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Production of seed-propagated compact potted *Corylopsis* plant in one year

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Abstract: The feasibility to produce compact *Corylopsis sinensis* var. *calvescens* and *C. coreana* plant in a 10 cm pot in one year from transplanting seedlings with maximized number of short shoots and inflorescences was investigated. *Corylopsis sinensis* var. *calvescens* was selected as a suitable species to produce compact plant with inflorescences. Slow release fertilizer (SRF) at a rate of 0, 0.125, 0.25, and 0.5 g per pot was applied to the surface of the growing medium (Expt. 1). Shoots were pinched 2 (Feb. 28), 4, 6, and 8 weeks (May 16) (Expt. 2) after transplanting, and ancymidol, paclobutrazol, chlormequat, and daminozide plant growth retardants were treated (Expt. 3). Application of a SRF at 0.5 g per pot and pinching four times at 2-week intervals before May 16 effectively increased the flowering percentages and the number of stems with inflorescences, to accelerate flowering, and also produced a compact plants. Paclobutrazol at 10-20 mg/L applied as soil drench was effective in inhibiting stem elongation in the first year; however, higher concentrations should be avoided to prevent excessive reduction in the growth of shoots and production of malformed inflorescences.

1. Introduction

The genus *Corylopsis* Siebold & Zucc., commonly known as Winter Hazel that flowers early in the spring in China and Korea, is a shrub or small tree. Most of the *Corylopsis* species grows tall reaching a height of 2-4 meters (Bean and Anisko, 2014). Flowers are bisexual and seeds are produced. Among 29 species, 19 species are endemic in China (Zhang *et al*., 2003). *Chinensis sinensis* Hems. var. *calvescens* Rehder & E.H. Wilson is growing in the mountains in Guangxi, Sichuan, and Jiangxi, among other provinces in China (Zhang *et al*., 2003) and *C. coreana* Uyeki (Son *et al*., 2016) in a rather restricted area in Korea. All species are deciduous shrubs producing light yellow pendant racemes (inflorescence) measuring about 5 cm in length, followed by appearance of leaves (Fig. 1).

Corylopsis, one of many germplasms native and indigenous to China that includes an endangered *Acer pentaphyllum* Diels (Roh *et al*., 2008 b), are not well known to horticulturist, growers, and landscape industry, but has a great potential to develop as a new ornamental plant. Although *Corylopsis* may be available from rooted cuttings or tissue-cultured propagules for a mass propagation (Moon *et al*., 2002; Koh and Lim, 2006), the success of the rooting of cuttings depends on the season when cuttings were collected and may not provide a large number of plants (Kwon *et al*., 2011) and acclimatization of tissue culture propagules is not easy (Moon *et al*., 2002; Koh and Lim, 2006). Therefore, seeds are a viable alternative source for mass propagation and for forcing seedlings to flower. Suitable species should first be identified and then excessive stem elongation must be controlled using plant growth retardants (Currey and Lopez, 2016), and pinching combined with plant growth retardant treatment (Jeong, 2000).

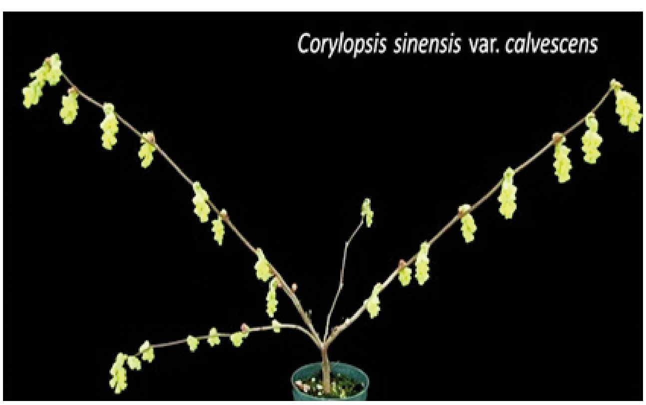

Fig. 1 - Appearance of *C. sinensis* var. *calvescens* at anthesis produced in a 10 cm pot from seeds. Clusters of flower buds (inflorescences) are well developed on long shoots.

