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THE PROPAGATION AND OVERWINTER SURVIVAL OF
*Viburnum carlesii* (KOREAN SPICE VIBURNUM)
SOFTWOOD CUTTINGS

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Timothy Duncan Wood

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# THE PROPAGATION AND OVERWINTER SURVIVAL OF *Viburnum carlesii* (KOREAN SPICE VIBURNUM) SOFTWOOD CUTTINGS

By

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Submitted to
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## ABSTRACT

### THE PROPAGATION AND OVERWINTER SURVIVAL OF *Viburnum carlesii* (KOREAN SPICE VIBURNUM) SOFTWOOD CUTTINGS

By

Timothy D. Wood

Experiments were conducted to investigate the overwinter survival of *Viburnum carlesii* propagated from softwood material. The growth and development of stock plants and cuttings were characterized. Lateral bud elongation was influenced by node location. Auxin did not improve percent rooting but improved rooting quality. Sixteen hours of high intensity lighting induced the greatest percentage of budbreak (97% at day 55), but did not improve overwinter survival. Eight hours of supplemental light plus a night break increased the number of cuttings that broke bud (68% at day 55) and increased the overwinter survival of subterminal cuttings. Eight hours supplemental HID light did not increase budbreak but improved the overwinter survival of subterminal cuttings. Survival ranged between 82% and 100% for subterminal cuttings under 8 hours of supplemental light if they had broken bud prior to overwintering.

To Tracy Lynn Wood

Whose patience, support and love gave me the strength to quit my job, move, go back to school and spend many long, sleepless nights away from her and our beautiful daughter Jenny.

## ACKNOWLEDGMENT

I would like to thank Dr. Arthur C. Cameron, my major professor, for his guidance, support, insight and friendship. I would also like to thank Dr. Robert Schutzki and Dr. Gerard Donnelly for help and guidance with my research and program.

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Special thanks to Ralph Shugert and Zelenka Nursery for providing encouragement and plant material. I would like to thank all of the people who assisted me over the last two years with both physical and moral support. Last, but not least, Thank you Lord. I could not have done it without you.

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# CHAPTER I

# CHARACTERIZATION AND ANALYSIS OF STEM AND BUD GROWTH IN *Viburnum carlesii*

*Abstract*. The formation and growth of *Viburnum carlesii* internodes and buds were analyzed on stock plant stems and cuttings defoliated and intact. Cuttings showed no visible signs of bud or internode growth. Defoliated cuttings died within two weeks. Stock plant buds and internodes showed continued growth and elongation. Stripping leaves off stock plant stems reduced average stem growth but had no influence on the number of nodes produced when compared to unstripped stems. The stripping of stock plant stems increased lateral budbreak compared to unstripped stems. Unstripped plants had relatively fewer laterals break bud. The lateral buds on the second and third nodes had the greatest tendency for lateral budbreak in both stripped and unstripped stems. Buds at the first node did not break unless the leaves were stripped. Extreme variations were found in node formation and internode expansion between two successive years. The relationship between growth patterns and the variability in rooting and overwinter survival is discussed.

*Introduction.* In Michigan, softwood cuttings of *Viburnum carlesii* Hemsl. are commonly collected between the first of June and the end of July, after the first flush of growth has hardened. One grower (Schaefer, 1985) recommends taking cuttings when the stems snap easily when bent. Dirr and Heuser, (1987) claimed that the timing of cutting propagation will probably continue to be based on trial and error because scientific methods are unable to analyze plant material to determine the time of its physiological disposition for rooting.

The stage of plant growth might offer a better indicator for the proper timing of cutting propagation. Aspects of plant growth and development are dictated by environmental conditions which trigger internal physiological and biochemical processes. Therefore the stages of plant growth and development may represent external signs that indicate internal physiological conditions. The of pattern of plant growth and development has the potential of providing an effective indicator for the proper timing of propagation.

The time of collection may also influence the success of overwintering *Viburnum carlesii* cuttings. Smalley and Dirr (1887) found that *Acer rubrum* 'October Glory' rooted cuttings survived at higher rates (93%) if taken in mid-August compared to cuttings taken in mid-June (81%). The maturity of the lateral buds may be a factor in their ability to break in spring.

The purpose of this experiment was to examine and characterize the growth and development of *Viburnum carlesii* and

to determine its relation to propagation and overwintering success.

*Botanical description. Viburnum carlesii*, a Korean member of the Caprifoliaceae family, is a medium sized (1-2 meters) deciduous shrub. Its leaves are simple, ovate-elliptical, rounded at the base and are 4 to 8 cm long and 3 to 5 cm wide. The leaves are a dull green above and pale below in the summer and turn a burgundy-red in the fall. The leaf is irregularly toothed and has stellate pubescence on each side. Its phyllotaxy is characterized as opposite and decussate with each succeeding set of leaves (or buds) being at right angles when compared head on to an adjacent leaf pair (Donahue, 1981). The buds are naked, having no scales for winter protection. Its stems are light green with stellate pubescence when young. As the stem ages it turns a light grey-brown, looses its pubescence and develops numerous small longitudinal fissures (Dirr, 1983). The inflorescence is a terminal, stalked, semi-globose cyme (5-8 cm across) and its many salverform flowers are fertile, fragrant and are a whitish-pink color (Bailey, 1949). The flower buds are formed in summer, overwinter as well- developed, compact, naked buds, and bloom in late April or May (Donahue, 1980).

Shoot growth from year to year can either be monopodial or sympodial (Donahue, 1980). If a flower bud is formed, no terminal vegetative bud will be formed and the main axis will be replaced by a either a lateral bud or branch (sympodial

growth). Shoot growth can continue to be monopodial, with one continuous main axis for several years until a terminal flower bud is formed.

*Materials and Methods.* On June 1, 1989 in East Lansing, Michigan, 20 stems were tagged randomly on three field plants. The Plants were approximately 10 years old. During the growing season the plants were watered as necessary and the soil was cultivated. Ten of the stems were continually stripped of their leaves. On the same day 40 two node (approximately 10-12 cm) stem cuttings were stuck in a greenhouse mist-bench for rooting. The cuttings were treated with a five second basal quick dip of Wood's Rooting Compound (1.03% IBA / 0.51% NAA). They were inserted into 10 cm of coarse perlite and misted for 3 seconds every 10 minutes from 0800 to 2000 HR. Bottom heat was maintained at 25°C with mylar heat strips (Agritape, Ken-Bar Inc., Reading, MA.). Cuttings were shaded with black polyethylene side curtains and 55 percent shade cloth. The greenhouse temperature was set at 25°C/21°C day/night. Twenty of the cuttings were stripped of all leaves.

The appearance of axillary buds and internodes were noted and their lengths were measured at least every two weeks from June 10, 1989 until September 8, 1989. Bud length was measured from the point of connection on the stem to the tip of the bud. Because the buds have no scales, budbreak was defined as the point when the upper surface of the leaf first

became visible. Growth analysis of field plants was repeated in 1990 from April 16 until July 3, 1990 using 20 tagged stems (no cuttings or stripped stems used).

*Results and discussion.* No visible change in bud length occurred on the cuttings in the mist bench (Figure 1.1). Stock plants buds continued to elongate until leaf unfolding occurred. Comparing mean internode length between the two type of stems revealed a similar trend. The cutting internodes did not expand in length, while the stock plant internodes continued to increase in length until June 16. The act of taking a cutting (removal from the stock plant) appears to result in the total cessation of bud and stem elongation.

Stripping a plant of its leaves has been shown to induce lateral budbreaks depending on the time of the year it is done (Fuchigami *et al.*, 1977). The stripping of leaves off cuttings has been suggested as a production method to force growth while rooting (Smalley and Dirr, 1986). Forcing growth prior to winter on rooted softwood cuttings has been shown to improve the overwinter survival of some species (Smalley and Dirr, 1987). Also, if lateral buds can be forced it gives an indication of bud maturity (Fuchigami *et al.*). In our experiment all cuttings died in a matter of weeks if the leaves were stripped (data not shown). Leaves are apparently required for a softwood cutting to remain alive until roots can be formed. If leaf removal is used on unrooted cuttings, as a technique

to force growth, some leaves should be retained.

If the leaves were removed from the stems on stock plants, mean stem growth was reduced compared to the mean growth of stems not stripped of their leaves (Figure 1.2). Interestingly, the removal of leaves from a stem did not reduce the total number of nodes produced by that stem. Both stripped and unstripped stems produced an average of about three nodes by September 8, 1989. This might indicate that all of the nodes were preformed before the June 1 stripping date.

Lateral budbreak was monitored at each node location. Nodes were numbered in the same sequence as they appeared (for example, node 1 appeared first and then node 2 appeared next above node 1). None of the buds at the first node broke on unstripped stems (Figure 1.3). The second node had 25% budbreak and the third node had 40% budbreak by July 14. Only 19% of the lateral buds broke on unstripped stems. This is expected considering the normal, limited branching of *Viburnum carlesii*. Overall lateral budbreak increased (36%) when stems were stripped of leaves. The first node had budbreaks when the leaves were stripped. Stripping induced a greater amount of budbreaks especially at the second node (70%) location.

Stripped of leaves or intact, different nodes appear to have different lateral bud breaking ability. This may have practical applications for increasing the overwinter survival

of *Viburnum carlesii* cuttings. When selecting cuttings it may be an advantage to place the node with the best chance of budbreak above the propagation medium. For example, if two 2-node cuttings were taken from a stem containing 4 nodes, the fourth node would be above the propagation medium on the terminal cuttings and the second node would be above the medium on the subterminal cutting. If eventual budbreak followed the same trend as our data from the stripping experiment, the terminal cutting would have only a 5% chance of budbreak and the subterminal cutting would have a 30% chance of budbreak. If a subterminal cutting is released of apical dominance (as were the stripped stems) it would have a 70% chance of budbreak. This does not take into account other environmental factors which might influence budbreak (eg. light, See Chapter 3).

The difference in bud breaking ability between different node locations could be explained by the natural growth pattern of the stem. The growth of each internode levels off as the next node begins to expand (Figure 1.4). The new node is probably a stronger sink for carbohydrates and has apical dominance over the older node. The formation of a new node may influence the overall development of the buds below that node. If this were true, the manipulation of stock plant growth could be used to increase the time between node appearance, and perhaps the breaking ability of the buds.

Also in question is the total length of time necessary

for a stem to reach full maturity. Stem developmental patterns (Figure 1.4), reveal that internode 2 did not reach its maximum length until August 11. Year to year differences are found in the pattern of mean internode extension. In 1990, internode 2 reached it maximum on June 5, more than two months sooner than in 1989. This clearly demonstrates the variability in plant growth and development from year to year. If cuttings were taken in mid-June each year two different types of stem material would have been used. This may help explain why rooting and overwinter survival can vary so much from year to year even when the same stock plants are used and when cuttings are collected on the same date.

Plant propagation researchers should further examine the growth and development patterns of stock plants. An attempt should be made to link specific stages of plant development with the rooting and overwinter survival of cuttings. For cutting propagation to be reliable, the timing of propagation must be based on indicators representative of the physiological status of the plant. The timing of cutting propagation based on a calendar date inherently creates variability from year-to-year.

