Propagation of Eastern Redbud (*Cercis canadensis*) by Stem Cuttings is Influenced by Clone and Date of Cutting Collection[1]

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Abstract

Stem cuttings of four popular clones of eastern redbud (*Cercis canadensis* L. 'Ace of Hearts', 'Appalachian Red', 'Hearts of Gold', and 'Forest Pansy') were taken on seven dates following budbreak during Spring and Summer 2007 and evaluated for rooting potential. Rooting was affected by a clone and cutting date interaction, indicating the optimum time to take cuttings was different for each clone. Cuttings of 'Ace of Hearts' taken 6 weeks after budbreak (WAB) rooted at 75 and 71% when treated with the potassium (K) salt (K-salt) of indolebutyric acid (K-IBA) at 5000 mg·liter^{-1} (ppm) or 15,000 mg·liter^{-1}, respectively. In contrast, cuttings of 'Appalachian Red' rooted at 96 and 93% when taken 15 WAB, the last date tested for that clone, and treated with K-IBA at 5000 mg·liter^{-1} or 15,000 mg·liter^{-1}, respectively. When taken 8 WAB and treated with K-IBA at 5000 mg·liter^{-1} or 15,000 mg·liter^{-1}, cuttings of 'Hearts of Gold' rooted at 42 and 58%, respectively. Cuttings of 'Forest Pansy' rooted poorly regardless of collection date or K-IBA treatment. Treatment of 'Ace of Hearts', 'Appalachian Red', and 'Hearts of Gold' with higher K-IBA rates generally did not increase rooting percentages, but often resulted in more robust root systems. Propagation by stem cuttings may be feasible for some clones of eastern redbud, but separate protocols are necessary for each clone.

Index words: adventitious rooting, auxin, K-indolebutyric acid, *Fabaceae*.

Significance to the Nursery Industry

Although clones of eastern redbud [*Cercis canadensis* (Fabaceae Lindl.)] are typically propagated by budding or micropropagation, recent research suggests some clones can be propagated by stem cuttings. Results herein support this hypothesis as the clones 'Appalachian Red', 'Ace of Hearts', and to a lesser extent, 'Hearts of Gold' demonstrated good rooting potential. However, results indicate the optimum time for taking stem cuttings and optimum K-IBA treatment differ for each clone. Stem cuttings of 'Appalachian Red' rooted at 96% when taken in July, 15 weeks after budbreak (WAB), and treated with the potassium (K) salt (K-salt) of indolebutyric acid (K-IBA) at 5000 mg·liter^{-1} (ppm). Stem cuttings of 'Ace of Hearts' rooted at 75% when taken in May, 6 WAB, and treated with K-IBA at 5000 mg·liter^{-1} whereas stem cuttings of 'Hearts of Gold' rooted at 58% when taken in June, 8 WAB, and treated with K-IBA at 15,000 mg·liter^{-1}. In contrast, stem cuttings of 'Forest Pansy' rooted poorly at all collection dates regardless of K-IBA treatment.

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Introduction

Eastern redbud is a small flowering tree native to the eastern United States. Several unique clones exist and are commonly grown by the nursery industry (1). Typically, propagation is by budding or micropropagation, though propagation by stem cuttings would be more economical (7). However, propagation by stem cuttings traditionally has been considered unfeasible (3, 7).

Previous research indicates some genotypes of redbud (*Cercis* L sp.) can be propagated successfully by stem cuttings, but only if cuttings are taken during a short period after budbreak. Tipton (8) was able to propagate Mexican redbud [*Cercis canadensis* var. *mexicana* (Rose) M. Hopkins] by stem cuttings when cuttings were taken shortly after budbreak. Regression analysis predicted rooting of 88% for cuttings taken 4 WAB, while cuttings taken 8, 12, or 16 WAB did not root. Dillion and Klingaman (2) reported 94% rooting of stem cuttings of an unidentified clone of eastern redbud when cuttings were taken in May whereas cuttings taken in June rooted at 50%, and cuttings taken after June did not root.