Stem elongation can be inhibited by practices such as pinching shoots in many floral and ornamental plants, resulting in short plant height (Lee *et al*., 2006; Latimer and Whipker, 2013). Growth and flowering is also affected by treatment with plant growth regulators. Among the many growth retardants, ancymidol (α-Cyclopropyl-α-(4-methoxyphenyl)-5-pyrimidinemethanol), daminozide (Butanedioic acid mono(2,2-dimethylhydrazide), chlormequat (2-Chloro-*N,N,N*-trimethylethanaminium chloride), and paclobutrazol [(2RS, 3RS)-1-(4-Chlorophenyl)-4,4-dimethyl-2-(1H-1,2,4-triazol-1-yl) penta-3-ol] have been used in many floral and ornamental plants to inhibit stem elongation (Currey and Lopez, 2016). Generally, ancymidol and paclobutrazol is effective when applied as a soil drench, and daminozide and chlormequat when applied as a foliar spray.

Germination of *Corylopsis* seeds as affected by warm and cold stratification and the X-ray imaging to separate full seeds from empty seeds is well documented (Kim *et al*., 2015, 2017, 2018). To produce compact and flowering *Corylopsis* plants in small pots in one year after transplanting seedlings, selection of proper species and the most suitable cultural practices should be identified. However, there is no report on the growth and flowering of *Corylopsis* starting from small propagules regardless of propagation methods: seed propagation, rooting of cuttings, and *in vitro* propagation. Shortening the total production time from 2-3 years to one year while ensuring the qualities of plants at flowering from seedlings in *Lilium longiflorum* Thunb. bulbils in *L.* ×*elegans* Thunb. and tissue-cultured propagules in interspecific hybrids between *L. longiflorum* and *L.* ×*elegans* was reviewed (Roh, 1992, 1996).

Production of *Corylopsis* in a small pot with inflorescence will attract and enable consumers to purchase at the nursery or the garden center in the early spring, and then plant them in the garden to enjoy the beauty of flowers for many years. The objectives of this research were (1) to select the species to grow starting from seeds in small pots, and to study the effect of (2) slow release fertilizer (SRF) treatments, (3) the pinching frequencies, and (4) plant growth retardant treatments to produce compact seed-propagated *Corylopsis* plants in 10 cm pots in one year from transplanting seedlings.

2. Materials and Methods

Preliminary field evaluation to select a suitable species for final evaluation

Seeds of 45 accessions (data not presented) including *C. glabrescens* (NA50804, Longwood 1997-0068B, Longwood Chimes), *C. spicata* (NA37208, NA40102, Arnold 7950A), *C. pauciflora* (NA37205, Longwood 1944-0213*H), and *C. vietchiana* (NA37208, NA65619) were sown between Oct. 2 and Nov. 2 and planted into 10 cm pot filled with ProMix BM (Premier Horticulture Inc., Quakertown, PA, USA) between Mar. 1 and Apr. 2, and grown in the field. The final evaluation based on the number of plants that flowered and the growth habits, *C. coreana* and *C. sinensis* var. *calvescens* (NA 57391) (Roh *et al*., 2008 a) were selected (Table 1) for evaluation in the next three experiments.

Effect of slow release fertilizer treatment on growth and flowering (Expt. 1)

About 200 seeds each of *C. sinensis* var. *calvescens* and *C. coreana* were sown on Oct. 20, 2009 in a 15 cm pot and received temperature treatments [20°C (Oct. 21 - Dec. 1) and 5°C (Dec. 2, 2009 - Feb. 16, 2010)]. One seedling was transplanted per 10 cm pot filled with ProMix BM on Mar. 4, 2010. On Mar. 18, 2010 when seedlings formed 4 nodes, the main shoot was pinched leaving two pair of leaves.

Slow release fertilizer (SRF; Osmocote, 14 N - 6.2 P - 11.6K; Scotts Co., Marysville, OH, USA) was applied to the surface of the growing medium at transplanting seedlings at a rate of 0, 0.125, 0.25, and 0.5 g per 10 cm pot (Table 2). During the culture, plants were fertilized with 1.33 g/L of 15N - 7P - 12.8K water soluble fertilizer once a month.

