Sodium Cellulose Glycolate as a Thickening Agent for Liquid Auxin Formulations can Enhance Rooting of Stem Cuttings[1]

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Abstract

Stem cuttings of *Abelia* 'Edward Goucher', *Buxus sinica* var. *insularis* 'Wintergreen', *Hedera helix*, *Hibiscus syriacus* 'Collie Mullens', *Ilex vomitoria* 'Nana', *Juniperus conferta* 'Blue Pacific', and *Rosa* 'Red Cascade' received a basal quick-dip in solutions of Dip 'N Grow at concentrations of 0 + 0, 50 + 25, 250 + 125, 500 + 250, 750 + 375, and 1000 + 500 ppm IBA + NAA prepared with and without 13.5 g/liter sodium cellulose glycolate (SCG) as a thickening agent. Cuttings of *Ilex vomitoria* 'Nana' exhibited increased rooting with increasing auxin concentration with inclusion of SCG. The other six taxa exhibited similar rooting percentages among all treatments, but exhibited an increase in root number and/or total root length with inclusion of SCG. Initial shoot growth on rooted cuttings of *Abelia* 'Edward Goucher' showed some reduction with increasing auxin concentration with inclusion of SCG, suggesting cuttings absorbed more auxin from solutions containing SCG owing to their extended period of exposure to the auxin. Otherwise, there were no negative responses to solutions containing SCG. The greater viscosity of solutions prepared with SCG can help reduce the possibility of spillage and evaporation of alcohol during use of the auxin solutions.

Index words: vegetative propagation, root-promoting chemicals, plant growth regulators, adventitious rooting.

Chemicals used in this study: indole-3-butyric acid (IBA), 1-naphthaleneacetic acid (NAA), sodium cellulose glycolate (SCG).

Taxa used in this study: Pink abelia (*Abelia* R. Br. 'Edward Goucher'); 'Wintergreen' boxwood [*Buxus sinica* (Rehd. & Wils.) M. Cheng var. *insularis* (Nakai) M. Cheng 'Wintergreen']; English ivy (*Hedera helix* L.); 'Collie Mullens' rose of Sharon (*Hibiscus syriacus* L. 'Collie Mullens'); Dwarf yaupon holly (*Ilex vomitoria* Ait. 'Nana'); 'Blue Pacific' shore juniper (*Juniperus conferta* Parl. 'Blue Pacific'); 'Red Cascade' miniature rose [*Rosa* L. 'Red Cascade'].

Significance to the Nursery Industry

Basal application methods are commonly used to apply auxin in liquid or powder formulations to stem cuttings in commercial propagation. An extended exposure of cuttings to auxin can increase the rooting response (rooting percentage, number of roots, and/or total root length) of some species. Compared to standard aqueous solutions of auxin, auxin solutions prepared with sodium cellulose glycolate (SCG) as a thickening agent exhibit greater viscosity, permitting adhesion of additional auxin solution to cuttings and extending the time the bases of cuttings are exposed to auxin.

Our study with seven woody taxa indicates, depending upon taxa, rooting response of stem cuttings can be increased by including SCG in auxin solutions used for a basal quick-dip treatment prior to insertion of cuttings in rooting substrate. Larger root systems on newly rooted cuttings may enhance subsequent establishment and growth of plants beyond the propagation phase. On taxa where the SCG treatments are more effective than with auxin alone, use of SCG may also allow lower rates of auxin to be used without a decrease in rooting response. Further studies should examine applicability of these results to cuttings of more-difficult-to-root taxa.

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Introduction

Auxins have been used in commercial horticulture to promote rooting of stem cuttings since the 1930s (4). Propagators typically apply auxin to the base of stem cuttings using a treatment in either liquid or dry powder (talc) formulations. An extended basal soak in a dilute auxin solution has also been used in the past (7). Absorption of auxin solutions at the base of stem cuttings can be influenced by auxin concentration and treatment duration, with increasing concentration and duration providing greater uptake (8). More recent studies (2, 3) in which auxin was applied to cuttings via a stabilized organic substrate indicated, depending upon the species and cultivar, an extended period of exposure can result in rooting that is equal to, or better than, results with a conventional basal quick-dip, while allowing use of a lower auxin rate. Subsequent research efforts have sought to identify a method that allows the auxin solution to remain in contact with the base of the cutting for a longer period, without sacrificing the simplicity of the basal quick-dip method or the ability to prepare (dilute) liquid auxin formulations to user-specified concentrations for use with specific taxa. One possible method could involve addition of a thickening agent to the liquid auxin solution.