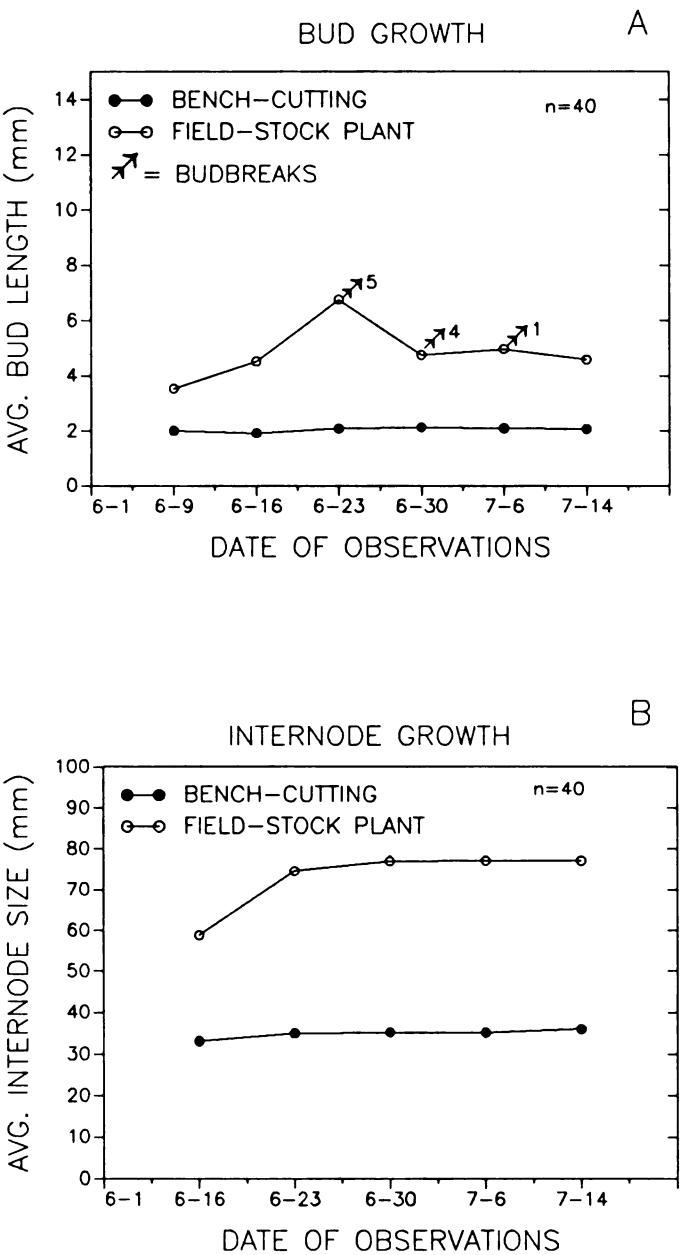


**Figure 1.1. Bud and internode growth of stock plant stems and bench cuttings in *Viburnum carlesii*. A. Average bud length and the number of budbreaks and B. internode growth, at two node locations (first and second nodes laid down) on *Viburnum carlesii* stems and on 2 to 3 node cuttings stuck on June 1, 1989 in a greenhouse mist bench.**

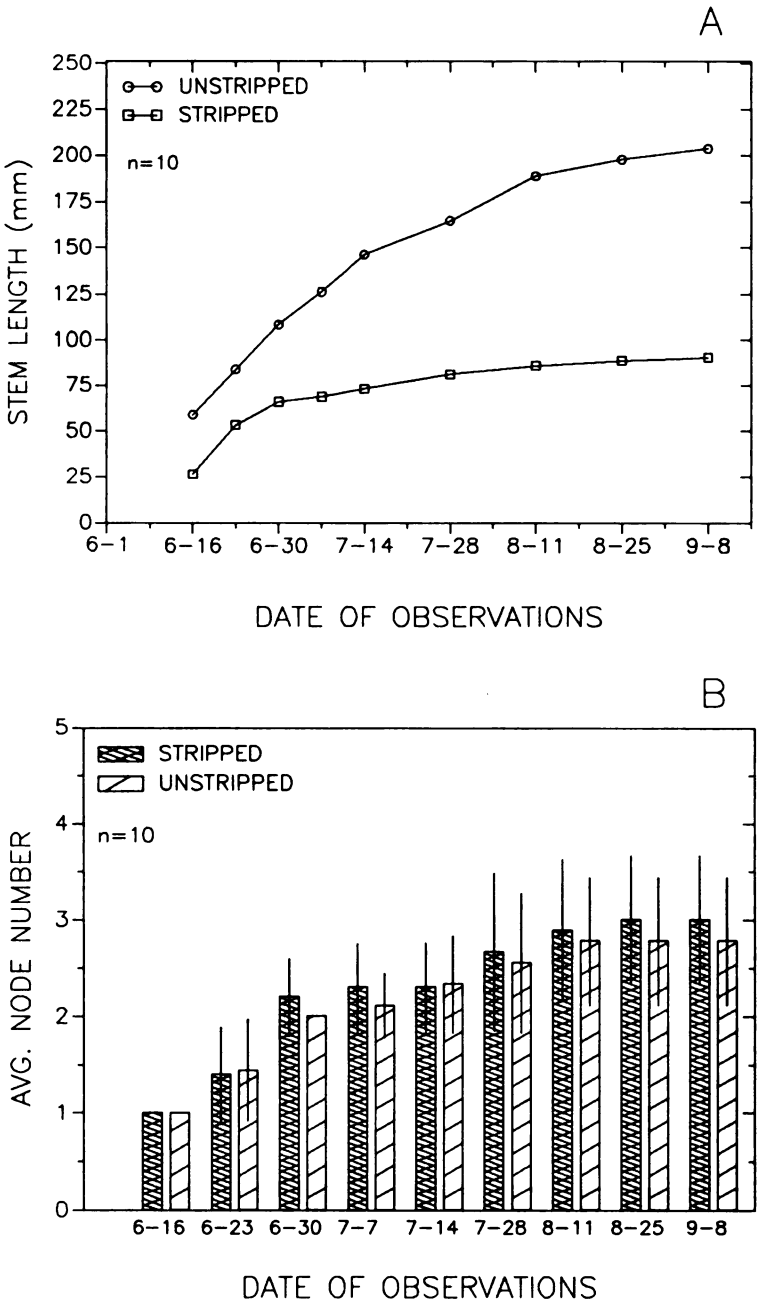


**Figure 1.2. Growth and development of *Viburnum carlesii* stems, stripped of leaves and not stripped. A. Stem elongation B. Node number. Leaves were stripped June 1, 1989.**

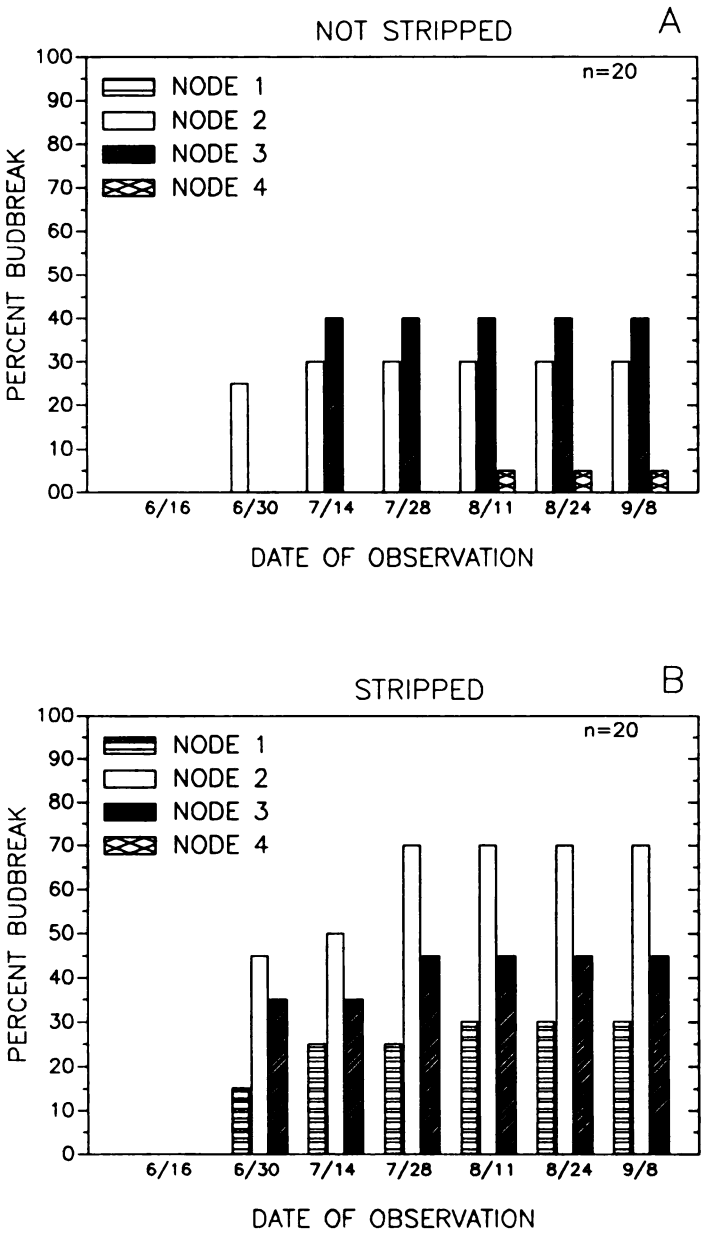


**Figure 1.3. Average number of lateral budbreaks at four node locations (node 1 being the first laid down and so on) on A. unstripped and B. stripped *Viburnum carlesii* stems. Leaves were stripped June 1, 1989.**

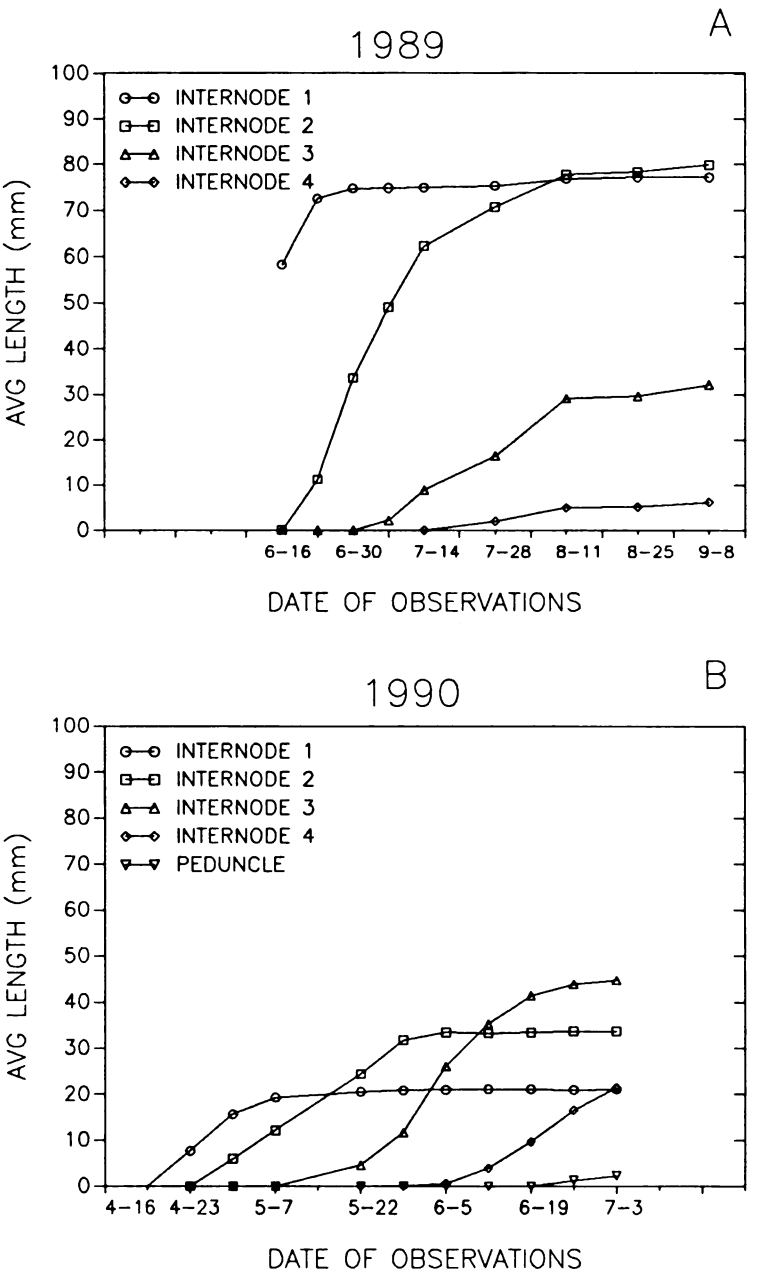


**Figure 1.4. The appearance of successive nodes and the average internode length on *Viburnum carlesii* stems on field grown stock-plants in A. 1989. B. 1990.**

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# CHAPTER II

## THE EFFECT OF AUXIN CONCENTRATION AND CUTTING TYPE ON THE ROOTING OF *Viburnum carlesii*

## ABSTRACT

Percent rooting and root quality of *Viburnum carlesii* softwood cuttings were measured and analyzed at six different concentrations of auxin, each comprised of Indole-3-butyric acid (IBA) to β-Napthleneacetic acid (NAA) mixed at a 2:1 ratio. Cuttings were collected July 7, 1989. The effect of cutting type, either two node terminal or subterminal, was also investigated. Cutting type had no affect on percent rooting or root quality. No significant difference in percent rooting was found between the levels of auxin concentration. Overall rooting was 84%. Rooting quality was slightly higher when auxin was used as compared to the control but decreased at the highest concentration of applied auxin.