Some clones, notably *C. canadensis* 'Forest Pansy', have been difficult to propagate by stem cuttings regardless of collection date. Murphy (6), working with hardwood cuttings, did not root a single cutting of 'Forest Pansy'. Wooldridge et al. (unpublished data) were unable to root semi-hardwood cuttings of 'Forest Pansy'. Because 'Forest Pansy' is a popular clone, many nursery professionals have also attempted to propagate this cultivar by stem cuttings without success. The reputation of eastern redbud as difficult to root likely resulted in part from work with 'Forest Pansy'.

The aforementioned studies indicate stem cuttings taken soon after budbreak provide the best chance for successful propagation. However, Wooldridge et al. (9) reported semi-hardwood cuttings of 'Flame' eastern redbud taken 16 WAB rooted in higher percentages (83%) than softwood cuttings (63%) taken 6 WAB. These findings suggest that A) cuttings should not always be taken soon after budbreak, and B) for some genotypes the window for successful rooting is greater than others. While semi-hardwood stem cuttings of 'Flame' rooted more successfully, softwood cuttings also rooted in relatively high percentages.

Previous research suggests the optimum time for collecting cuttings of eastern redbud depends on the genotype. While reports of clonal effects on adventitious rooting are not uncommon (4), reports of interactions between clone and optimum cutting collection date are rare. Members of the genus *Populus* L. (poplars) appear to be influenced by this interaction. Yu et al. (10) collected stem cuttings of hybrid aspen clones (*Populus tremula* L. × *P. tremuloides* Michx.) in May and again in July. For most clones, cuttings collected in May rooted better, but for a few clones, cuttings taken in July performed better. Zalesny and Wiese (11) evaluated cuttings of several genomic groups of poplar taken every 3 weeks from December to April. Collection date accounted for much of the variation in root number and root dry weight. Kibbler et al. (5) conducted a study in Australia on the effects of genotype on propagation of lemon myrtle (*Backhousia citriodora* F. Muell) by stem cuttings. While most genotypes rooted in higher percentages from cuttings taken in spring, some genotypes rooted better when cuttings were taken in autumn.

Eastern redbud may respond similarly as reported in the aforementioned studies, and a protocol for propagation of particular clones may differ slightly. Therefore, the following research was conducted to determine the optimum growth stage to take stem cuttings for propagation of four popular clones of eastern redbud.

Describing growth stage can be difficult. Reporting the date when a stem cutting is taken is not an adequate indicator of growth stage as plant/tissue maturity on a given date can vary yearly because of environmental factors that influence growth of stock plants. Interpreting the growth stage based on calendar dates is especially problematic for growers in different geographic regions. Cuttings are often described as 'softwood', 'semi-hardwood', or 'hardwood', but these descriptions are not precise. One method of using calendar dates and reducing variation caused by environmental conditions is to record the number of weeks after budbreak the cutting is taken. This approach helps to mitigate the influence of environmental conditions prior to budbreak. In the following study WAB was used to describe when the cuttings were taken. Additional descriptions including stem diameter, color of leaves and stems, extent of leaf expansion, and lignification of the stems are also provided.

Materials and Methods

On seven dates during Spring and Summer 2007, stem cuttings were taken from four clones of eastern redbud growing in containers at Hawksridge Nursery, Hickory, NC. The clones were 'Ace of Hearts', 'Appalachian Red', 'Hearts of Gold', and 'Forest Pansy'. 'Ace of Hearts' is a dwarf cultivar with small leaves. 'Appalachian Red' has reddish flowers. 'Hearts of Gold' has golden yellow foliage, and 'Forest Pansy' has purple foliage. Each clone was growing in a block of approximately 50 to 100 trees under uniform cultural management, and cuttings were taken at random. Cuttings were taken 4, 6, 8, 10, 12, 15, and 18 weeks after budbreak (WAB) (Table 1). Cuttings were not taken from 'Appalachian Red' 18 WAB because sufficient cutting material was not available.