The objective of the present study was to determine whether inclusion of the sodium cellulose glycolate (SCG) product Dip-Gel (Dip 'N Grow, Inc., Clackamas, OR) as a thickening agent for solutions of Dip 'N Grow [10,000 ppm indole-3-butyric acid (IBA) + 5000 ppm 1-naphthaleneacetic acid (NAA); Dip 'N Grow, Inc., Clackamas, OR] would affect rooting response and initial shoot development of stem cuttings of selected woody ornamentals. Beeson (1) and Childs and Beeson (5) previously tested the SCG product Cell-U-Wett for treating cuttings using moderate to high rates of auxin and found no improvement in rooting response. SCG, also known as sodium carboxymethylcellulose, is used as a thickener, binder, emulsifier, stabilizer, and colloidal suspending agent in salad dressing, fruit pie fillings, baked goods, dietetic foods, and other products (9).

Materials and Methods

Auxin solutions were prepared by diluting Dip 'N Grow concentrate (10,000 ppm IBA + 5000 ppm NAA; Dip 'N Grow, Inc., Clackamas, OR) with deionized water to final concentrations of 0 + 0, 50 + 25, 250 + 125, 500 + 250, 750 + 375, and 1000 + 500 ppm IBA + NAA. Solutions were prepared both with and without 13.5 g/liter SCG, providing a total of 12 treatments. (Preliminary studies indicated adhesion of SCG solutions was maximized using a rate of 13.5 g/liter.) SCG was added to auxin solutions at room temperature (23C) with continuous hand stirring until all SCG had dissolved. Solutions containing SCG were placed in capped containers and allowed to set overnight at room temperature before use.

Cutting propagation material was collected from outdoor container-grown stock plants (*Buxus sinica* var. *insularis* 'Wintergreen'), indoor container-grown stock plants (*Hedera helix* and *Rosa* 'Red Cascade'), or landscape stock plants (all other taxa) on the campus of Auburn University, Auburn, AL (32º36'N, 85º29'W, USDA Hardiness Zone 8a). Semi-hardwood stem cuttings of *Abelia* 'Edward Goucher' were prepared as two-node, 5 cm (2 in) long subterminal cuttings with leaves removed from the basal node, inserted into substrate on May 24, 2003, and evaluated after 35 days. Semi-hardwood stem cuttings of *Buxus sinica* var. *insularis* 'Wintergreen' were prepared as 5 cm (2 in) long, three-node subterminal cuttings with leaves removed from the basal node, inserted into substrate on March 5, 2003, and evaluated after 90 days. Softwood stem cuttings of *Hedera helix* were prepared as 3.8 cm (1.5 in), single-node cuttings, inserted into substrate on May 23, 2003, and evaluated after 28 days. Semi-hardwood stem cuttings of *Hibiscus syriacus* 'Collie Mullens' were prepared as 7.6 cm (3 in), three-node subterminal cuttings with the leaf removed from the basal node, inserted into substrate on May 23, 2003, and evaluated after 35 days. Hardwood stem cuttings of *Ilex vomitoria* 'Nana' were prepared as 7.6 cm (3 in) long terminal cuttings with leaves removed from the basal 1.3 cm (0.5 in), inserted into substrate on March 5, 2003, and evaluated after 91 days. Hardwood stem cuttings of *Juniperus conferta* 'Blue Pacific' were prepared as 7.6 cm (3 in) subterminal cuttings with branchlets removed from the basal 1.3 cm (0.5 in), inserted into substrate on March 6, 2003, and evaluated after 89 days. Semi-hardwood stem cuttings of *Rosa* 'Red Cascade' were prepared as 1 cm (1 in), single-node cuttings, inserted into substrate on May 23, 2003, and evaluated after 28 days.