*Introduction.* *Viburnum carlesii* Hemsl. (Korean Spice Viburnum) is commonly propagated by softwood cuttings because of the variability associated with seed and a suckering problem encountered with grafted plants (Dirr and Heuser, 1987). Researchers and growers have reported different degrees of rooting success and serious production problems when propagating from softwood cuttings (Dirr and Heuser, 1987; McMillan Browse, 1970; Miller and Smeal, 1972; Schaefer, 1985).

Dirr and Heuser (1987) reported 80% rooting of *Viburnum carlesii* in peat:perlite before mid-July when treated with 8000 ppm Indole-3-butyric acid (IBA) talc. Schaefer (1985) recommends 2,500 ppm IBA but gives no rooting data. Miller and Smeal (1972) tested seven different commercial rooting substances on *Viburnum carlesii* stuck June 16, 1970. Rooting percentages ranged from 8% (Hormodin #3, 8,000 ppm IBA in talc) to 60% (Jiffy Grow #2, hormone composition unknown) and 30% rooting for the control. In the same study, rooting quality was rated on scale of 1 to 5, with 1 equaling light rooting and 5 representing very heavy rooting. Out of a possible 250 total points, Hormodin #3 received the lowest rating (7 points) and Jiffy Grow #2 was highest with a rating (66 points). The control received 21 points. Some researchers have suggested that more research is needed to find the optimum auxin concentration for rooting *Viburnum carlesii*

(McMillan Browes, 1970; Miller and Smeal, 1972). To determine the optimum hormone range, Dirr and Heuser (1987) have recommended testing with 0, 2,500, 5,000, 10,000, and 20,000 ppm IBA.

Hartmann and Kester (1974) note that, in general, terminal cuttings root better than subterminal softwood cuttings. Higher concentrations of endogenous hormones, and softer, less differentiated tissue are suggested as possible explanations.

The purpose of this study was to: 1) identify the optimum range of auxin concentration for rooting *Viburnum carlesii* and 2) determine the influence of cutting type (terminal and subterminal) on rooting.

*Materials and Methods.* Shoots of *Viburnum carlesii* Helms. were harvested on July 7, 1989 from 10-year-old field-grown stock plants at Zelenka nursery in Grand Haven, Michigan. Growers in Michigan normally root *Viburnum carlesii* between mid-June and mid-July. Shoots consisted of soft, green, unhardened tissue produced that season. Shoots were transported to East Lansing, Michigan in an ice-cooled, polystyrene container to maintain turgor. They were later packaged in polyethylene bags and stored at 5°C for two days until processing. Two types of cuttings were made from the shoots: 1) terminal cuttings that contained an active apical meristem and 2) subterminal cuttings taken from directly below the apical cutting (Figure 2.1). Each cutting was approximately 10-12

cm and contained two nodes. The basal set of leaves were removed. Each cutting type was treated with 6 different auxin concentrations, including a zero-auxin control (Table 2.1). Auxin was applied as a 5-second quick dip composed of IBA and NAA at a 2:1 ratio dissolved in 2-propanol. The control dip contained only 2-propanol. The experimental design was a randomized complete block design. It was arranged as a factorial with 2 cutting types x 6 auxin levels x 4 blocks (1200 total cuttings with 25 cuttings per block). Analysis of variance was performed to determine the significance of treatments and interaction. Arcsin transformation was used on percent rooting data.

On July 10, 1989 the cuttings were stuck in a greenhouse mist bench, 10 cm in depth, containing coarse grade perlite. The greenhouse was set at 25°C/21°C day/night temperature, although actual temperatures sometimes exceeded these set points. Mist was applied for 3 seconds every 10 minutes, from 0800 to 2000 HR. Bottom heat was maintained at 25°C with mylar heating strips (Agritape, Ken-Bar Inc., Reading, MA.). Cuttings were shaded with black polyethylene side curtains and 55 percent Saran shade cloth over top.

Eight weeks after sticking the cuttings, misting was reduced to 6 hours and the shade cloth removed. At 10 weeks the mist was discontinued and, thereafter, the cuttings were watered manually. Once a week, 10 - 10 - 10 (NPK) water soluble fertilizer, at 150 ppm, was applied when the cuttings

were watered. After 12 weeks the cuttings were harvested to determine the rooting percentage and rated on a relative scale of 1 to 5 (Figure 2.2) to determine rooting quality.

*Results and Discussion.* No significant difference in percent rooting was found following treatment with any of the auxin concentrations measured 12 weeks after sticking (Table 2.2). Furthermore, cutting type (terminal or subterminal) had no affect on percent rooting. No interaction was found between cutting type and auxin concentration. Averaged over all treatments, rooting was 84% (Table 2.4). Auxin in the form of a 2:1 IBA/NAA mixture did not improve percent rooting at any of the applied concentrations. The auxin treatments may have shortened the time to rooting, but because the cuttings were not harvested until week twelve these results were not noticed. Control cuttings rooted a at high enough level (84%) to question the necessity of auxin for rooting of *Viburnum carlesii* softwood cuttings. The economic break-even point for untreated cuttings has been suggested to be above 50 to 60% rooting (Dirr and Heuser, 1987).

Auxin treatments had a significant influence on rooting quality (Table 2.3). Auxin treatments with 1,000 ppm to 10,000 ppm IBA had significantly higher ratings compared to the control and the 20,000 ppm IBA treatment (Table 2.4). At the highest IBA concentration (20,000 ppm IBA) rooting quality was significantly reduced compared to other auxin

concentrations used. Auxin levels above 1,000 ppm IBA did not further improve root quality. From an economic standpoint, there is no benefit in using more auxin than necessary and for this reason future investigation should examine auxin levels below 1,000 ppm IBA/500 ppm NAA.

Our results indicate that cutting type, terminal or subterminal, had no influence on the rooting or quality of *Viburnum carlesii* cuttings. This is of practical benefit to growers who use only tip cuttings. The additional use of subterminal cuttings would double the amount of available cutting material.

Any technique(s) that can improve the rooting percentage and overall quality of *Viburnum carlesii* cuttings may help overcome the high losses encountered during overwintering. An auxin quick-dip of no more than 1,000 ppm IBA / 500 ppm NAA is recommended for the satisfactory rooting of both terminal and subterminal softwood.

Table 2.1. Auxin concentrations applied in parts per million 2-propanol solvent.

| Treatment number | IBA | NAA | Total auxin |
|---|---|---|---|
| 1. Control | 0 | 0 | 0 |
| 2. | 1,000 | 500 | 1,500 |
| 3. | 2,500 | 1,250 | 3,750 |
| 4. | 5,000 | 2,500 | 7,500 |
| 5. | 10,000 | 5,000 | 15,000 |
| 6. | 20,000 | 10,000 | 30,000 |

Table 2.2. Analysis of variance for percent rooting of *Viburnum carlesii* as influenced by cutting type and auxin concentration.[z]

| SOURCE[y] | DF | Sum of Squares | Mean Square | F Value[x] |
|---|---|---|---|---|
| BLOCK | 3 | 769.062 | 256.354 | 1.46 |
| TYPE | 1 | 163.430 | 163.430 | 0.93 |
| CONC. | 5 | 882.519 | 176.504 | 1.01 |
| TYPE*CONC. | 5 | 783.285 | 156.657 | 0.89 |
| ERROR | 33 | 5781.415 | 175.194 | |

[z] Data transformed by arcsin percentage transformation.
[y] TYPE = cuttings type (terminal or subterminal), CONC. = auxin concentration.
[x] All nonsignificant Prob. = .05.

Table 2.3. Analysis of variance for root quality rating of *Viburnum carlesii* as influenced by cutting type and auxin concentration.

| SOURCE[y] | DF | Sum of Squares | Mean Square | F Value[z] |
|---|---|---|---|---|
| REP | 3 | 0.351 | 0.117 | 0.78 |
| TYPE | 1 | 0.017 | 0.018 | 0.12 |
| CONC. | 5 | 4.962 | 0.993 | 6.56** |
| TYPE*CONC. | 5 | 0.689 | 0.138 | 0.91 |
| ERROR | 33 | 4.991 | 0.151 | |

[z] Prob. = .025, ** highly significant
[y] TYPE = cuttings type (terminal or subterminal), CONC. = auxin concentration.

Table 2.4. The effect of auxin concentration on percent rooting and rooting quality of *Viburnum carlesii*.[z]

| Auxin Concentration (IBA / NAA ppm) | Percent Rooting[x] | Mean Rating[y] |
|---|---|---|
| Control | 84.0 % | 2.9 b |
| 1,000 / 500 | 85.5 % | 3.6 a |
| 2,500 / 1,250 | 83.5 % | 3.6 a |
| 5,000 / 2,500 | 89.0 % | 3.6 a |
| 10,000 / 5,000 | 86.5 % | 3.4 a |
| 20,000 / 10,000 | 77.5 % | 2.9 b |

[z] The difference between terminal and subterminal cuttings is nonsignificant and the results have been combined.
[y] Mean seperation in columns by Duncan's multiple range test, 5% level.
[x] Percentages shown are not transformed, but statistics were proformed using arcsin transformation. All treatments nonsignificant for percent rooting.

Figure 2.1. Cutting types (terminal and subterminal) used in rooting *Viburnum carlesii*. Leaves are not shown for better visibility of the nodes.

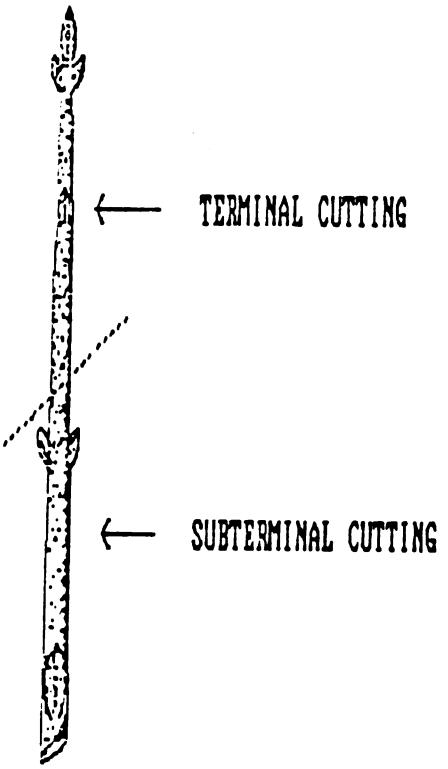

Figure 2.2. Rating scale from 1-5 after 12 weeks for *Viburnum carlesii* rooting quality.