After severance, cuttings were placed in plastic bags, and the bags placed in a cooler with ice for transport to NC State University, Raleigh. In Raleigh, cuttings were stored overnight in a coldroom maintained at 4C (40F). The following day, cuttings were removed from the cooler and processed. Cuttings of 'Appalachian Red', 'Forest Pansy', and 'Hearts of Gold' were trimmed from the bases resulting in final lengths of 12 to 15 cm (5 to 6 in). Cuttings of 'Ace of Hearts' were also trimmed from the bases resulting in final lengths of 7 to 9 cm (3 to 4 in). The diameter immediately above the base of each cutting was then measured using calipers. If there was a node at the base, the diameter was measured above the node where the stem had returned to normal size. Mean diameter was calculated for each clone at the times of collection (WAB). The basal 5 cm (2 in) of each cutting was stripped of leaves and remaining leaves wider than 10 cm (4 in) were cut in half perpendicular to the midribs. Each cutting was administered a heavy wound with a razor blade by removing a 1 to 2 mm (0.04 to 0.08 in) wide strip of bark to expose the cambium on the basal 2 cm (0.8 in). Following wounding, the basal 1.5 cm (0.6 in) of each cutting was dipped for 2 sec in a solution of K-IBA at 5000 or 15,000 mg·liter^{-1} and cuttings were allowed to air dry for approximately 15 min. Each cutting was set (inserted) in a plastic Anderson Deep Tree Band (Anderson Tool and Die, Portland, OR) [6 × 6 × 12 cm (2.4 × 2.4 × 5 in)] containing perlite and peat (2:1, by vol). Bands (containers) were held in deep propagation flats [41 × 41 × 13 cm (16 × 16 × 5 in)] with 36 bands per flat (6

Table 1. Weeks after budbreak (WAB) and dates stem cuttings were taken with corresponding mean basal stem diameters of stem cuttings of four clones of eastern redbud and mean air temperatures during the 8 weeks the cuttings were under intermittent mist.

WAB	Cutting date (mm/dd)	Mean basal stem diameter (mm)[z] 'Ace of Hearts'	'Appalachian Red'	'Hearts of Gold'	'Forest Pansy'	Mean temp (C)[y]
4	05/09	1.67	3.38	2.57	2.48	24.8
6	05/23	1.74	2.53	2.36	2.39	25.6
8	06/06	1.84	2.43	2.31	2.64	25.8
10	06/20	2.00	2.92	2.57	2.77	26.7
12	07/02	1.87	2.78	2.53	2.28	26.9
15	07/25	1.93	3.09	2.33	2.46	26.4
18	08/15	2.14	—	2.66	2.70	24.7

[z]Each mean is based on the total number of cuttings collected.

[y]Mean temperature is an average of air temperature readings recorded every 15 min for the 8 weeks the cuttings were in the mist bed.

rows × 6 columns), and flats were placed under intermittent mist in a ventilated, polyethylene covered greenhouse. The greenhouse, also covered with 50% shade cloth, was located at the Horticulture Field Laboratory, Raleigh.

The experiment was a split-split plot arrangement of treatments with four replications and six cuttings per replication. K-IBA rate was at the whole plot level, clone at the split-plot level, and WAB at the split-split plot level. Each block was bordered on two ends by a buffer row of cuttings. Cuttings were taken over the course of 14 weeks but remained in the mist for only 8 weeks. Therefore, not all the cuttings were under mist at the same time. Position in the mist bed for each WAB, as well as K-IBA rate and clone, was based on randomization. To not have gaps in the canopy of the cuttings, cuttings were repositioned when a new group of cuttings was inserted or removed.

Mist was applied by nozzles that emitted fine mist at the rate of 11.4 liters·hr^{-1} (3 gal·hr^{-1}). Timing of mist application was designed to keep cuttings cool and moist. Periodically timing was adjusted to account for changing air temperature within the propagation house (Table 1). In general, mist was applied as follows: 12 am to 5 am: 6 sec every 45 min; 5 am to 10 am: 6 sec every 8 min; 10 am to 8 pm: 8 sec every 4 min; 8 pm to 12 am: 6 sec every 12 min. Temperature in the mist bed was recorded every 15 min by a HOBO Pendant Temperature Data Logger (Onset Computer Corp, Bourne, MA) shielded from solar radiation.