Greenhouse day temperature was maintained at 21-22°C on Oct. 1, 15-17°C on Nov. 1, 13-14°C on Nov. 16, 10-12°C on Dec. 1, 7-8°C on Dec. 16, 2010 and at 4-5°C on Jan. 1, 21-24°C on Apr. 16, 2011, and was raised by 2.5°C every 2 weeks until Sept. 1, 2011. Night temperature was maintained 2°C lower than the day temperature. The number of weeks to flower counted from the date of transplanting seedlings to pots, and the number and length of nodes with inflorescences from the three longest shoots, and the number of nodes with 2 inflorescences was recorded from 15 plants per treatment. Flowering date was recorded when two florets each from two inflorescences reached anthesis, and data were subjected to the regression analysis for each species using Statistical Analysis System program (SAS, 2002).

Effect of pinching frequencies on growth and flowering (Expt. 2)

After sowing about 200 seeds as described in Expt. 1, seedlings were transplanted. On Mar. 18, 2010, 0.25 g of slow release fertilizer was applied to the surface of growing medium and the effect of pinching frequencies on *C. sinensis* var. *calvescens* was evaluated. Shoots were either not-pinched or pinched 2 (Feb. 28), 4 (Apr. 18), 6 (May 2), and 8 weeks (May 16) after transplanting as outlined (Table 3). To the surface of the growing medium at transplanting seedlings 0.8 g of slow release fertilizer per pot was applied, and plants were fertilized with 1.33 g/L of 15N - 7P - 12.8K water soluble fertilizer once a month.

The number of weeks to flower, and the total number of shoots with flowers and flower buds, and the length and number of flowers from the first and second longest shoots was recorded from 15 plants per treatment. The number of days to flower was counted from the date of transplanting. Data were subjected to the analysis of variance (ANOVA) and means were compared with Tukey's honestly significant difference (HSD) test.

Effect of growth retardants treatment on growth and flowering (Expt. 3)

Corylopsis sinensis var. *calvescens* seeds were sown and transplanted, and pinched as described in Expt. 1, and pinched again on May 26, 2010. Plants were grown in greenhouse maintained at 18-21°C/16-19°C (day/night) and then in greenhouse maintained at 22-25°C/20-23°C until July 6. To the surface of the growing medium at transplanting seedlings 0.8 g of slow release fertilizer per pot was applied, and plants were fertilized with 1.33 g/L of 15N - 7P - 12.8K water soluble fertilizer once a month.

Growth retardants were applied on Jul. 7, when new shoots were about 5-8 cm long. Each pot was treated with 25 mL of ancymidol [0.026% active ingredient (a.i.)] and paclobutrazol (0.4% a.i.) at 0, 10, 20, 40, and 80 mg/L was applied as a soil drench. Daminozide (85% a.i.) and chlormequat (11.8% a.i.) at 0, 2,500,

Table 1 - Evaluation of flowering and growth habit in the field *C. coreana* and *C. sinensis* var. *calvescens*

Species	Seed harvest	2008		2009		
		Germination	Transplanting	Flowering [z]	No. of plants [y]	Growth characteristics [x]
C. coreana	2007	Mar. 6	Mar. 12	Mar. 19-25 (Mar. 21)	9 (21)	Upright (12), prostrate/upright (1)
C. sinensis var. *calvescens*	2007	Mar. 1	Apr. 2	Mar. 27-Apr. 7 (Apr. 2)	14 (16)	Upright (13), prostrate/upright (1)
	2008	Feb. 26	Apr. 8	Mar. 22-Apr. 3 (Mar. 28)	16 (16)	Upright (16)

[z] Range and mean of flowering.
[y] Plants that produced inflorescence and the total number of plants evaluated (parenthesis).
[x] Number of plants (parenthesis) showing upright and prostrate growth characteristics.

5,000, 7,500, and 10,000 mg/L was applied as a foliar spray, and 200 mL of solution was applied to 15 plants. On Nov. 20, 2010, plants were grown in a greenhouse maintained at 4-5°C for cold treatment until Mar. 1, 2011.