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# CHAPTER III

## THE EFFECT OF SUPPLEMENTAL LIGHTING AND PHOTOPERIOD ON TERMINAL AND SUBTERMINAL *Viburnum carlesii* ROOTED CUTTINGS AND SUBSEQUENT OVERWINTER SURVIVAL

## ABSTRACT

Newly rooted terminal and subterminal *Viburnum carlesii* cuttings were exposed to four light treatments: 1) natural Michigan photoperiod, 2) 8-hour photoperiod and supplemental HID light, 3) 8-hour photoperiod and supplemental HID light plus a 4-hour night break and 4) 16-hour photoperiod and supplemental HID light. Light treatments lasted 55 days. Percent budbreak and growth one week after budbreak were measured, as well as post-storage budbreak and overwinter survival. No difference in budbreak was found between cutting type. Terminal cuttings had significantly more growth than subterminal cuttings. Long day photoperiod and supplemental light induced bud break and growth. The 16 hour treatment induced the most budbreaks (97%) and the most growth (19 mm). There was no difference between cutting type in post-storage budbreak except for the 16 hour treatment. Subterminal cuttings had the greatest survival rates if previously held under 8 hours of supplemental light. Sixteen hours of supplemental light reduced survival, especially for terminal cuttings. Survival ranged from 82% to 100% if subterminal cuttings had pre-storage growth induced by 8 hours of supplemental light.

# INTRODUCTION

*Viburnum carlesii* Hemsl. (Korean Spice Viburnum) is a popular landscape shrub noted for it showy, fragrant flowers, burgundy fall color, and neat habit. It is commonly propagated by softwood cuttings because of the variability associated with seed and a suckering problem encountered when grafted (Dirr, 1987). A serious problem cited by growers and in the literature is the poor overwinter survival rates of *Viburnum carlesii* from softwood cuttings. Cuttings of many important ornamental plants have been reported as difficult-to-overwinter (Table 3.1). Donnelly and Yawney (1972) stored *Acer saccharum* cuttings under 6 different conditions including field planting, cold cellar storage and refrigerated storage in pots and bare-root in polyethylene bags. Cuttings planted directly to the field in the fall had 100% mortality. All other storage methods had survival rates ranging form 32% to 48%. Cuttings potted in the fall and stored at 1°C in a controlled temperature chamber had the best survival. Flint and McGuire (1962) stored 8 *Viburnum spp.* under controlled temperature conditions. The rooted cuttings were bare-rooted, placed in polyethylene bags, and stored at either 0°C or 4°C for 5

months. Temperature influenced the survival in one half of the species, where all, of these survived better at the lower temperature. Viburnum carlesii 'Compactum' had statistically higher survival at 0°C but with only 13% survival. Wood and Cameron (1989) stored June-rooted, bare-root *Viburnum carlesii* cuttings in polyethylene bags for five and 7 months in controlled temperature chambers. The cuttings were stored at temperatures of either 2.5°C or -2.5°C. Cuttings survival ranged from only 1% to 8% regardless of treatment.

Characteristically many of these rooted cuttings appear healthy at the onset of dormancy and throughout winter but in the spring the buds either fail to break or break bud and wither (Waxman, 1965; Donnelly and Yawney, 1981). The roots appear healthy at the end of storage and initiate growth even though the tops do not (McMillan Browes, 1970). The roots die several weeks later. Stem splitting and darkened stems have been reported at the end of storage (Hess, 1955; Flemer, 1982; Smith and Treaster, 1985), indicative of damage to the vascular cambium or vascular system.

*Budbreak and Growth.* It has been observed in some species that are difficult to overwinter that if the cuttings break bud before the onset of dormancy they survive at a higher rate than those without growth (Smalley and Dirr, 1987; Waxman, 1951; Loach and Whalley, 1975; Harvis, 1982). It has not been reported if budbreak improves the survival of *Viburnum carlesii*. It is not fully understood how budbreak and the resulting

growth interacts with subsequent overwinter survival. Budbreak may only be an indicator of a vigorous cutting that would survive regardless of growth. Donnelly and Yawney (1972) collected cuttings from eight different *Acer saccharum* trees and found that cuttings from each tree had a different capacity to form roots (ranging from 10% to 90%). Rooted cuttings originating from the trees that rooted easiest also stored better.

Carbohydrate depletion is the most widely accepted hypothesis for explaining the poor overwinter survival of cuttings (Harvis, 1982; Loach and Whalley, 1975; Smalley and Dirr, 1987; Waxman, 1951). It is thought that photosynthesis from leaves on new growth replenishes carbohydrates depleted during the rooting process, thus improving survival. Deciduous plants depend on carbohydrates accumulated the previous season for spring budbreak (Stassen *et al.*, 1981).

The association between budbreak and improved survival has generated much interest. Growers (Wells, 1970; Flemer, 1982) and researchers (Loach and Whalley, 1975; McConnell and Herman, 1980; Smalley and Dirr, 1987; Smith and Treaster, 1985) have worked with different plant species and have artificially attempted to force growth with light treatments and growth hormones. Results have been mixed in both percent budbreak and percent overwinter survival.

Smalley and Dirr (1987) studied the effect of photoperiod on budbreak and overwinter survival of *Acer rubrum* 'October

Glory' cuttings rooted in June and August. Carbohydrates were analyzed to determine if they influenced overwintering. Short day and night-interrupted, long day photoperiod were studied. June cuttings received photoperiod treatments from July 25 until October 22, 1984 (89 days). August cuttings received photoperiod treatments from September 10 until October 22, 1984 (32 days). The night break was produced by an incandescent lamp with a light intensity of 3 to 5 umol $m^{-2}$ $sec^{-1}$. Cuttings were moved outside and held for 42 days and then stored in a double poly-house maintained at or above -1°C for 165 days. The June cuttings had significantly more plants which broke bud (60%) under the long day (night interruption) photoperiod compared to (43%) short day conditions. However, no significant difference in winter survival was found between long day (81%) and short day (82%) treatments. In the August cuttings, neither treatment forced new growth and yet both had survival rates greater than 90%. Regardless of treatment, however, all cuttings that broke bud survived the winter. Those that did not break bud survived at a higher rate under the short day treatment (68%) than did the cutting under long days (52%). Analysis of carbohydrates revealed that both soluble sugars and starch were greater in the roots of plants that broke bud over those that did not break bud. No difference in carbohydrates was found in cuttings that did not break bud within the two photoperiod. Even though Smalley and Dirr's work showed that cuttings that

broke bud had higher levels of root carbohydrates there is no proof that the difference is responsible for increased survival. Growth and its physiological consequences are more complex than increased carbohydrates alone. Donnelly and Yawney (1972) also investigated the relationship between carbohydrates and overwinter survival. Total carbohydrates (Percent dry weight) were found to be higher (20%) in 1-year old *Acer saccharum* seedlings and than in rooted cuttings (10%). Dormant feedings of sugar and nutrient solutions, however, did not improve the survival of *Acer saccharum* rooted cuttings stored for two months at 1°C (Donnelly and Yawney, 1972).

Hormones have also been used to force growth in efforts to improve survival rates. Carthaigh (1983) significantly increased budbreak and growth of *Prunus triloba* with 500 ppm $GA_3$ but increased overwinter survival only moderately (no statistics used). McConnell and Herman (1980) used two concentrations of $GA_3$ (1000 and 4000 ppm) as well as two levels of N-6-benzyladenine (200 and 1000 ppm) to induce growth on *Salix pentandra* L. and *Viburnum lantana* L. Gibberellic acid was found to significantly improve budbreak for both species but had little effect on overwinter survival. Benzyladenine treatments did not improve budbreak but it did show a small but significant increase (15%) in survival over the control.

Loach and Whalley (1975) examined the effects of $GA_3$, extended photoperiod (low intensity, dusk to dawn), and a combination of extended photoperiod and $CO_2$ on the survival

of *Betula pendula* and *Berberis thunbergii* 'Atropurpurea Rosea'. For birch, extended photoperiod with supplemental $CO_2$ and the extended photoperiod treatment showed the highest survival rates (70% and 62% respectively) compared to $GA_3$ (21%) and control (16%). In barberry (which is known to be difficult to overwinter), extended photoperiod had the best survival rate (87%) while all other treatments were only slightly better than the control (55%). In both experiments survival rates loosely correlated with the number of leaves per plant produced prior to storage under each treatment, however, no statistics were used.

The problem of overwinter survival is particularly severe in the genus Viburnum (Dirr, 1987; McMillan Browes, 1970; Smith and Treaster, 1985; Waxman, 1951), specifically *Viburnum carlseii* Helms and its hybrids. As is the case with many of the species that are difficult to overwinter, long days cause continuous vegetative growth of *Viburnum* (Nitsch, 1975). Several researchers have studied the effect of photoperiod on the overwinter survival of *Viburnum*.

Bhella and Moore (1980) who studied the propagation of *Viburnum lantana* L. 'Mohican', *Viburnum* x *rhytidophylloides* Sur. 'Alleghany' and *Viburnum sargentii* Koehne 'Onondaga' found the survival rate to be greater than 95 percent for all cultivars when subjected to a high intensity 18 hour photoperiod. However, the plants were never allowed to go dormant and no

control plants were used.

Downs and Piringer (1958) examined the response of five different *Viburnum* spp. (including *Viburnum carlesii* Hemsl.) under four different photoperiod (8, 12, 14, and 16 hours) after 24 weeks. Stem growth was significantly greater under photoperiod longer than 12 hours. Plants under 14 and 16 hour photoperiod averaged 101 cm of growth per plant while the 8 and 12 hour treatments averaged 39 cm per plant. The plants were overwintered in the field with a recorded low temperature of 13°C. All plants survived the winter regardless of photoperiod treatment. It should be noted that the experimental plants used had been rooted the previous summer and overwintered in the field before being subjected to photoperiod treatments. This suggests that *Viburnum carlesii* responds to a long day photoperiod over 12 hours and that overwintering death is related to specifically to newly propagation rooted cuttings. Wood and Cameron (unpublished) also found that 1-year-old *Viburnum carlesii* plants overwintered at rates greater than 90%.

*Nitrogen.* Several factors have been identified that contribute to poor overwinter survival of cuttings. High nitrogen levels can cause problems in overwintering softwood cuttings. Stimart and Goodman (1985) studied the effect of nitrogen on the overwinter survival under two different photoperiod. Working with *Acer palmatum* 'Bloodgood' and *Cornus*

*florida* forma *rubra* they subjected cuttings to either long day or day neutral photoperiod while treating them with two levels of nitrogen. Cuttings were rooted in mid-June, transplanted and held under shade cloth in a greenhouse until late September. The light treatment consisted of an 18 hour photoperiod produced by incandescent bulbs (9 umoles s-1 m-2). The plants were given a constant feed of either 0 or 200 ppm nitrogen ($NH_4NO_3$). Plants were moved outside in mid-November for hardening off. In mid December the plants were covered with covered with microfoam and sash. The microfoam was removed in mid-March and survival rates were calculated one month later. Overwinter survival was highest in both species (100% and 98% respectively) if the plants had growth before dormancy and received no nitrogen. The author stated that "No detectable patterns of overwinter survival were related to previous season photoperiod treatment" although no data was presented on the growth response to photoperiod and no statistics were presented. Nitrogen decreased survival rates for both species under both photoperiod if no growth was initiated before dormancy (a combined average under 12%). Growth appeared to counteract the affect of nitrogen resulting in a combined average of 81% survival. The adverse affect of nitrogen on cold hardiness is well known. Weiser (1965) states that nitrogen increases cold injury for two reasons; 1) late autumn growth promoted by nitrogen delays hardening, and 2) nitrogen induced growth depletes carbohydrate reserves.

