisture affected percent rooting of stem cuttings of loblolly pine of the same genetic origin when mist was applied sub-optimally or excessively (6). Otherwise, proper mist application was the overriding factor determining successful rooting when medium moisture was adequate (6). Therefore, the objective of the present study was to test the effect of various levels of mist application on  $\psi_{\text{cut}}$  and percent rooting of stem cuttings of loblolly pine utilizing one constant medium moisture level for all mist levels. Additionally,  $\psi_{\text{cut}}$  was used as an independent variable to determine the relationship with rooting percentage.

In February 2002, hardwood, terminal stem cuttings were collected from serially propagated, hedged, stock-plants of two full-sib families of loblolly pine each consisting of approximately 60 clones. The cuttings were bulked together randomly and stored at 37F (4C) until setting in April 2002. Prior to inserting cuttings in 91.4 (L) x 61 (W) x 20.3 cm (H) (36 x 24 x 8 in) black plastic super tubs (Rosti OS, Inc., Irving, Texas), cuttings were first recut from the bases to a length of 9 cm (3.5 in) and then the basal 1 cm (0.4 in) (needles were not

removed) was dipped for 3 s in a solution of 10 mM 1-napthaleneacetic acid (NAA). Following auxin treatment, cuttings were inserted to a 1 cm (0.4 in) depth into fine blasting sand (BX-30, Foster Dixiana, Corp., Columbia, S.C.). Cuttings were maintained in a clear polyethylene-covered greenhouse under natural photoperiod and irradiance. Mist was applied intermittently by a traveling gantry (boom) system (McConkey Co., Mt. Puyallup, Wash.) at a variable frequency related inversely to the relative humidity within the greenhouse. Misting frequency (boom pass) was similar for all cuttings, however, alterations to boom traveling speeds created the difference among mist application treatments.

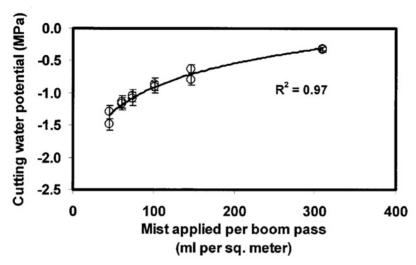
A randomized complete block design was utilized comprising two replications of six mist treatments. The mist treatments were 45 (1.3), 61 (1.7), 75 (2.1), 102 (2.9), 147 (4.2), or 310 (8.8) ml/m² (oz/yd²) of mist application per boom pass.  $\psi_{\text{med}}$  was set at -2.2 kPa for all mist treatments and maintained as described previously (6). Approximately 100 stem cuttings were placed in each plot. A pressure chamber was used to measure  $\psi_{\text{cut}}$  destructively every 3 hr between 0500 and 2300 HR (seven measurements) on two cuttings per plot 7, 14, 21, or 28 days after setting (DAS). Plot means for  $\psi_{\text{cut}}$  were the mean of seven measurement times each day averaged over the 28-day measurement period. Percentage of cuttings that remained and produced at least one root  $\geq$  1 mm was recorded 70 DAS. Regression analysis was used to determine the effect of mist level on  $\psi_{\text{cut}}$  and rooting percentage. Regression analysis also determined the relationship between  $\psi_{\text{cut}}$  and rooting percentage.

**Results and Discussion:**  $\psi_{\text{med}}$  remained constant among all mist levels, so mist application accounted for all variation in  $\psi_{\text{cut}}$  (Fig. 1). The steepest increase in  $\psi_{\text{cut}}$  was between 45 (1.3) and 102 (2.9) ml/m² (oz/yd²) per boom pass, whereas above 147 (4.2) ml/m² (oz/yd²), the increase was more gradual. Because cuttings were approaching full turgidity with further mist application,  $\psi_{\text{cut}}$  increased more slowly. This suggests that absorption through the foliage decreased for cuttings experiencing little water deficit.