All cuttings were dipped to a depth of 1.3 cm (0.5 in) into their respective solutions for 1 sec and inserted to a depth of 1.3 cm (0.5 in) into Fafard 3B mix (peat/perlite/vermiculite/pine bark) (Conrad Fafard, Inc., Agawam, MA) in individual cells of X-50SPS plug sheets [95 cm^3 (5.8 in^3) soil vol per cell] (for cuttings of *Hibiscus syriacus* 'Collie Mullens' and *Juniperus conferta* 'Blue Pacific') or X-72SPS plug sheets [72 cm^3 (4.4 in^3) soil vol per cell] (for cuttings of all other taxa) placed in L1020NCR polyethylene trays (Landmark Plastics, Akron, OH). Treatments were assigned to tray cells using a completely randomized design. Each treatment contained 15 cuttings per taxon, resulting in 180 cuttings per taxon. Cuttings were placed under a greenhouse mist system providing overhead mist with municipal tap water (pH ~7.0) for 6 sec every 20 min during daylight hours. Maximum photosynthetically active radiation measured in the greenhouse on the cutting bench with a LI-6200 portable photosynthesis system (LI-COR, Inc., Lincoln, NE) was 600 μmol/m^2/sec and daily maximum/minimum temperatures in the greenhouse were 27 ± 6C (80 ± 10F)/18 ± 3C (65 ± 5F).

Rooting response was evaluated based on rooting percentage, number of primary roots per rooted cuttings, and total root length per rooted cutting. A cutting was classified as rooted if it produced at least one root ≥ 5 mm (0.2 in) in length. Initial shoot growth was evaluated based on total shoot length per rooted cutting. Rooting percentage was analyzed with a generalized linear model with a binomial distribution and a logit link using the GENMOD procedure of SAS (SAS Version 9.1, SAS Institute, Inc., Cary, NC). Number of primary roots was analyzed with a generalized linear model with a negative binomial distribution and a log link using the GENMOD procedure of SAS. Total root length and total shoot length were analyzed with a linear model using the GLM procedure of SAS.

Results and Discussion

Abelia 'Edward Goucher'. Cuttings rooted at or near 100% in all treatments (Table 1). Increasing auxin concentration and inclusion of SCG in auxin solutions increased size of the root system produced by cuttings in an additive manner (no significant interaction) as indicated by number of roots and total root length. Number of roots per rooted cutting, based on coefficients of the generalized linear model (Table 2), increased by an average of approximately 7.8% for every 250 ppm increase in IBA concentration, while inclusion of SCG increased number of roots by approximately 15%. Total root length increased by 73 mm (2.9 in) for every 250 ppm increase in IBA concentration and by an additional 114 mm (4.5 in) when SCG was included in the auxin solution. Initial shoot growth response varied depending on whether SCG was included in the auxin solution (Table 1), with no notable change in treatments without SCG, but a decrease in shoot length with increasing IBA concentration when SCG was included (Table 2). This suggests uptake of auxin was greater with use of SCG, resulting in an increasing degree of shoot growth inhibition with increasing auxin concentration. A reduction in initial shoot development on cuttings receiving auxin over an extended period has been shown to occur with certain species and auxin formulations (2).

Buxus sinica var. *insularis* 'Wintergreen'. All treatments resulted in 100% rooting, and number of roots and initial shoot growth were similar among all treatments (Table 1). However, average total root length increased by an average of 68 mm (2.7 in) when SCG was included in auxin solutions.

Hedera helix. Cuttings rooted at 100% with all treatments (Table 1). Cuttings showed an overall increase in number of roots with increasing auxin concentration, with the effect being more pronounced when SCG was included in the auxin solution (Table 2). Both increasing auxin concentration and inclusion of SCG produced additive increases in total root length, with an average increase of 66 mm (2.6 in) for each 250 ppm increase in IBA concentration and 101 mm (4.0 in)

Table 1. Rooting percentage, root number, total root length, and total shoot length of stem cuttings of seven woody ornamentals treated with Dip 'N Grow[z] rooting compound solutions prepared with 0 or 13.5 g/liter sodium cellulose glycolate (SCG).