Statistically contradictory to this reasoning, Stimart and Goodman's cuttings receiving nitrogen that grew survived at higher rates than those that did not grow.

*Hardening.* Proper hardening can also be a source of overwintering problems in newly rooted cuttings, especially if growth techniques have been used after rooting. Smith and Treaster (1985) studied the effects of extended photoperiod (high intensity night interruption) on growth and survival of mid-June propagated *Viburnum opulus* 'Nanum' cuttings. In mid-July cuttings (except for controls) were place under high pressure sodium lamps that operated from 10:00 p.m. to 2:00 a.m. each night. Every two weeks 25 plants were removed (for a total of twelve weeks). The plants were stored in an unheated poly-house from mid-November to the first week of May. Long days resulted in increased growth through the first eight weeks. Survival was highest (68%) for plants left under lights for 8 weeks compared to the control (24%). Survival decreased under the 10 week (36%) and 12 week (12%) treatments. Leaf drop was measured in storage as an indication of hardening. The 8 week treatment had 20% leaf drop at the end of February. The remaining leaves were brown and attached to the plant. Control plants had 100% leaf drop and the 12 week plants had green leaves and no leaf drop. Clearly the induction of growth after rooting can inhibit the proper cold hardening of newly rooted cutting.

*Cuttings Material.* Cutting type has been reported to

influence overwinter survival. Donnelly and Yawney (1972) found that longer *Acer saccharum* cuttings rooted and survived better than shorter cuttings. Smalley and Dirr (1987b) working with *Acer rubrum* found no difference in overwinter survival between terminal cuttings with 3 to 5 nodes, subterminal cuttings with one node, and subterminal cuttings with three nodes. Subterminal three node cuttings had significantly greater lateral budbreak but all cutting types survived above 92 percent.

*Root Disturbance.* Fall transplanting has been implicated as a factor in lowering overwinter survival. Fordham (1976, 1982) claims improved overwinter survival of *Hamamelis* spp. and *Stewartia* spp. cuttings if left undisturbed until the following spring. English (1981) makes the same claim for *Acer rubrum* cuttings. Dirr (1987) recommends non-disturbance for *Acer, Hamamelis, Stewartia* and *Viburnum* species. Only Donnelly and Yawney (1972) have published experimental results on transplanting and found no statistical differences in survival between *Acer saccharum* cuttings transplanted and those left undisturbed. Still, some growers leave rooted cuttings in propagation containers for up to two years before transplanting (Dirr, 1987). Further research on transplant shock is needed to decisively separate observation and fact.

*Disease.* Fungi can be serious problem for plants overwintering in both common and refrigerated storage

facilities (Davidson *et al.*, 1981). Flint and McGuire (1962) found a 54% increase in survival of *Viburnum carlesii compactum* if cuttings were treated with Captan prior to refrigerated storage at 0°C. However, no attempt was made to isolate or identify molds.

Research on the overwinter survival of cuttings has been limited and varied. Due to the time consuming nature and poor funding of woody ornamental research, few experiments have been repeated. Adding to the confusion, variability occurs in overwinter survival rates from year to year, crop to crop, and from grower to grower. The use of different storage methods, propagation techniques and plant species also serves to cloud the investigation of overwintering death of rooted cuttings.

Why cuttings with growth prior to dormancy survive better that those without growth is not fully understood. Budbreak and growth are very complex physiological processes that result in many anatomical, physiological and biochemical changes. Although new growth has been shown to improve carbohydrate levels in some cases (Smalley and Dirr, 1987) it can also deplete carbohydrates (Stassen *et al.*, 1981). It has not, however, been demonstrated that cuttings that are difficult to store have insufficient carbohydrates to overwinter.

Softwood cuttings are taken in the spring when stems are actively growing. It is separated from its root system and

the water, nutrients, and hormones the roots once supplied. Cuttings encounter many forms of stress throughout rooting and storage. What is viewed as one causal agent may be several individual or related factors that contribute to the low survival rate of cuttings.

The purpose of this experiment was to determine the influence of high intensity supplemental lighting, and photoperiod (long and short days) on the overwinter survival of terminal and subterminal *Viburnum carlesii* rooted cuttings.

## MATERIALS AND METHODS

*Plant material.* On 16 October 1989, 200 terminal and 200 subterminal two-node *Viburnum carlesii* cuttings were randomly selected from uniform, well rooted material propagated July 5, 1989. The cuttings were potted into four-inch clay pots in a peat-perlite-vermiculite mix. Cuttings were held in a greenhouse with a day/night temperature of 25°C/21°C.

*Light treatments.* On October 20, fifty cuttings of each type were randomly assigned to one of four light treatments: 1) natural light and day length (control), 2) eight hour supplemental lighting and photoperiod (8 HID), 3) eight hour supplemental lighting and photoperiod plus a four hour night break (8 HID + NB) and 4) sixteen hour supplemental light and photoperiod (16 HID). All supplemental light was provided by high pressure sodium (HID) lamps having a light intensity of 100 to 150 $\mu$mole $m^{-2}$ $sec^{-1}$ at plant height. Supplemental lighting was initiated at 0800 HR and ended at 1600 HR except for the 16 HID treatment which ended at 2400 HR. The photoperiod of the 8 HID and the 8 HR + NB treatments were maintained by covering the plants with black cloth from 1600 until 0800 HR. The four hour night break was provided by two 75 Watt incandescent lights, with a light intensity of 10 -

22 $\mu$mole $m^{-2}$ $sec^{-1}$. The lamps were suspended 60 cm above the plants and under the black cloth from 2200 to 0200 HR. The night break resulted in a maximum temperature increase of 4°C at plant level (data not shown). A back plastic barrier separated the control group from the other light treatments.

All plants were fertilized when watered with 150 ppm 10 - 10 - 10 (NPK) water soluble fertilizer. All plants were watered once a week with straight water to leach out excess soluble salts. Fertilization was discontinued after 30 days. On December 13, 1990 final budbreak data were collected. Date of budbreak was noted for each cutting. Stem length was measured 7 days after each plant broke bud. Because *Viburnum carlesii* has no bud scales, budbreak was arbitrarily defined as the first visible sign of the upper leaf surface as a leaf unfolded. Differences in percent budbreak between treatments were statistically analyzed by two-way chi-squared contingency tables because the results were binomial. Cuttings either break bud or they do not. Analysis of variance for week one growth data was by the (SAS) General Linear Model (GLM) procedure because not all plants broke bud, yielding unequal sample sizes.

All of the cuttings, except 50 control and 50, 16 HID cuttings, were tagged if they had growth. They were held in a greenhouse at 25°C/21°C under normal Michigan photoperiod in preparation for hardening. The 50 control and 50, 16 HID cuttings (each containing equal numbers of the two cutting

types) were left under their respective light treatments. Survival rates for these cuttings were calculated on the same day the stored cuttings were evaluated for survival.

*Overwintering.* On January 15, 1990, approximately one month after removal from supplemental light, 20 *Viburnum carlesii* cuttings were randomly selected from each of the eight treatments and placed in a 5°C controlled temperature chamber for hardening. The cuttings received an 8 hour photoperiod supplied by florescent lamps delivering a light intensity of 45 to 70 $\mu$mole $m^{-2}sec^{-1}$ for 3 months and watered as necessary. On April 5, 1990 the cuttings were bare-rooted, placed into 4 mil. polyethylene bags and stored for 75 days at 0°C. On June 21, 1990 cuttings were transplanted into 6 in. clay pots, watered and placed under 55% shade cloth and misted regularly. Plant budbreak was tabulated at one week and plant survival was observed two weeks after removal from storage. Statistical analysis was by chi- squared contingency tables for both budbreak and survival.

## RESULTS

*Forced budbreak.* The difference in percent budbreak between terminal and subterminal cuttings for each light treatment was primarily nonsignificant over the 55 day treatment period (Figure 3.1). Slight differences were found at day 30 and day 40 under the 8 hour photoperiod and at day 30 under the 8 HID + NB treatment but all differences were non-significant by 55 days. Averaged over all light treatments there was no statistical difference in budbreak between cutting type within the 55 day period. At the end of the treatment period (55 days) 101 out of 200 terminal cuttings broke while 105 subterminal cuttings broke over all treatments (Figure 3.2).

Light treatments had a pronounced influence on the number of plants breaking bud and the rate at which plants broke bud (Figure 3.3). The 16 HID treatment, which combined long days and high light intensity, induced significantly more breaks (97% at 55 days) and induced them quicker (50% at day 18) than all other treatments (Table 3.2). The 8 HID + NB treatment, which also had a long day photoperiod but a lower light intensity, had fewer plants break after 55 days and broke at a slower rate (50% at day 35) compared to the 16 HID treatment. Basically no statistical difference was found between the two short day treatments (control and the 8 HID)

based on chi-square analysis even though the 8 HID treatment had a higher light intensity (Table 3.2). The simulated long days produced by the 8 HID + NB treatment significantly increased the amount of plants that broke bud (68% at 55 days) compared to the 8 HR HID treatment (27% at 55 days) which had the same light intensity.

*Forced growth.* Cutting type and light treatment both statistically influenced the amount of growth produced one week after budbreak (Table 3.4). There was no statistical interaction. The 16 HR HID treatment produced the greatest mean growth per plant at one week (19 mm) and was significantly greater than the 8 HR + NB treatment (12 mm) (Figure 3.3). Both long day treatments (16 HR HID and 8 HR + NB) induced significantly more growth than the short day treatments (8 HR and 8 HR + NB) which were statistically the same as one another. Variability in plant growth at one week was relatively high (C.V.=82.9).

Mean growth per plant for terminal cuttings (17 mm) was significantly greater than for subterminal cuttings (11 mm) at one week after budbreak (Figure 3.5).

The cuttings that remained in the greenhouse under their original light treatments, (control and 16 HID never hardened or stored) from October 20, 1989 to June 27, 1990, had 100% survival (data not shown).

*Post-storage performance.* Subterminal control and subterminal 8 HID + NB had the greatest amount of cuttings break bud (80%

each) following bare-root storage and both were significantly greater than the terminal 16 HID cuttings which had the least amount of budbreaks (25%, Figure 3.6). The subterminal 8 HID and terminal control treatments also had significantly more cuttings break bud (65% and 70% respectively) than the terminal 16 HID treatment (Table 3.4). Averaged over all treatments, 60% of all cuttings broke bud.

Not all cuttings that broke bud after storage went on to survive. An additional 22% more cuttings wilted and died by week two (Figure 3.6). Control cuttings, both terminal and subterminal, and all other terminal treatments suffered considerable losses after breaking bud. Ultimately, the subterminal 8 HID + NB treatment had the greatest amount of cuttings survive (75%). Statistically this treatment had greater survival than all of the other treatments except subterminal 8 HID (50%, Table 3.5). The subterminal cuttings in all treatments, except the control, had greater survival statistically, than the terminal cuttings. Terminal 16 HID cuttings had the lowest survival (10%) and were statistically lower than all subterminal treatments and the terminal control. Averaged over all light treatments subterminal cuttings had a higher survival rate (51%) than terminal cuttings (25%). When averaged over all treatments survival was only 38%.