Dates of flowering, when two florets from an inflorescence reached anthesis were recorded and the lengths of two longest shoots (shoot length A) per plant and shoots longer than 3 cm were counted on Jan. 16. Plants were moved outdoors on Mar. 27, and the new growth of two longest shoots (shoot length B) was also recorded on May 10, 2011. Data collected from 15 plants per treatment were analyzed by two-way ANOVA with plant growth retardants and concentration as variables.

3. Results

Selection of a suitable species for final evaluation

Following evaluation of 45 accessions including *C. glabrescens,C. spicata*, *C. pauciflora*, and *C. vietchiana* (data not presented), *C. sinensis* var. *calvescens* and *C. coreana* showing upright growth characteristics of shoots and flowering response were selected-for the final evaluation. All accessions grew taller than 1.3 m and spread over 65 cm wide in case of *C. spicata*, but with a few inflorescence (data not presented). The selection criteria were based on the number of plants that had flowered exhibiting upright growth characteristics. In less than one year counting from the time of transplanting, 14 from 16 *C. sinensis* var. *calvescens* plants flowered showing up-right growth (Table 1). *Corylopsis coreana* was also selected for its large foliage for its good fall foliage color, even though only nine out of 21 plants had flowered.

Effect of slow release fertilizer treatment on growth and flowering (Expt. 1)

The number of weeks to flower in 52 to 53 weeks in *C. sinensis* var. *calvescens* and *C. coreana* was not affected by the rate of SRF treatments (Table 2). The number of total shoots and of shoots with inflorescences increased linearly with SRF treatment from 2.5 to 4.1 in *C. coreana* and from 2.1 to 4.1 in *C. sinensis* var. *calvescens*. The lengths of the three longest shoots also increased in both species, from 11.9 to 25.6 cm for the longest shoot, from 4.8 to 15.8 cm for the third shoots in *C. coreana,* and from 12.8 cm to 29.3 cm for the longest shoot in *C. sinensis* var. *calvescens*.

The number of nodes with inflorescences in all the three shoots of *C. coreana* received 0.5 g SRF treatment was 0.3 or less than 0.3 and there was only one node with more than 2 inflorescences. However, the number of nodes with inflorescence produced and the number of nodes with 2 inflorescences was higher in *C. sinensis* var. *calvescens* than in *C. coreana.* The number was increased to 4.8 nodes in the first

Table 2 - The effect of slow release fertilizer treatment on the growth and flowering of *Corylopsis coreana* and *C. sinensis* var. *calvescens* [z]

Species	Slow release fertilizer (g/10 pot)	No. of weeks to flower [y]	No. of total shoots	Length (cm) of three longest shoots (SH)			No. of nodes with inflorescences [x]		
				SH 1	SH2	SH 3	SH1	SH2	SH 3
C. coreana	0	52	2.5	11.9	6.7	4.8	0.1	0.1	0.0
	0.125	52	3.3	14.4	9.8	7.4	0.3	0.1	0.0
	0.25	53	4.6	20.3	13.6	10.1	0.1	0.0	0.0
	0.5	52	4.1	25.6	22.0	15.8	0.1	0.3	0.3
Regression analysis - linear effect [w]		NS	*	**	**	**	NS	NS	NS
C. sinensis var. *calvescens*	0	53	2.1	12.8	6.7	4.5	0.1	0.0	0.0
	0.125	53	2.9	14.3	9.9	7.5	0.8	0.7	0.0
	0.25	52	3.4	21.3	13.0	10.4	3.1	2.8	1.8
	0.5	52	4.1	29.3	21.8	19.8	4.8	4.4	2.7
Regression analysis - linear effect [w]		NS	**	**	**	**	*	*	*

[z] There was a significant difference between two species; data for each species were subjected to the linear regression analysis.

[y] The number of weeks to flower was counted from the date of transplanting seedlings.

[x] Nodes with inflorescence that were formed on new growth by pinching.

[w] Non-significant (NS), significant at $P \leq 0.05$ (*) and $P \leq 0.01$ (**).

shoot and to 4.4 nodes in the second shoot following treatment with 0.5 g of SRF and the number of nodes with more than 2 inflorescences was also increased. *C. sinensis* var. *calvescens* treated with 0.125, 0.25, and 0.5 g SRF has the potential to produce a small potted plant (Fig. 2).