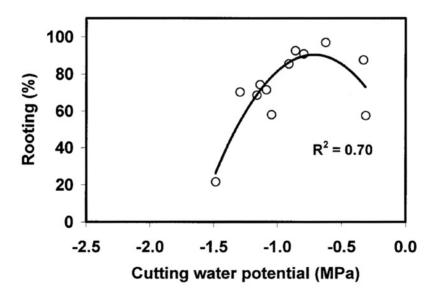
Mean rooting percentage for all treatments was 73%. Rooting percentage was moderately related to the linear and quadratic terms of mist level (data not presented, P=0.06, R<sup>2</sup>=0.54). Rooting increased to 94% at a mist level of 147 (4.2) ml/m<sup>2</sup> (oz/yd<sup>2</sup>) then decreased. Rooting percentage was more closely related to  $\psi_{cut}$  and the square of  $\psi_{cut}$  (P=0.01, R<sup>2</sup>=0.70) (Fig. 2). Not surprisingly, cuttings experiencing the greatest water deficit rooted poorly. This is consistent with rooting in many species (7). What is surprising is that cuttings experiencing little or no water deficit also rooted poorly (6). Excessive mist decreased rooting in stem cuttings of loblolly pine, but this decline was attributed to basal stem necrosis in an overly wet rooting medium (3). In the present study, however, all cuttings were subjected to the same consistent medium moisture and no basal stem necrosis was noted on cuttings in any mist treatments. Therefore, decreased rooting was due to cuttings experiencing little water deficit and not the detrimental effects of an anaerobic medium. The greatest rooting occurred for cuttings experiencing moderate water deficit with mean  $\psi_{cut}$  between - 0.5 and - 1.0 MPa during the rooting period.

Significance to Industry: Results indicated that mist application contributed to the water status of unrooted stem cuttings of loblolly pine by absorption through the above-ground foliage. Absorption declined, however, as cuttings experienced less water deficit. Hardwood stem cuttings of loblolly pine rooted at high percentages while experiencing a moderate amount of water deficit prior to initiating adventitious roots. Thus, propagators should not endeavor to eliminate all water deficit experienced by cuttings during the rooting period. Suitable rooting environments and propagation protocols for rooting hardwood stem cuttings of loblolly pine should maintain a mean moderate water deficit in unrooted cuttings. Additional research utilizing these results in various rooting environments would validate the findings.

- Gocke, M.H. 2001. Effects of three propagation systems on survival, growth and morphology of loblolly pine and sweetgum rooted cuttings. Proc. 26th Biennial Southern For. Tree Improvement. Conf., Athens, Ga., June 26-29, 2001. p. 15.
- 2. Goldfarb, B., R. Weir, B. Li, S.E. Surles, R. Murthy, B. Rowe, and J. Frampton. 1997. Progress toward operational deployment of loblolly and slash pine rooted cuttings. Proc. 24th Biennial Southern For. Tree Improvement Conf., Orlando, Fla., June 9-13, 1997. p. 361-362.
- 3. Greenwood, M.S., T.M. Marino, R.D. Meier, and K.W. Shahan. 1980. The role of mist and chemical treatments in rooting loblolly and shortleaf pine cuttings. For. Sci. 26:651-655.
- 4. Hartmann, H.T., D.E. Kester, F.T. Davies, Jr., and R.L. Geneve. 2002. Hartmann and Kester's Plant Propagation: Principles and Practices. 7th ed. Prentice Hall, Upper Saddle River, N.J.
- 5. Kramer, P.J. and T.T. Kozlowski. 1979. Physiology of woody plants. Academic Press, San Diego, Calif.
- LeBude, A.V., F.A. Blazich, and B. Goldfarb. 2002. Effect of soil water potential and mist on rooting stem cuttings of loblolly pine (Pinus taeda L.). Proc. SNA Res. Conf., 47th Annu. Rpt. p. 300-305.
- 7. Loach, K. 1988. Water relations and adventitious rooting, p. 102-116. In: T.D. Davis, B.E. Haissig, and N. Sankhla (eds.). Adventitious root formation in cuttings. Dioscorides Press, Portland, Ore.
- 8. Tukey, H.B., Jr. 1978. The effects of intermittent mist on cuttings. Acta Hort. 79:49-56



**Fig. 1.** Effect of six mist levels on cutting water potential  $(\psi_{cut})$  of hardwood stem cuttings of loblolly pine. Data points are plot means for  $\psi_{cut}$  recorded seven times, 7, 14, 21, or 28 days after setting. Vertical bars represent  $\pm$  1 standard error of the mean for the four measurement dates.