When cuttings taken 6 WAB were set, an unidentified fungus was observed on especially succulent cuttings of 'Hearts of Gold' taken 4 WAB. Subsequently all cuttings were sprayed periodically alternately with Cleary's 3336 (Cleary Chem. Corp., Dayton, NJ) or Quadris (Syngenta Crop Protection, Inc., Greensboro, NC) at recommended rates.

On the morning of July 13, (13 WAB) it was discovered the mist had not been operating for approximately the past 36 hr. At the time, cuttings taken 6, 8, 10, and 12 WAB were under mist. The problem was corrected, and the study continued. Cuttings taken 6 and 8 WAB had been in the mist bed for 7 and 5 weeks, respectively. Because rooting was likely to have already occurred (or not) for these cuttings, they were included in the statistical analysis. No data recorded from cuttings taken 10 and 12 WAB were included in the statistical analysis.

Cuttings were evaluated for rooting 8 weeks after they were set. A cutting having one primary root ≥ 1 mm (0.04 in) in length was classified as rooted. After recording number of primary roots, root length and root area were obtained using a Monochrome Agvision System 286 Image Analyzer (Decagon Devices, Inc., Pullman, WA). Roots were placed in an oven and dried at 65C (149F) until weight stabilized and then weighed. Rooting percentages were calculated, and all data were subjected to analysis of variance (ANOVA) procedures. Data were also analyzed by regression analysis, and when regression analysis was significant, simple linear and polynomial curves were fitted to the data. The maximum of the polynomial curve was calculated as a first order derivative of the independent variable where the dependent variable equaled zero. Treatment means of K-IBA rate were separated with Student's t test (unpaired) at $P \leq 0.05$.

Results and Discussion

Rooting percentage, root number, total root length, and total root dry weight were affected significantly by the three-

Table 2. Rooting response of stem cuttings of 'Ace of Hearts' eastern redbud as influenced by K-IBA rate and collection date.

K-IBA (mg·liter^{-1})	WAB[z]	Rooting[y] (%)	Root no.[x]	Total root length[x] (cm)	Total root area[x] (cm^2)	Total root dry wt.[x] (mg)
5000	4	50 ± 12	2.6 ± 0.5	2.5 ± 0.5	0.19 ± 0.02	1.7 ± 0.2
	6	75 ± 5	2.4 ± 0.6	3.9 ± 0.8	0.37 ± 0.07	2.3 ± 0.2
	8	33 ± 7	2.2 ± 0.5	3.9 ± 1.5	1.06 ± 0.85	1.1 ± 0.1
	15	58 ± 5	2.3 ± 0.6	4.6 ± 0.9	0.43 ± 0.08	3.2 ± 0.5
	18	17 ± 10	1.3 ± 0.3	5.1 ± 0.8	0.55 ± 0.12	4.8 ± 1.3
Linear[w]		NS	NS	NS	NS	***
Quadratic		NS	NS	NS	NS	*
Cubic		NS	NS	NS	NS	NS
15,000	4	33 ± 7	2.4 ± 0.6	4.5 ± 0.8	0.38 ± 0.06	2.3 ± 0.5
	6	71 ± 4	4.2 ± 0.6	6.7 ± 0.6	0.71 ± 0.07	3.9 ± 0.4
	8	50 ± 7	5.3 ± 1.1	5.5 ± 1.0	0.73 ± 0.18	1.7 ± 0.2
	15	46 ± 13	2.6 ± 0.7	5.3 ± 1.6	0.46 ± 0.15	3.0 ± 0.8
	18	63 ± 8	4.1 ± 0.8	10.3 ± 2.5	1.04 ± 0.23	6.9 ± 1.1
Linear[w]		NS	NS	NS	NS	**
Quadratic		NS	NS	NS	NS	*
Cubic		*	*	NS	**	*

[z]WAB = weeks after budbreak

[y]Data are means based on four replications with six cuttings per replication ± 1 SE.

[x]Data are means based on four replications and the number of cuttings which rooted per replication ± 1 SE.