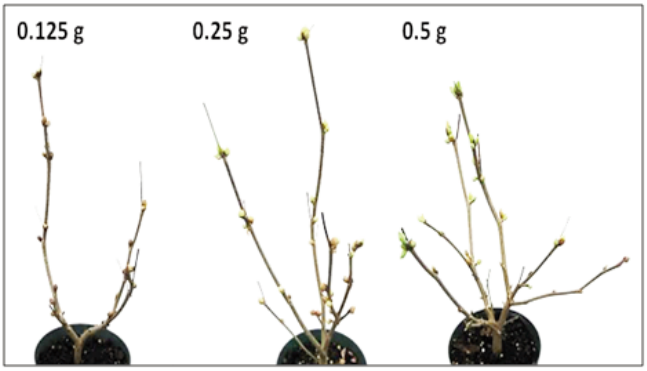

Fig. 2 - Appearance of the *Corylopsis sinensis* var. *calvescens* plants in a 10 cm pot treated with 0.125, 0.25, and 0.5 g of slow release fertilizer per pot prior to leaf emergence and anthesis.

Effect of pinching frequencies on growth and flowering (Expt. 2)

Regardless of frequencies and timing of pinching, the flowering of *C.sinensis* var. *calvescens* occurred in 53 weeks (Table 3). Flowering ranged between 73 and 93%, and the highest flowering rate was recorded when pinched for 4 times at 2, 4, 6, and 8 weeks, yielding a significantly higher number of shoots with inflorescences (5.3) and consequently the highest number of inflorescences (22.1) compared with the control.

The length of the first and the second non-pinched shoot was 49.3 and 33 cm, respectively, with a difference of 16.3 cm (Table 3). However, when pinched 4 times, the lengths were 38.0 and 31.8 cm with a difference of 6.2 cm. The number of inflorescences in non-pinched and pinched shoots, which was 9.2 and 7.1 in the first shoot and 4.0 and 6.9 in the second shoot, respectively, did not vary significantly. However, the difference in the number of inflorescences (0.2) between the first and the second shoot was significantly lower in the pinched shoot compared with the non-pinched shoot (5.2). In general, when pinched, the difference in the inflorescences between the first and the second shoot was less than 1.9, which was significantly less than that of the control.

Effect of growth retardant treatments on growth and flowering (Expt. 3)

When plants were treated with ancymidol, chlormequat, and daminozide, flowering took 22 to 28 days regardless of treatment concentrations, which was not significantly different from that of control (Table 2). However, soil drench treatments with paclobutrazol (20 mg/L or higher concentrations) took longer than 36 days. Flowering percentage was higher than 60% when plants were treated with ancymidol, chlormequat, and daminozide, regardless of treatment concentrations.Treatment with 20 mg/L of paclobutrazol severely inhibited the extension of peduncle bearing inflorescence triggering the death of inflorescence immediately after

Table 3 - The effect of pinching frequencies on growth and flowering of *Corylopsis sinensis* var. *calvescens*

Pinching [z]				No. of weeks to flower [y]	Flowering %	Total shoots no. with inflores-cences	Flowers (Total No.)	Shoot length (cm)			No. of nodes withinflorescences [x]		
2 Weeks	4 Weeks	6 Weeks	8 Weeks					First shoot	Second shoot	Difference	First	Second shoot	Difference
x	x	x	x	53	87	2.9	17.2	49.3	33.0	16.3	9.2	4.0	5.2
o	x	x	x	53	87	2.1	12.8	49.0	38.8	10.2	6.9	6.8	0.1
o	o	x	x	54	73	2.4	13.1	47.1	35.5	11.6	6.4	4.8	1.6
o	o	o	x	53	87	3.5	18.5	41.6	35.2	6.4	6.8	5.7	1.1
o	o	o	o	53	93	5.3	22.1	38.0	31.8	6.2	7.1	6.9	0.2
o	x	o	o	53	87	4.3	17.3	32.4	29.2	3.2	5.7	5.2	0.5
o	o	x	o	54	80	3.1	10.4	37.3	26.0	11.3	4.7	3.9	0.8
o	x	o	x	53	73	3.3	14.8	39.5	29.8	9.7	6.5	6.3	0.2
o	x	x	o	53	87	3.3	16.3	39.0	22.2	16.8	7.6	5.7	1.9
Level of significance [w]													
HSD at P<0.05				NS	-	0.94	3.58	8.25	5.61	5.82	4.27	3.84	1.59