Auxin (IBA + NAA) conc. (mg/L)	Rooted (%)[y]		Roots/rooted cutting (no.)		Total root length/ rooted cutting (mm)		Total shoot length/ rooted cutting (mm)	
	0 g/L SCG	13.5 g/L SCG	0 g/L SCG	13.5 g/L SCG	0 g/L SCG	13.5 g/L SCG	0 g/L SCG	13.5 g/L SCG
Abelia 'Edward Goucher'								
0 + 0	93	100	22.6	26.5	618	726	158.2	151.8
50 + 25	93	100	23.0	26.1	805	810	174.3	146.0
250 + 125	100	100	26.0	27.3	815	928	161.5	151.7
500 + 250	100	100	26.8	30.3	879	986	169.7	119.0
750 + 375	100	100	26.3	34.4	821	1034	176.0	109.8
1000 + 500	100	100	32.2	35.9	979	1115	174.9	81.8
Significance[x]								
Auxin rate	0.3897		<0.0001		<0.0001		0.4677	
SCG	1.0000		<0.0001		0.0029		0.5406	
Auxin rate × SCG	NS		NS		NS		0.0008	
Buxus sinica var. *insularis* 'Wintergreen'								
0 + 0	100	100	10.2	11.7	482	556	10.9	12.9
50 + 25	100	100	12.5	11.9	540	599	15.8	13.3
250 + 125	100	100	10.9	11.2	569	612	14.2	15.3
500 + 250	100	100	11.6	12.6	568	637	15.8	14.7
750 + 375	100	100	10.9	11.5	554	625	13.0	16.7
1000 + 500	100	100	11.0	13.0	529	621	13.1	16.2
Significance								
Auxin rate	1.000		0.6994		0.3839		0.3151	
SCG	1.000		0.2293		0.0311		0.3653	
Auxin rate × SCG	NS		NS		NS		NS	
Hedera helix								
0 + 0	100	100	18.5	15.9	659	659	26.3	27.7
50 + 25	100	100	17.0	14.9	633	642	29.5	29.1
250 + 125	100	100	17.3	18.5	685	844	28.7	30.3
500 + 250	100	100	16.9	22.7	649	1016	26.5	29.7
750 + 375	100	100	20.7	21.3	831	875	33.5	27.8
1000 + 500	100	100	20.4	23.1	893	922	28.2	25.7
Significance								
Auxin rate	1.000		0.0331		<0.0001		0.9663	
SCG	1.000		0.3306		0.0088		0.7557	
Auxin rate × SCG	NS		0.0291		NS		NS	
Hibiscus syriacus 'Collie Mullens'								
0 + 0	100	100	13.5	14.7	1221	1231	13.5	13.1
50 + 25	100	100	14.9	17.7	1331	1364	16.1	14.7
250 + 125	100	100	18.1	18.3	1548	1534	15.9	16.5
500 + 250	100	100	17.9	19.1	1519	1821	14.9	15.0
750 + 375	100	100	20.5	21.3	1566	1924	18.4	15.7
1000 + 500	100	100	18.3	24.1	1398	2049	16.2	19.2
Significance								
Auxin rate	1.000		<0.0001		<0.0001		0.0057	
SCG	1.000		0.0025		0.6366		0.8948	
Auxin rate × SCG	NS		NS		0.0002		NS	
Ilex vomitoria 'Nana'								
0 + 0	87	73	8.1	10.7	207	289	24.8	18.0
50 + 25	87	87	12.6	10.1	335	336	27.7	26.7
250 + 125	100	100	11.1	10.7	311	387	19.8	24.9
500 + 250	80	100	15.0	11.9	443	413	17.8	27.0
750 + 375	73	100	11.5	11.3	394	470	17.2	29.9
1000 + 500	73	100	13.9	11.9	436	415	21.5	23.9
Significance								
Auxin rate	0.8844		0.0247		0.0014		0.7617	
SCG	0.0429		0.2576		0.3319		0.1560	
Auxin rate × SCG	NS		NS		NS		NS	

(Table 1 continued next page)

Table 1. (continued).