[w]NS, *, **, *** Nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

Regression equations for K-IBA at 5000 mg·liter^{-1} are: total root dry wt. (linear) = 0.6 + 0.2x, $R^2 = 0.51$; total root dry wt (quadratic) = 3.4 – 0.5x + 0.03x^2, $R^2 = 0.66$.

Regression equations for K-IBA at 15,000 mg·liter^{-1} are: rooting = –66.2 + 40.2x – 4.0x^2 + 0.1x^3, $R^2 = 0.28$; root no. = –9.4 + 4.5x – 0.4x^2 + 0.01x^3, $R^2 = 0.37$; total root area = –1.6 + 0.8x – 0.08x^2 + 0.003x^3, $R^2 = 0.44$; total root dry wt. (linear) = 1.1 + 0.2x, $R^2 = 0.34$; total root dry wt. (quadratic) = 6.3 – 1.0x + 0.05x^2, $R^2 = 0.51$; total root dry wt. (cubic) = –1.6 + 1.9x – 0.3x^2 + 0.009x^3, $R^2 = 0.63$.

Table 3. Effect of K-IBA at 5000 or 15,000 mg·liter^{-1} on rooting response of selected clones of eastern redbud.

Clone	WAB[z]	Rooting (%)	Root no.	Total root length (cm)	Total root area (cm^2)	Total root dry wt. (mg)
'Ace of Hearts'	4	NS[y]	NS	NS	*[x]	NS
	6	NS	NS	*[x]	*[x]	*[x]
	8	NS	*[x]	NS	NS	*[x]
	15	NS	NS	NS	NS	NS
	18	*[x]	NS	NS	NS	NS
'Appalachian Red'	4	*[w]	NS	NS	NS	NS
	6	NS	NS	NS	NS	NS
	8	NS	NS	NS	NS	NS
	15	NS	***[x]	*[x]	*[x]	*[x]
'Hearts of Gold'	4	NS	—	—	—	—
	6	NS	**[x]	*[x]	*[x]	NS
	8	NS	***[x]	**[x]	**[x]	NS
	15	NS	NS	NS	NS	NS
	18	NS	NS	NS	NS	NS

[z]WAB = weeks after budbreak.

[y]Means separated with Student's *t* tests (unpaired) with NS, *, **, and *** indicating nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

[x]Rooting response of cuttings greater when treated with K-IBA at 15,000 mg·liter^{-1}.

[w]Rooting response of cuttings greater when treated with K-IBA at 5000 mg·liter^{-1}.

way interaction of WAB, K-IBA rate, and clone. Due to the interactions and the desire to determine the optimum collection date for cuttings, data are presented for each clone.

'Ace of Hearts'. Rooting percentages of cuttings of 'Ace of Hearts' were good with values observed as high as 75% (cuttings taken 6 WAB and treated with K-IBA at 5000 mg·liter^{-1}) (Table 2). There was no affect of WAB on rooting percentage of cuttings treated with K-IBA at 5000 mg·liter^{-1}, though root systems generally were larger for cuttings taken later in the season as evidenced by the strong linear effect of WAB on total root dry weight. For cuttings treated with K-IBA at 15,000 mg·liter^{-1}, there was a cubic effect of WAB on rooting percentage, root number, and total root area, and total root dry weight, demonstrating there were two periods during which good rooting occurred. Peak rooting of these cuttings was observed at 6 WAB (71%) and 18 WAB (63%). In contrast, at 18 WAB cuttings treated with K-IBA at 5000 mg·liter^{-1} rooted at a lower percentage (17%), indicating as the stem tissue matured, a higher auxin concentration was necessary to stimulate rooting. In many cases cuttings treated with the higher K-IBA rate also displayed larger root systems. For example, cuttings taken 6 WAB had significantly greater total root length, total root area, and total root dry weight when treated with K-IBA at 15,000 mg·liter^{-1} compared to 5000 mg·liter^{-1} (Table 3).