[z] Not pinched (x) or pinched (o) 2 (Feb. 28), 4 (Apr. 18), 6 (May 2), and 8 weeks (May 16) after transplanting.
[y] The number of weeks to flower was counted from the date of transplanting seedlings.
[x] Nodes with inflorescence induced by pinching.
[w] Non-significant (NS) or significance at $P \leq 0.05$, F-test.

emergence following leaf emergence (Fig. 3). Therefore, days to flower were estimated on the date of leaf emergence. Flowering percentage was significantly reduced to less than 30% when plants were treated at 20 and 40 mg/L paclobutrazol.

When shoot lengths following 80 mg/L ancymidol were recorded on Jan. 16 (26 weeks after growth retardant treatment), the length of the first and the second longest shoots was significantly reduced from 26.3 cm to 15.6 cm and from 16.4 cm to 12.2 cm, respectively (Table 4).

The length of the two longest shoots treated with daminozide and chlormequat showed similar trends as observed in plants treated with ancymidol. The length of the two longest shoots was significantly reduced to 12.9 cm and 9.8 cm following treatment with 10 mg/L paclobutrazol (Fig. 3), responding to the quadratic effect of concentrations. The length of shoot B showing new growth on May 10 was significantly inhibited to less than 5.0 cm when treated with paclobutrazol. The number of shoots longer than 3 cm varied from 4.8 to 5.7, from 3.8 to 4.8, 4.3 to 5.5, and 5.0 to 3.9 upon treatment with ancymidol, chlormequat, daminozide, and paclobutrazol, respectively. The numbers were not affected by concentrations of these three retardants (data not presented).

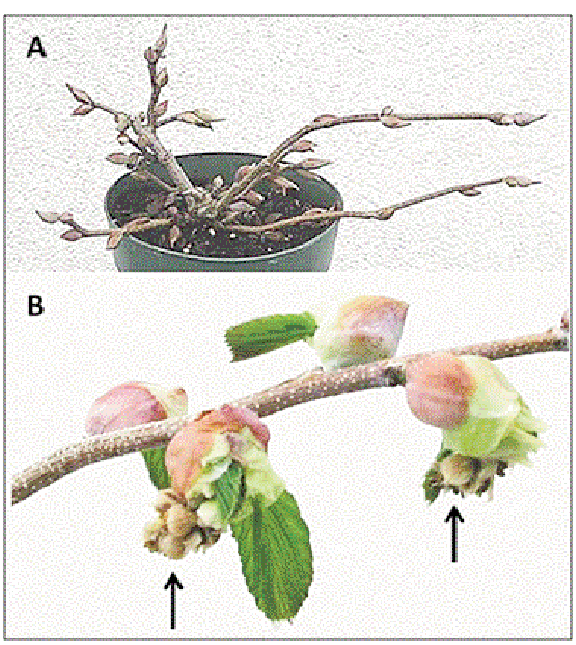

Fig. 3 - *Corylopsis sinensis* var. *calvescens* in a 10 cm pot treated with 25 mL of 40 mg/L paclobutrazol (A). Blasted inflorescences (arrow) and emerging of dark green leaves of reduced size indicate excessive doses of paclobutrazol (B). Photographed on Mar. 27, 2011.

4. Discussion and Conclusions

Successful acclimatization rate of *in vitro* propagated *C. coreana* was low (Moon *et al*., 2002) and limited time of the season to propagate by rooting of cuttings (Kwon *et al*., 2011) are the limiting factors for mass propagation to secure sufficient and uniform propagules for experiments, and further, reports are not available on flowering of *in vitro* propagules and rooted cuttings. This clearly indicates that seeds can be used as a propagule to produce sufficient number of seedlings to produceflowering plants in a year from transplanting seedlingsby various cultural practices reported in this study. The morphological characteristics of *C. sinensis* var. *calvescens* are suitable to produce in 10 cm pots compared with *C. coreana*, if stem elongation can be controlled and many shoots with well-developed inflorescences can be formed (Fig. 1).