Auxin (IBA + NAA) conc. (mg/L)	Rooted (%)[y]		Roots/rooted cutting (no.)		Total root length/ rooted cutting (mm)		Total shoot length/ rooted cutting (mm)	
	0 g/L SCG	13.5 g/L SCG	0 g/L SCG	13.5 g/L SCG	0 g/L SCG	13.5 g/L SCG	0 g/L SCG	13.5 g/L SCG
				Juniperus conferta 'Blue Pacific'				
0 + 0	73	73	4.4	4.0	214	187	5.2	4.3
50 + 25	87	67	2.9	4.2	132	220	4.7	5.5
250 + 125	93	87	4.1	3.9	187	269	5.1	5.5
500 + 250	73	73	5.1	3.6	303	234	6.5	4.5
750 + 375	73	93	4.3	5.6	239	423	6.5	7.6
1000 + 500	93	87	5.0	7.0	271	565	5.7	9.6
Significance								
Auxin rate	0.1761		0.0007		<0.0001		0.0137	
SCG	0.7020		0.3001		0.0070		0.4472	
Auxin rate × SCG	NS		NS		0.0176		NS	
				Rosa 'Red Cascade'				
0 + 0	100	100	5.9	7.2	266	345	34.5	35.3
50 + 25	100	100	5.7	7.0	247	336	34.3	38.3
250 + 125	100	93	6.3	6.3	347	413	41.9	39.4
500 + 250	100	100	6.5	6.8	399	423	41.8	39.7
750 + 375	100	100	7.7	7.5	410	485	36.3	38.3
1000 + 500	93	100	6.6	7.6	411	502	35.6	32.9
Significance								
Auxin rate	0.4509		0.0234		<0.0001		0.7930	
SCG	1.0000		0.0506		0.0011		0.9481	
Auxin rate × SCG	NS		NS		NS		NS	

[z]Indole-3-butyric acid (IBA) + 1-naphthaleneacetic acid (NAA).

[y]Fifteen cuttings per treatment combination per taxon.

[x]*P*-value for main effects (auxin rate and SCG) and interaction. If the interaction term was nonsignificant, significance is shown for a model with main effects only.

when SCG was included in the auxin solution. Initial shoot growth was similar among all treatments, indicating no suppression of shoot growth at the auxin concentrations used in this study.

Hibiscus syriacus 'Collie Mullens'. All treatments resulted in 100% rooting (Table 1). Number of roots per rooted cutting, based on the coefficients of the generalized linear model (Table 2), increased by approximately 7.8% for every 250 ppm increase in IBA concentration, while inclusion of SCG increased the number of roots by approximately 12%. Total number of roots per rooted cutting was similar in treatments without SCG, but increased an average of approximately 201 mm (7.9 in) per 250 ppm increase in IBA concentration. Total shoot length showed some (but not a strong) indication of an increase with increasing auxin concentration, but was not affected by inclusion of SCG.

Ilex vomitoria 'Nana'. Cuttings rooted at 73 to 100%, depending on treatment (Table 1). Cuttings tended to show some increase in rooting percentage when SCG was included in the auxin solution (Table 2). Number of roots and total root length showed a tendency to increase with increasing auxin concentration, but were not notably affected by inclusion of SCG in the auxin solutions. Total shoot length was similar among all treatments.

Juniperus conferta 'Blue Pacific'. Rooting percentages were similar among all treatments (Table 1). There was some indication of an increase in number of roots with increasing auxin concentration, although this seemed to be more evident with treatments in which SCG was included (Table 2). This was also reflected by total root length, which was similar in treatments without SCG, but increased by an average of 87 mm (3.4 in) for each 250 ppm increase in IBA concentration. Total length of new shoots also increased with increasing auxin concentration, possibly due to larger root systems, but was unaffected by inclusion of SCG.

Rosa 'Red Cascade'. Cuttings rooted at or near 100% in all treatments (Table 1). Number of roots showed some (but not a strong) tendency to increase with increasing IBA concentration. Total root length increased by an average of 42 mm (1.7 in) for every 250 ppm increase in IBA concentration and by 70 mm (2.8 in) with inclusion of SCG in the rooting solution. Shoot length (one shoot per cutting) was similar among all treatments.

Overall, results suggest, depending on taxon, rooting response of stem cuttings can be increased by including SCG in auxin solutions used for a 1-sec basal quick-dip treatment prior to insertion of cuttings in rooting substrate. SCG as a thickening agent allows more auxin solution to adhere to the cutting base, exposing the tissue to auxin over a longer time compared with use of an aqueous auxin solution alone. Results are consistent with those exhibited by cuttings exposed to auxin over an extended period via an auxin-treated stabilized organic substrate (3). Our results differ from those of Beeson (1) who reported similar rooting results using Dip