While moderate rooting percentages occurred throughout the summer, we recommend taking cuttings of 'Ace of Hearts' 6 WAB and treating with K-IBA at 15,000 mg·liter^{-1}. The leaves of cuttings taken 6 WAB were not fully expanded and were tinged with a bronze color. Basal stem diameter of the cuttings was 1.74 mm (0.07 in) (Table 1). The diameter of cuttings taken earlier was smaller and the diameter of cuttings taken in subsequent weeks was larger. This suggests that 6 WAB stem elongation of the plants was slowing and stems were beginning to thicken after an initial growth flush. The stems were green in color, and when pressure was applied the stems broke without sound and remained attached.

'Appalachian Red'. At 5000 and 15,000 mg·liter^{-1} rooting of cuttings of 'Appalachian Red' increased linearly with increasing WAB, resulting in the highest rooting percentages at 15 WAB, the last date sampled for this clone (Table 4). Cuttings treated with K-IBA at 5000 mg·liter^{-1} or 15,000 mg·liter^{-1} rooted at 96 and 93%, respectively and had an average of 8.0 and 19.2 primary roots, respectively. For cuttings treated with K-IBA at 15,000 mg·liter^{-1} the effect of WAB on root number, total root length, total root area, and total root dry weight was linear, whereas for cuttings treated with K-IBA at 5000 mg·liter^{-1} the effect of WAB on total root length, total root area, and total root dry weight was cubic.

Rooting percentages were comparable for cuttings treated with K-IBA at 5000 mg·liter^{-1} or 15,000 mg·liter^{-1}, except when cuttings were taken 4 WAB (Table 3). At that time cuttings treated with the lower K-IBA rate rooted at 67% compared to 25% for cuttings treated with the higher K-IBA rate. The higher K-IBA rate resulted in basal tissue necrosis and higher mortality. As noted above, the highest rooting percentages occurred when cuttings were taken at 15 WAB. For those cuttings, root number, total root length, total root area, and total root dry weight were greater when treated with K-IBA at 15,000 mg·liter^{-1} (Table 3).

Good results likely can be obtained by taking cuttings over the entire summer, but those cuttings taken at the end of the growing season and treated with high auxin rates are likely to have the largest root systems. When cuttings were taken 15 WAB on July 25, the stems were thick and dark green or brown in color. Growth had stopped on many shoots. When the stems were flexed, they broke without a snapping sound.

'Hearts of Gold'. At both levels of K-IBA treatment, rooting percentage of stem cuttings of 'Hearts of Gold' responded quadratically to increasing WAB, with the highest rooting observed for cuttings taken 8 WAB. Cuttings treated with K-IBA at 5000 mg·liter^{-1} or 15,000 mg·liter^{-1} rooted at 42 and 58%, respectively (Table 5). Cuttings taken 8 WAB and treated with K-IBA at 15,000 mg·liter^{-1} had significantly

Table 4. Rooting response of stem cuttings of 'Appalachian Red' eastern redbud as influenced by K-IBA rate and collection date.

K-IBA (mg·liter^{-1})	WAB[z]	Rooting[y] (%)	Root no.[x]	Total root length[x] (cm)	Total root area[x] (cm^2)	Total root dry wt.[x] (mg)
5000	4	67 ± 7	6.9 ± 2.4	7.7 ± 1.9	0.52 ± 0.14	4.0 ± 0.8
	6	63 ± 19	7.1 ± 1.4	25.6 ± 6.4	2.98 ± 0.79	13.6 ± 3.6
	8	88 ± 8	7.6 ± 1.2	15.3 ± 2.2	1.75 ± 0.27	6.3 ± 1.0
	15	96 ± 4	8.0 ± 1.2	18.6 ± 4.2	1.93 ± 0.42	11.8 ± 3.3
Linear[w]		*	NS	NS	NS	NS
Quadratic		NS	NS	NS	NS	NS
Cubic		NS	NS	*	*	*
15,000	4	25 ± 14	9.5 ± 0.3	7.1 ± 1.2	0.50 ± 0.12	1.9 ± 0.9
	6	54 ± 17	8.2 ± 1.4	18.0 ± 3.7	2.07 ± 0.50	9.1 ± 2.4
	8	75 ± 8	11.7 ± 2.5	21.3 ± 5.2	2.40 ± 0.55	9.0 ± 2.0
	15	93 ± 5	19.2 ± 0.6	45.7 ± 7.6	4.46 ± 0.76	28.4 ± 5.3
Linear[w]		**	***	***	***	***
Quadratic		NS	NS	NS	NS	NS
Cubic		NS	NS	NS	NS	NS

[z]WAB = weeks after budbreak.