Cuttings with forced growth survived at statistically higher survival rates than those without growth under three

treatments: 1) terminal 8 HID, 2) subterminal 8 HID and 3) subterminal 8 HID + NB (Table 3.6). Subterminal cuttings with growth survived at significantly higher levels than terminal cuttings in the 8 HID + NB and 16 HID treatments. Subterminal 8 HID + NB cuttings with growth survived at the highest rate (100%). Statistically, this group of cuttings had a survival rate greater than all other treatments, growth or no growth, except for the subterminal 8 HID cuttings with growth (82%). Subterminal 8 HID cuttings with growth had statistically greater survival than all other groups except terminal 8 HID cuttings with growth and 8 HID + NB cuttings with growth. No significant difference existed between the control cuttings, terminal or subterminal, even if they had growth. Averaged over all light treatments subterminal cuttings with growth had the highest survival rate (65%). When also averaged over cutting type cuttings with growth survived at 48% while those with out growth had only 25% survival.

## DISCUSSION

The results of this experiment clearly demonstrate the difficulty of overwintering dormant *Viburnum carlesii* cuttings. Cutting survival was only 38% (Table 3.6) when averaged over all treatments. Cuttings held in a warm greenhouse for the duration of winter all survived. This suggests overwintering problems occur only if the cuttings are dormant and stored at low temperatures.

Cuttings exhibited two types of symptoms when failing to survive after storage: 1) they either failed to break bud or 2) they broke bud and then later wilted and died. This may also indicate that more than one factor is involved. Sclerotium of *Sclerotinia* sp. (White mold), *Pythium* sp. and *Fusarium* sp. were identified, on all treatments groups at the end storage, by the Michigan State University Diagnostic Clinic. Stem lesions were visible on only a few plants. *Sclerotinia,* and damping of diseases can produce stem splitting and a darkening of the stems (Agrios, 1988). Several authors have reported stem splitting and darkened stems after overwintering cuttings (Flemer,1982; Hess,1955; Smith and Treaster,1985). Flint and McGuire (1962) significantly

improved the survival rates of *Viburnum* spp. by treating the cuttings with 5% Captan. However, no attempt was made to identify molds in that study. Fungal disease may not be the primary cause of overwintering death for these cuttings. It may have been secondary infection or perhaps one of several factors contributing to cutting death.

Cutting type, and its influence on budbreak, was investigated for several reasons. It was thought that subterminal cuttings might have an advantage because the lateral buds are formed chronologically earlier than those on terminal cuttings. Buds that are on the stock plant longer may have reached a higher state of maturity, thus increasing their ability to break when forced after storage. Also in question was the role of the apical meristem in controlling budbreak. The stem apex can inhibit the growth of lateral buds and its removal eliminates the inhibition (Martin, 1987). Subterminal cuttings did not respond as the above hypothesis would indicate. The only sign that subterminal cuttings had greater breaking ability was in the 8 HR HID treatment at days 20 and 30 (Figure 3.1). In all other treatments there was either no difference or the terminal cuttings had more breaks. Also there was no statistical difference in budbreak after storage between the two types of cuttings within each light treatment (Table 3.4).

Cutting type did however have an influence on survival. Subterminal cuttings given supplemental lighting (8 HID, 8

HID + NB and 16 HID) had a statistical advantage over terminal cuttings within each light regime (Table 3.5). Cutting type had no influence on the post-storage budbreak or survival of the control cuttings. This indicates an interaction between the supplemental light and the subterminal cutting. Larger subterminal cuttings may have a greater capacity to transport and store assimilates produced by high light levels than do smaller, less mature terminal stems.

It has been suggested that forced growth before dormancy will improve the overwinter survival of cuttings. The results of this research indicate that forced growth will not improve the survival of *Viburnum carlesii* cuttings under all conditions. Statistically, terminal 16 HID cuttings had the poorest survival (Figure 3.6) of all the treatments even though this light treatment induced the greatest amount of budbreaks and growth (Figures 3.3 and 3.4). Extremely long exposure to high light levels and forced growth has been shown to adversely affect the fall hardening process and overwinter survival. Smith and Treaster (1985) reduced the overwinter survival of *Viburnum opulus* cuttings by subjecting them to 12 weeks of high intensity light breaks. The forcing of extended stem growth by long photoperiod can prevent plant hardening even after returning them to short days (Levitt, 1980). Cuttings in this study were held under naturally short days in a warm greenhouse for one month and were then held at 5°C, under an 8 hour photoperiod, for three months before storing

them at 0°C. Cold hardiness should not have been a factor in reducing the survival of the 16 HID cuttings since they had considerable time under hardening conditions and were store at only 0°C. Extended periods of rapid growth followed by prolonged short days can reduce reserve carbohydrates (Tumanov *et al.*, 1972). Actively growing plant tissue can be a strong sink for assimilates. If the net energy balance of the cutting is not positive before encountering low light conditions, little or no assimilate is reserved for spring growth.

Under some circumstances growth improved survival. The best overwinter survival was in subterminal cuttings under the 8 HID + NB (75%) and the 8 HID (50%) light treatments (Figure 3.6). If the subterminal cuttings under these two light treatments had new growth prior to storage, survival rates were greater than those without growth (Table 3.6). Subterminal cuttings in the 8 HID + NB treatment had 100% survival if they had growth, compared to only 33% survival of those without growth. Subterminal cuttings in the 8 HID treatment survived at 82% with forced growth and only 11% survival for cuttings without growth. Terminal cuttings in the 8 HID treatment had greater survival (57%) with growth and no survival without growth. In the control group there were no statistical differences between terminal or subterminal cuttings with or without growth. Growth appears only to improve survival following treatments with specific

levels of light. It also appears that subterminal cuttings have a survival advantage under long photoperiod.

From a practical standpoint subterminal cuttings under the 8 HID + NB treatments should yield the highest number of cuttings surviving the winter. For example, based on the techniques and statistical results of this research, if a grower stuck 1200 subterminal *Viburnum carlesii* cuttings approximately 1000 cuttings would root (Chapter 2). If the 1000 cuttings were then given 55 days of 8 hour supplemental HID light with a 4 hour night break approximately 700 plants (70%) would break bud and 300 would not. The following spring 814 cuttings would have survived. Overall this represents a 68%

**1200 cuttings stuck x 84% rooting = approximately 1000 rooted cuttings.**

**1000 cuttings x 70% forced budbreak = 700 cuttings with growth and 300 without growth**

**[700 x 100% survival with growth] + [300 x 38% survival w/o growth] = 814 cuttings**

**( 814 cuttings / 1200 stuck ) x 100 = 68% success rate**

success rate, which is above the economic break-point (50% to 60%) that Dirr and Heuser (1987) claimed was necessary for the profitable production of rooted cuttings. If a grower stuck 1200 terminal cuttings and held them under natural Michigan photoperiod only 315 cuttings would successfully overwinter, exhibiting only a 26% success rate.

**1200 cuttings stuck x 84% rooting = approximately 1000 rooted cuttings**

**(0.25 + 0.38 / 2) = 31.5% * survival rate averaged because growth was nonsignificant**

**1000 rooted cuttings x 31.5% survival rate = 315 cuttings**

**(315 cuttings surviving / 1200 stuck) x 100 = 26% success rate**

While the results of this study do not totally solve the problem of overwintering *Viburnum carlesii*, they do offer new insight into the problem and a starting-point for future research. *Viburnum Carlesii* has been shown to be an excellent system test plant because it roots easily, is extremely difficult to overwinter and breaks bud readily under long photoperiod. Future research should be conducted to verify the positive interaction found between supplemental light, growth and subterminal cuttings. An anatomical study of stems may shed light on why subterminal cuttings survived at higher rates under supplemental light. Sugar feeding experiments and other methods of carbohydrate manipulation would provide greater insight into the role carbohydrates play in the overwinter survival of cuttings. Hardwood cutting propagation (late season rooting) of *Viburnum carlesii* should also be studied since no published reports can be found to document if they also exhibit overwintering problems. And finally the role of transplanting and root disturbance should be investigated by scientific methods to either verify or disclaim the reports that post-propagation transplanting contributes to the reduced overwinter survival of cuttings.

Table 3.1. Taxa reported to be difficult to overwinter as rooted cuttings.

| Taxa | Reference |
|---|---|
| *Acer griseum* | (Brotzman, 1980; Fordham, 1982) |
| *Acer japonicum* | (Dixon, 1980) |
| *Acer palmatum* | (Anstey, 1969; Flemer, 1982) |
| *Acer rubrum* | (Flemer, 1982; Struve, 1980) |
| *Acer saccharum* | (Donnelly and Yawney, 1972) |
| *Betula pendula* | (Loach and Whalley, 1975) |
| *Cornus florida* | (Flemer, 1982) |
| *Cornus florida* forma *rubra* | (Waxman, 1965; Goodman and Stimart, 1987) |
| *Cornus kousa* 'Summer Stars' | (Flemer, 1982) |
| *Corylpsis* spp. | (Verstage, 1979) |
| *Enkianthus* spp. | (Fordham, 1962) |
| *Fothergillia* spp. | (Humphrey, 1979) |
| *Hamamelis* spp. | (Humphrey, 1979) |
| *Magnolia* spp. | (Fillmore, 1951) |
| *Rhododendron prunifolium* | (Fordham, 1962) |
| *Stewartia* spp. | (Fordham, 1982) |
| *Viburnum carlesii* | (Fillmore, 1951; Fordham, 1962; McMillan Browse, 1972; Templeton, 1957; Waxman, 1965; Wood and Cameron, 1989) |
| *Viburnum carlesii* 'Compactum' | (Flint and McGuire, 1961) |
| *Viburnum* X *burkwoodii* | (Templeton, 1957) |
| *Viburnum* X *juddii* | (Fillmore, 1951; Templeton, 1957) |
| *Viburnum opulus* 'Nanum' | (Smith and Treaster, 1985) |
| *Viburnum plicatum* var. *tomentosum* | (McMillan Browse, 1972) |

Table 3.2. Budbreaks of *Viburnum carlesii* induced by light treatments averaged over cutting type. Budbreak averaged over cutting type. Chi-square contingency table comparisons at days 20, 30, 40 and 55. n=100.

| TREATMENT | | DAY | | | |
|---|---|---|---|---|---|
| | | 20 | 30 | 40 | 55 |
| Control | | 9 | 11 | 12 | 16 |
| 8 HID | | 14 | 20 | 24 | 27 |
| 8 HID+NB | | 25 | 44 | 63 | 68 |
| 16 HID | | 56 | 83 | 91 | 97 |
| **CONTRAST** | | **DAY** | | | |
| Tmt 1 | Tmt 2 | 20 | 30 | 40 | 55 |
| Control | 8 HID | $1.23^{ns}$ | $3.09^{ns}$ | $4.80^{*}$ | $3.59^{ns}$ |
| Control | 8 HID+NB | $9.07^{***}$ | $27.31^{***}$ | $55.49^{***}$ | $55.50^{***}$ |
| Control | 16 HID | $50.35^{***}$ | $104.05^{***}$ | $124.93^{***}$ | $133.48^{***}$ |
| 8 HID | 8 HID+NB | $3.85^{*}$ | $13.24^{***}$ | $30.94^{***}$ | $33.70^{***}$ |
| 8 HID | 16 HID | $38.77^{***}$ | $79.45^{***}$ | $91.85^{***}$ | $103.99^{***}$ |
| 8 HID+NB | 16 HID | $19.94^{***}$ | $32.81^{***}$ | $22.13^{***}$ | $29.13^{***}$ |

Tab $X^2_{.05(1)}$=3.84, .025=5.02, .001=6.63

Table 3.3. Analysis of variance for stem growth of *Viburnum carlesii* at one week after budbreak.[z]

| Source[x] | DF | S.S. | Mean Sq. | F Value[y] |
|---|---|---|---|---|
| Light | 3 | 6420.06 | 2140.02 | 16.95*** |
| Cutting | 1 | 1399.96 | 1399.96 | 11.09*** |
| Light*Cut | 3 | 628.01 | 209.34 | 1.66 |
| Error | 198 | 24992.91 | 126.27 | |

z SAS GLM procedure, type I SS. adjusted for nonuniform observations.
y *** Highly significant at .001 prob.
x Light=light treatments, Cutting and Cut=cutting type.