Table 2. **Linear coefficients of model terms for the response variables logit(rooted)[z], log(roots)[y], root length[x], and shoot length[w] representing the rooting response of stem cuttings of seven woody ornamentals treated with a basal quick-dip using auxin solutions prepared with and without 13.5 g/liter sodium cellulose glycolate (SCG).**

Response	Intercept	Auxin rate[v]	SCG[u]
	Abelia 'Edward Goucher'		
Logit(rooted)	2.40**[t]	0.0127	26.34
Log(roots)	3.12***	0.0003***	0.14***
Root length	694.58***	0.2934***	113.78**
Shoot length (without SCG)[s]	163.86***	0.0122	
Shoot length (with SCG)	155.70***	–0.0682***	
	Buxus sinica var. *insularis* 'Wintergreen'		
Logit(rooted)	1.00[r]		
Log(roots)	2.40***	0.0000	0.07
Root length	524.50***	0.0375	67.90*
Shoot length	13.12***	0.0016	1.04
	Hedera helix		
Rooted	1.00[r]		
Log(roots) (without SCG)	2.844***	0.0002*	
Log(roots) (with SCG)	2.78***	0.0004***	
Root length	613.52***	0.2626***	101.16**
Shoot length	28.83***	–0.0001	–0.43
	Hibiscus syriacus 'Collie Mullens'		
Rooted	1.00[r]		
Log(roots)	2.69***	0.0003***	0.11**
Root length (without SCG)	1356.81***	0.1736	
Root length (with SCG)	1313.13***	0.8020***	
Shoot length	14.46***	0.0032**	–0.11
	Ilex vomitoria 'Nana'		
Logit(rooted)	1.57***	0.0001	1.03*
Log(roots)	2.39***	0.0002*	–0.08
Root length	287.81***	0.1541**	33.08
Shoot length	22.03***	–0.0011	3.85
	Juniperus conferta 'Blue Pacific'		
Logit(rooted)	1.24***	0.0007	–0.15
Log(roots)	1.26***	0.0004***	0.10
Root length (without SCG)	175.99***	0.1073	
Root length (with SCG)	169.94***	0.3476***	
Shoot length	13.11***	0.0085*	1.93
	Rosa 'Red Cascade'		
Logit(rooted)	5.28***	–0.0015	0.00
Log(roots)	1.81***	0.0001*	0.09
Root length	275.16***	0.1690***	70.12**
Shoot length	37.75***	–0.0008	–0.14

[z]Logit (log odds) of the proportion of rooted cuttings based on analysis using a generalized linear model with a binomial distribution and a logit link.

[y]Log of the number of primary roots per rooted cutting based on analysis using a generalized linear model with a negative binomial distribution and a log link.

[x]Total root length (mm) per rooted cutting based on analysis using a linear model.

[w]Total shoot length (mm) per rooted cutting based on analysis using a linear model.

[v]Rate of IBA (ppm) provided by diluting Dip 'N Grow (IBA + NAA) rooting compound.

[u]Coefficient represents a change in response when solutions were prepared with SCG in comparison with solutions prepared without SCG.

[t]Nonsignificant (NS) or significant (*, **, ***) at $P \leq 0.05$, 0.01, or 0.001, respectively.

[s]When there as a significant interaction between auxin rate and SCG, results are presented separately for treatments with and without SCG.

[r]100% of cuttings rooted; therefore, only an intercept of 1.00 is shown.

'N Grow prepared with and without SCG; however, Beeson used different species and higher rates of auxin.

Owing to its viscosity, use of SCG in auxin solutions may be of additional convenience to the propagator by reducing the chance of spillage and evaporation of the alcohol used as a solvent for the auxin. Whether use of SCG can enhance rooting of cuttings in the absence of auxin remains questionable. Alginate gels have been shown capable of protecting wounds of cuttings (6), so SCG solutions might work in a similar manner. Beeson (1) reported another advantage of using SCG in alcohol-based auxin solutions is the auxins remain in solution and are active for at least several weeks without refrigeration. Beeson also suggested more cuttings could be treated in a given amount of time using auxin solutions prepared with SCG than those prepared with water alone, assuming the former treatment requires a 1-sec dip and the latter treatment requires a 2- to 4-sec treatment. However, in the present study, a 1-sec dip was utilized for all treatments, as we considered a 1-sec dip to be more common in large-volume commercial cutting propagation practice.

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