[y]Data are means based on four replications with six cuttings ± 1 SE.

[x]Data are means based on four replications and the number of cuttings which rooted per replication ± 1 SE.

[w]NS, *, **, *** Nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

Regression equations for K-IBA at 5000 mg·liter^{-1} are: rooting = 54.0 + 2.9x, R^2 = 0.27; total root length = –185.3 + 83.5x – 10.3x^2 + 0.4x^3, R^2 = 0.45; total root area = –24.7 + 10.8x – 1.3x^2 + 0.005x^3, R^2 = 0.53; total root dry wt. = –111.1 + 50.5x – 6.4x^2 + 0.2x^3, R^2 = 0.45.

Regression equations for K-IBA at 15,000 mg·liter^{-1} are: rooting = 16.8 + 5.4x, R^2 = 0.47; root no. = 3.7 + 1.0x, R^2 = 0.68; total root length = –4.5 + 3.4x, R^2 = 0.70; total root area = –0.3 + 0.3x, R^2 = 0.64; total root dry wt. = –7.1 + 2.3x, R^2 = 0.73.

greater root number, total root length, and total root area than cuttings treated with K-IBA at 5000 mg·liter^{-1} (Table 3). For cuttings treated with K-IBA at 5000 mg·liter^{-1}, total root length and total root area increased linearly with increasing WAB (Table 5).

Rooting > 50% was achieved only when cuttings were taken 8 WAB and treated with K-IBA at 15,000 mg·liter^{-1} (Table 5). Rooting percentages increased from early collection dates, peaked when cuttings were taken 8 WAB, and subsequently decreased for K-IBA at both 5000 and 15,000

Table 5. Rooting response of stem cuttings of 'Hearts of Gold' eastern redbud as influenced by K-IBA rate and collection date.

K-IBA (mg·liter^{-1})	WAB[z]	Rooting[y] (%)	Root no.[x]	Total root length[x] (cm)	Total root area[x] (cm^2)	Total root dry wt.[x] (mg)
5000	4	4 ± 4	2.0[v]	0.9[v]	0.05[v]	1.0[v]
	6	25 ± 5	1.4 ± 0.2	2.6 ± 0.6	0.25 ± 0.07	3.1 ± 0.7
	8	42 ± 11	1.4 ± 0.3	3.1 ± 0.5	0.29 ± 0.06	1.6 ± 0.2
	15	17 ± 12	3.0 ± 2.0	3.8 ± 1.4	0.36 ± 0.02	1.8 ± 0.2
	18	13 ± 8	1.3 ± 0.3	13.5 ± 10.1	1.74 ± 1.45	8.8 ± 6.8
Linear[w]		NS	NS	*	*	NS
Quadratic		*	NS	NS	NS	NS
Cubic		NS	NS	NS	NS	NS
15,000	4	4 ± 4	2.0[v]	5.1[v]	0.33[v]	3.0[v]
	6	29 ± 12	4.7 ± 0.9	15.0 ± 5.1	1.53 ± 0.52	6.9 ± 2.2
	8	58 ± 8	4.3 ± 0.4	8.4 ± 1.3	0.87 ± 0.14	3.0 ± 0.6
	15	25 ± 8	3.1 ± 1.7	10.2 ± 6.2	0.90 ± 0.61	5.5 ± 3.5
	18	8 ± 8	1.5[v]	9.3[v]	1.07[v]	7.5[v]
Linear[w]		NS	NS	NS	NS	NS
Quadratic		***	NS	NS	NS	NS
Cubic		NS	NS	NS	NS	NS

[z]WAB = weeks after budbreak.

[y]Data are means based on four replications with six cuttings per replication ± 1 SE.

[x]Data are means based on four replications and the number of cuttings which rooted per replication ± 1 SE.

[w]NS, *, *** Nonsignificant or significant at $P < 0.05$, or 0.001, respectively.