Table 3.4. Budbreak of *Viburnum carlesii* at one week after 75 days of storage at 0°C. Chi-square contingency table comparisons.

| Contrast | | |
|---|---|---|
| Treatment 1 | Treatment 2 | Chi square value[z] |
| T. control | T. 16 HID | 5.59** |
| S. control | S. 16 HID | 7.81*** |
| T. 16 HID | S. 8 HID | 4.58* |
| T. 16 HID | S. 8 HID+NB | 7.81*** |

$X^2_{(1)}$.05=3.84, .025=5.02, .01=6.63

Table 3.5. Survival of *Viburnum carlesii* at two weeks after 75 days of storage at 0°C. Chi-square contingency table comparisons[z].

| Contrast | | |
|---|---|---|
| Treatment 1 | Treatment 2 | Chi square value[z] |
| T. Control | S. 8 HID+NB | 5.01* |
| T. Control | T. 16 HID | 4.80* |
| S. Control | S. 8 HID+NB | 6.47** |
| T. 8 HID | S. 8 HID | 3.96* |
| T. 8 HID | S. 8 HID+NB | 12.13*** |
| S. 8 HID | T. 16 HID | 7.62*** |
| T. 8 HID+NB | S. 8 HID+NB | 8.12*** |
| S. 8 HID+NB | T. 16 HID | 17.27*** |
| T. 16 HID | S. 16 HID | 6.14** |

$X^2_{(1)}$.05=3.84, .025=5.02, .01=6.63
z nonsignificant comparisions are not shown

Table 3.6. Percent survival of cuttings of *Viburnum carlesii* after 75 days storage as a function of light treatment and cutting type with regard to the presence or abscence of growth prior to storage. Relavent chi-square contingency table comparisons presented at the bottom of the table.

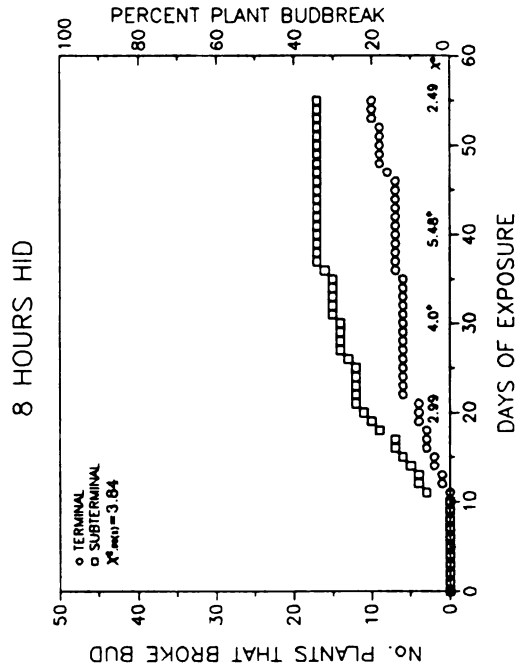
| Treatment | % Survival | Growth[z] response | n | Percent survival[y] term. | subterm. | total |
|---|---|---|---|---|---|---|
| Control | 38% | growth | 10 | 50 [1] | 33 [9] | 40% |
| | | none | 30 | 38 [2] | 36 [10] | 37% |
| 8 HID | 33% | growth | 18 | 57 [3] | 82 [11] | 72% |
| | | none | 22 | 0 [4] | 11 [12] | 8% |
| 8 HID+NB | 53% | growth | 24 | 33 [5] | 100 [13] | 67% |
| | | none | 16 | 25 [6] | 38 [14] | 31% |
| 16 HID | 28% | growth | 40 | 10 [7] | 45 [15] | 28% |
| | | none | 0 | ---[8] | ---[16] | --- |
| | | growth | 92 | 28% | 65% | 48% |
| | | none | 68 | 21% | 29% | 25% |
| Total | | | 160 | 25% | 51% | 38% |

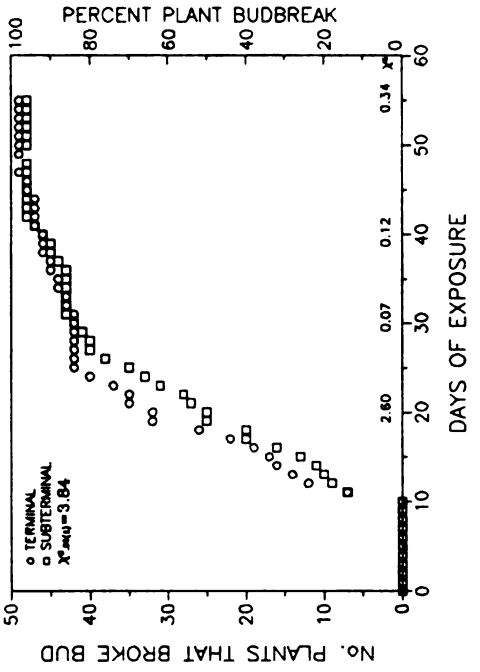
z Growth response defined as new budbreaks induced by light treatments before storage.

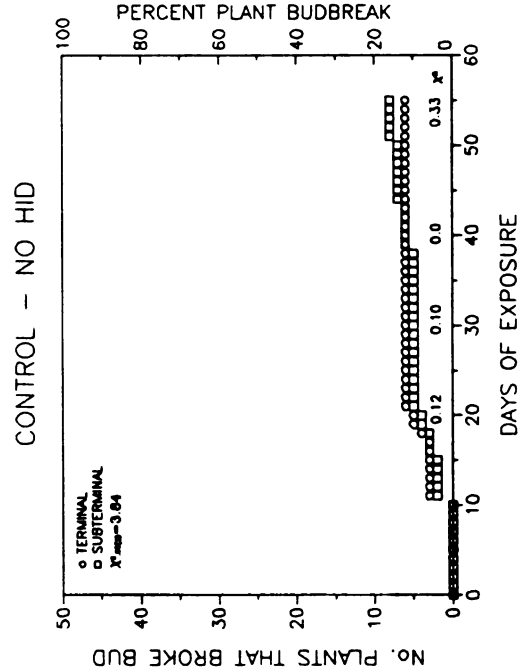
y Relavent chi-square comparisons at .05 prob., 1 df.:

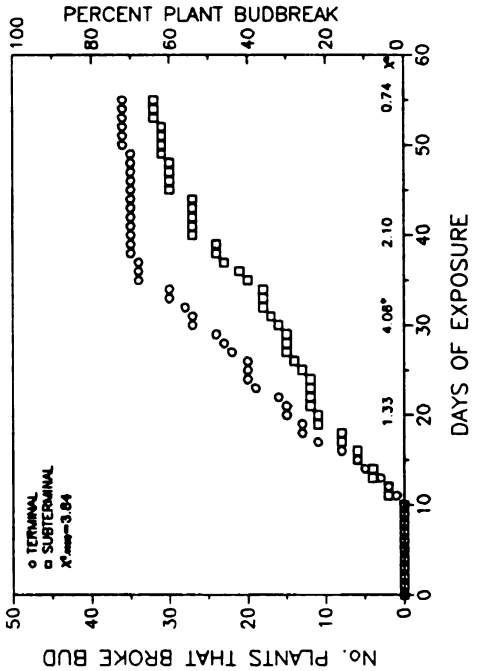
Comparisons between 1,2,9,10 all nonsignificant.
Comparisons between 11+13, 3+11, 4+12, 6+14 and 5+6 are nonsignificant.
Comparisons between 3+4, 11+12, 4+11, 5+13, 13+14, and 7+15 are significant.

Figure. 3.1. Cumulative budbreak response of terminal and subterminal rooted of *Viburnum carlesii* cuttings under four-55 day light treatments. Chi-square contingency table comparisons between terminal and subterminal cuttings (located at the bottom of each graph) with a tabular chi-square value of 3.84, 1 degree of freedom and * .05 prob.


8 HOURS HID
PERCENT PLANT BUDBREAK
No. PLANTS THAT BROKE BUD
DAYS OF EXPOSURE
TERMINAL
SUBTERMINAL


16 HOURS HID
PERCENT PLANT BUDBREAK
No. PLANTS THAT BROKE BUD
DAYS OF EXPOSURE
TERMINAL
SUBTERMINAL


CONTROL - NO HID
PERCENT PLANT BUDBREAK
No. PLANTS THAT BROKE BUD
DAYS OF EXPOSURE
TERMINAL
SUBTERMINAL


8 HOURS HID + NIGHT BREAK
PERCENT PLANT BUDBREAK
No. PLANTS THAT BROKE BUD
DAYS OF EXPOSURE
TERMINAL
SUBTERMINAL

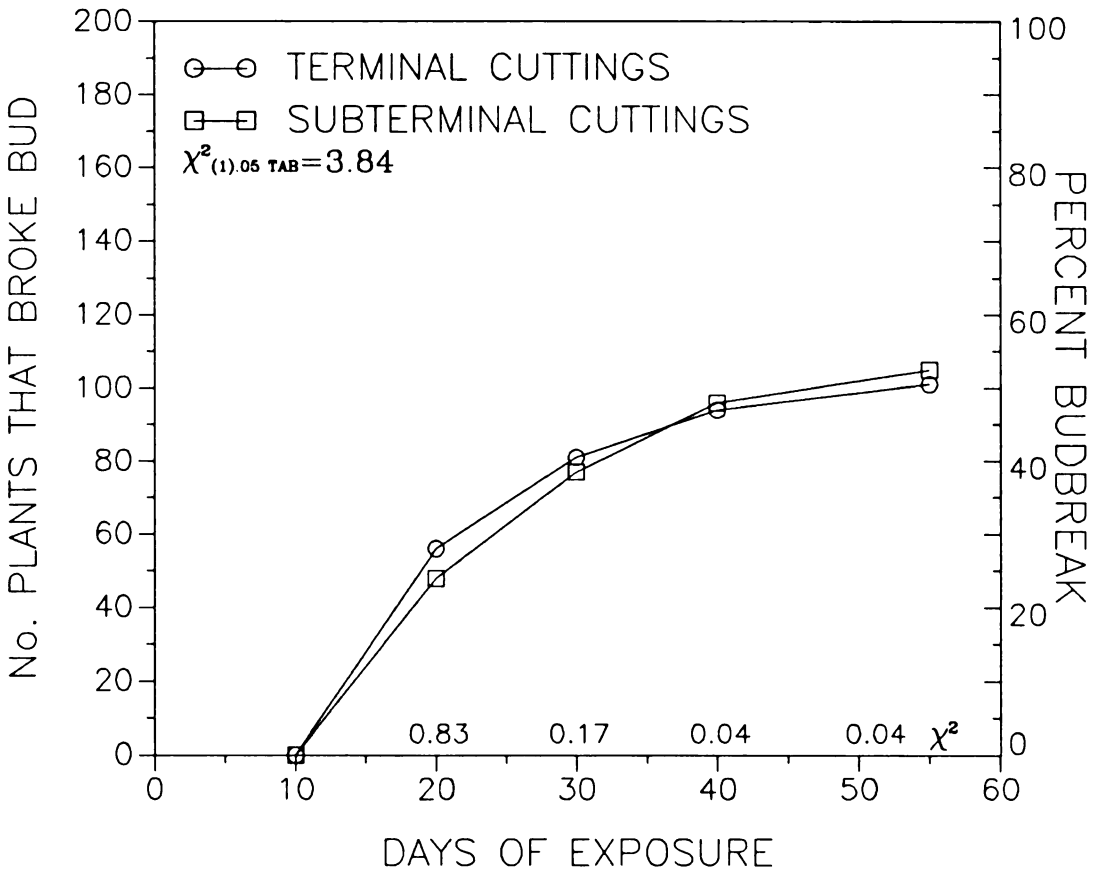



**Figure 3.2. Cumulative plant budbreak response of terminal and subterminal rooted cuttings of *Viburnum carlesii* averaged over four different 55 day light treatments. Chi-square contingency table comparisons between terminal and subterminal cuttings (located at the bottom of graph) with a tabular chi square value of 3.84, 1 degree of freedom and .05 prob.**