**Fig. 2.** Relationship between rooting percentage and  $\psi_{cut}$ . For explanation of data points, see the caption for Fig. 1.

### Hardwood Cutting Propagation of Hydrangea macrophylla

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**Index Words:** Hydrangea macrophylla, hardwood cuttings, propagation

**Nature of Work:** A study was conducted in the greenhouse at the UK Horticulture Farm, Lexington to determine how late into the season cuttings from *Hydrangea macrophylla* could be rooted in a successful manner. Stock plants were field grown under drip irrigation at the site on a Maury Silt Loam.

Cuttings 4 in. to 6 in. (10 –15 cm) in length were collected and stuck on October 20th, November 27th and on December 16, 2002. Cuttings taken in October were terminal cuttings while cuttings obtained in November and December were both terminal cuttings and stem tissue which was immediately distil to the terminal cutting(secondary). All cuttings were quick dip treated with Wood's Rooting Compound - 1 part to 10 parts water. Cuttings were stuck into Premium Pine Bark Nursery Media from Barky Beaver, Inc. The media was placed into a Quick Pot QP 35 T tray with cell shape 1.968 in. X 1.968 in. X 4.527 in. (50 X 50 X 115 mm). Mist was applied for 5 seconds every 6 minutes during daylight hours.

**Results and Discussion:** The lowest temperature before the October 20 collection date was 37° F and occurred on Oct. 14th. The lowest temperature before the Nov. 27 collection was 26° F and occurred on Nov. 18th. The lowest temperature before the Dec. 16 collection date was 15° F and occurred on Dec. 6th. Foliage on cuttings was green on both the Oct. 20 and Nov. 27 collection dates. The stems had defoliated by the Dec. 16 collection date.

Cuttings were evaluated for a final time on March 27, 2003 (Table 1). All cutting from the October 20th collection date rooted regardless of cultivar. The later into the season the cuttings were propagated, the lower the rooting response. Only 36% of the terminal cuttings stuck on November 27th rooted and none of the nodal cutting (secondary) distil to the terminal cutting rooted Three cultivars(Nikko Blue, Dooly, All Summer Beauty) cumulatively had 13% rooting for the December 16th collection date. Three cultivars (Emily, Merritt's Supreme, Madame Faustin Travouillon)propagated on Dec. 16th did not root at all from terminal cuttings. Only two secondary cuttings, out of 105, taken on December 6th rooted . The presumption is that freezing temperatures caused stem damage that prevented the cuttings from rooting during the November and December collection dates.

**Significance to Industry:** *Hydrangea macrophylla* can be propagated during the fall by hardwood cuttings. Yields of 100% should be obtainable as long as the temperature has remained above freezing. As temperatures become more severe, the rooting percent will decrease and finally reach 0%. Cultivar variability exists as to which selections can survive cold temperature injury the furthest into the season.

**Table 1.** Rooting rsponse of Hyrdrangea cultivars to timing and cutting location during fall 2002 propagation.

Cultivar	October 20 Terminal	November 27 Terminal	November 27 Secondary	December 16 Terminal	December 16 Secondary
Glowing Embers	35 rooted/ 35	19 rooted/ 35			,
Masja	25 rooted/ 25				
Dooley	35 rooted/ 35			2 rooted/35	
Nikko Blue		10 rooted/ 35		3 rooted/35	0 rooted/35
All Summer Beauty		12 rooted/ 35		9 rooted/35	1 rooted/35
Domotoi		10 rooted/ 35			
Emily				0 rooted/35	
Merritt's Supreme				0 rooted/ 35	1 rooted/35
Madame Faustin Travouillon				0 rooted/35	