[v]Datum is based on a single observation.

Regression equations for K-IBA at 5000 mg·liter^{-1} are: rooting = –35.7 + 13.7x – 0.6x^2, R^2 = 0.30; total root length = –2.2 + 0.7x, R^2 = 0.33; total root area = –0.4 + 0.09x, R^2 = 0.31.

Regression equations for K-IBA at 15,000 mg·liter^{-1} are: rooting = –64.6 + 22.2x – 1.0x^2, R^2 = 0.53.

mg·liter^{-1}. Successful propagation of 'Hearts of Gold' by stem cuttings is likely dependent on collecting cuttings during a relatively short period of time when stem growth is most conducive for adventitious root formation. It is conceivable rooting percentages would have continued to increase for cuttings taken 10 WAB, but these cuttings experienced high mortality because of the mist malfunction explained previously. Those cuttings rooted at an average of 10% (data not presented) and were not included in the analysis.

Leaves of cuttings taken 8 WAB were not fully expanded, and when stems were flexed, they broke without a snapping sound and remained attached. The basal diameter of the cuttings was 2.31 mm (0.09 in), the smallest of any collection date (Table 1). Cuttings taken in prior and subsequent weeks had larger diameters suggesting these cuttings were taken during a stage of rapid growth. We recommend taking cuttings during this period and treating the cuttings with high rates of auxin.

'Forest Pansy'. Cuttings of 'Forest Pansy' rooted poorly (0 to 12.5%) for all treatments (data not presented). Of a total of 336 cuttings of 'Forest Pansy' set during the study, 15 rooted and only one of these had a robust root system (cutting taken 15 WAB and treated with K-IBA at 15,000 mg·liter^{-1}). Thus, propagation of 'Forest Pansy' by stem cuttings is probably not feasible. This conclusion is based on the aforementioned results, the findings of Murphy (6), previous unpublished work by the authors, and other anecdotal reports from nursery professionals.

In summary, good rooting percentages were observed for stem cuttings of 'Ace of Hearts' 'Appalachian Red', and 'Hearts of Gold'. In contrast, cuttings of 'Forest Pansy' rooted poorly. Similar to poplars (10, 11) and lemon myrtle (5), the optimum time to take cuttings of eastern redbud differed for each clone. Cuttings of 'Appalachian Red' rooted well all summer, but cuttings consisting of the most mature wood clearly had the strongest response. Cuttings of 'Hearts of Gold' only rooted well when taken 8 WAB. Cuttings of 'Ace of Hearts' also rooted well all summer. High K-IBA rates did not generally increase rooting percentages, but in some cases it increased root development.

Tipton (8) reported highest rooting percentages of Mexican redbud from stem cuttings taken 4 WAB and treated with K-IBA at 20,000 mg·liter^{-1}. Tipton (8) also suggested higher rooting percentages could be obtained if cuttings were taken < 4 WAB, as soon as possible after budbreak. In the present study, however, the first cuttings taken following budbreak did not root best. Additionally, cuttings taken at that time (4 WAB) did not root in higher percentages when treated with higher rates of K-IBA. These results support previous findings of Wooldridge et al. (9) in which 'Flame' rooted better from semi-hardwood cuttings than softwood cuttings. In that same study, however, other clones (dwarf white and two F_1s from a cross of 'Flame' and dwarf white) responded similarly to Tipton's (8) hypothesis and rooted in higher percentages from softwood cuttings treated with high rates of K-IBA (15,000 mg·liter^{-1}).

Results herein indicate propagation by stem cuttings might be feasible for some clones of eastern redbud, while other clones remain difficult to root. For the clones that exhibit good rooting potential, the protocol for each one is slightly different. Cuttings of 'Ace of Hearts' rooted best when taken 6 or 18 WAB, while 'Hearts of Gold' showed the most rooting potential when cuttings were taken 8 WAB. Cuttings of 'Appalachian Red', rooted better from more mature wood. Treatment of cuttings with K-IBA at low rates yielded rooting percentages comparable to higher rates, but higher rates sometimes resulted in larger root systems.

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