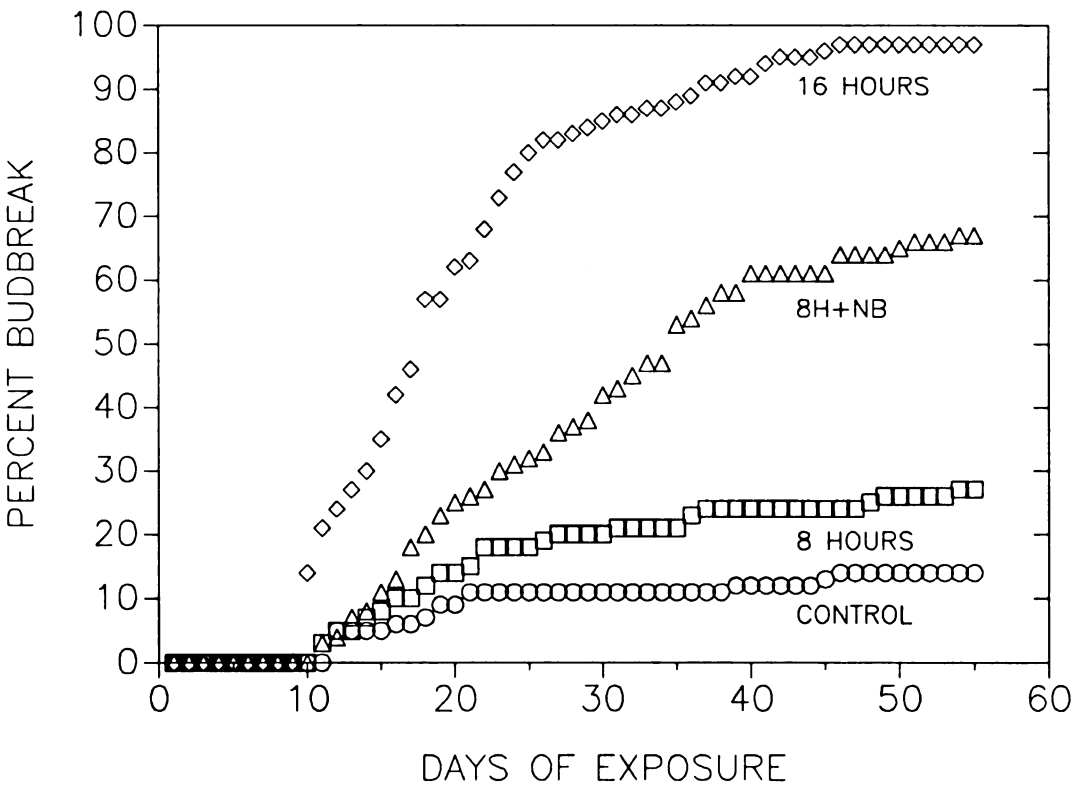



**Figure. 3.3. Cummulative plant budbreak response of rooted cuttings of *Viburnum carlesii* under four different 55-day light treatments averaged over terminal and subterminal cutting types.**

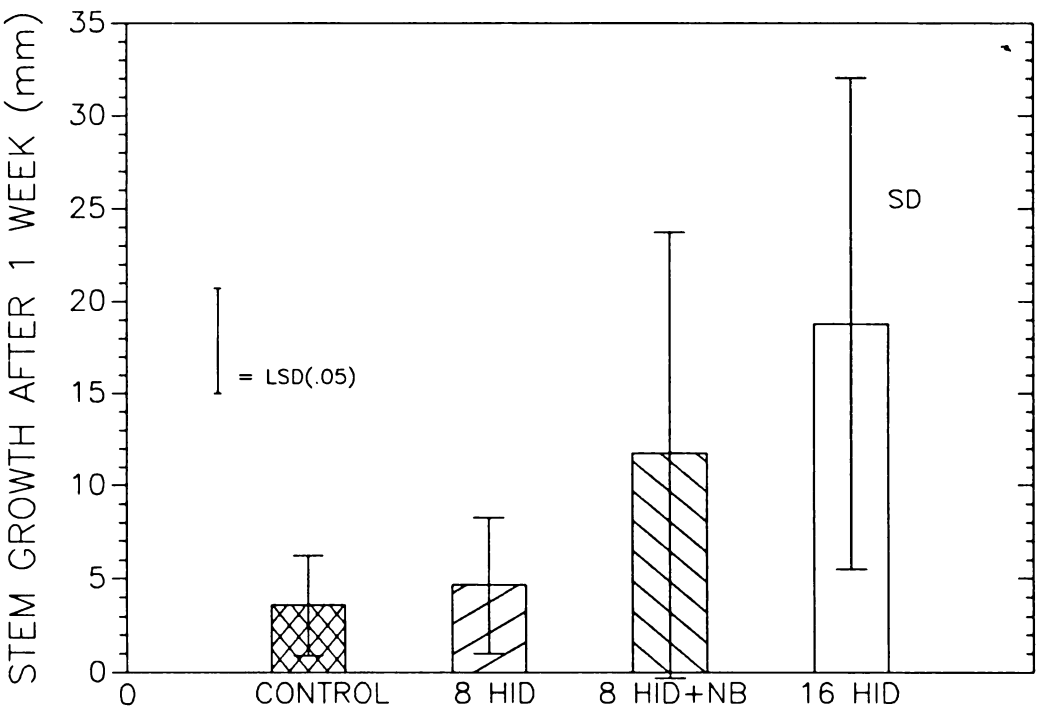



**Figure. 3.4. Mean stem growth per plant *Viburnum carlesii* 1 week after induced budbreak under four different 55-day light treatments and averaged over terminal and subterminal cutting type.**

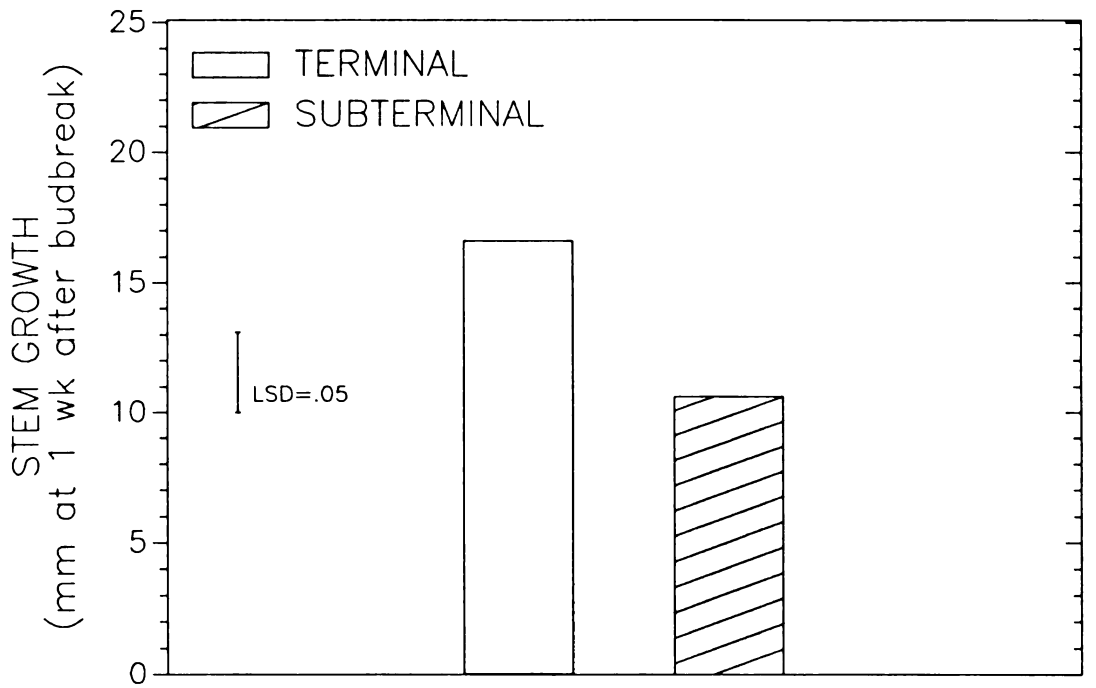



**Figure. 3.5. Mean stem growth of *Viburnum carlesii* terminal and subterminal cuttings (per plant 1 week after budbreak and averaged over four different 55-day light treatments).**

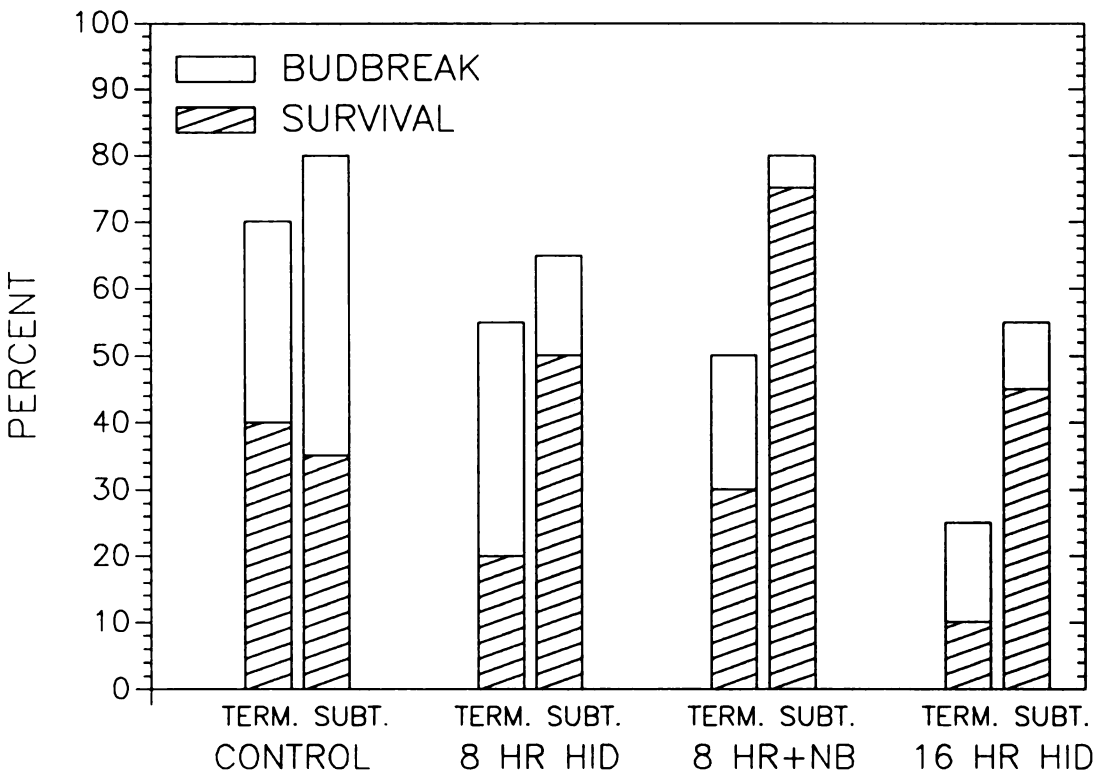



**Figure. 3.6. Percent budbreak and survival of terminal and subterminal cuttings of *Viburnum carlesii* that had been treated with four different 55-day light treatments and stored for 75 days at 0°C.**

# LIST OF REFERENCES

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