Growth and flowering as influenced by slow release fertilizer (SRF)

There is a clear difference between *C. coreana* and *C. sinensis* var. *calvescens* responding to SRF application per 10 cm pot. Responding to the increased rates of slow release fertilizer, especially at 0.5 g SRF application, and *C. sinensis* var. *sinensi*s is recommended to produce as a 10 cm potted plant in one year as the number of inflorescences and of nodes with more than two inflorescences are increased. Production of *C. coreana* may not be recommended due to fewer numbers of nodes with inflorescences and only 0.1 node produced more than 2 inflorescences.

Growth and flowering as influenced by pinching and growth retardant treatments

Stem length is one of the limitations to produce compact *C. sinensis* var. *calvescens* in small pots, which can be reduced either by pinching or growth retardant treatments. Manual or mechanical pinching is associated with increased labor costs. Treatment with growth retardant may not induce branching when compared with pinching.

Pinching shoots four times in 2, 4, 6, and 8 weeks prior to May 2 is an effective cultural practice to produce compact plants for small pots without affecting days to flowering and flowering percentage. The increase in the number of shoots with inflorescences, the total number of inflorescences, and the number of nodes with inflorescences may result from an increased number of shoots that are formed prior to the development of inflorescence, which may occur

Table 4 - Growth and flowering of *Corylopsis sinensis* var. *calvescens* as influenced by growth retardant treatments

Plant growth regulator	No. of days to flower (Mar. 1) (flowering percent)	Shoot lenght A (cm) (Jan. 16, 2011 z)		Shoot length B (cm) of new growth (May 10, 2011)	
		FIR y	SEC	FIR	SEC
Ancymidol (soil drench) (mg/L)					
0	22 (60)	26.3	16.4	21.0	20.0
10	23 (80)	28.4	17.5	20.2	19.4
20	24 (70)	27.9	21.7	20.2	20.0
40	25 (70)	23.9	19.1	21.9	17.9
80	25 (60)	15.6	12.2	16.5	16.3
Regression analysis	NS	L*	L*	NS	NS
Paclobutrazol (soil drench) (mg/L)					
0	22 (60)	24.7	20.0	24.0	20.0
10	28 w (50)	12.9	9.8	5.0	3.5
20	38 w (30)	11.2	8.1	1.7	1.2
40	36 w (10)	10.3	7.9	1.3	0.8
80	36 w (30)	11.0	8.5	1.1	0.6
Regression analysis x	-	Q**	Q**	Q**	Q**
Chlormequat (foliar spray) (mg/L)					
0	22 (70)	28.9	20.3	23.1	20.9
2.5	22 (80)	35.1	24.9	22.9	20.1
5	25 (70)	26.5	20.0	18.3	18.1
7.5	27 (60)	23.7	14.5	17.9	17.0
10	25 (70)	24.3	18.5	20.2	19.9
Regression analysis	NS	L*	NS	NS	NS
Daminozide (foliar spray) (mg/L)					
0	23 (60)	29.2	23.0	21.0	19.9
2.5	27 (80)	33.3	23.5	23.5	18.5
5	25 (70)	28.5	22.0	22.5	18.9
7.5	25 (60)	29.3	22.7	22.7	19.1
10	27 (70)	25.5	19.5	21.2	18.5
Regression analysis	NS	L*	NS	NS	NS
Level of significance v					
Growth retardant (PGR)	NS	***	***	***	***
Concentratio	NS	**	*	*	*
PGR × Concentration	NS	**	**	**	**

z Data collected from over-wintered plants.
y Length of the first (FIR) and second (SEC) longest shoots.
x Analysis was not carried out due to the estimated days of flowering and low flowering percentage, and regression analysis was performed for each growth retardant. Linear (L) and quadratic (Q) effect.
w Days to flower following paclobutrazol treatment were recorded upon leaf emergence following the death of inflorescence. Generally, about 15 days elapsed between flowering and the appearance of leaf emergence.
v Non-significant (NS) or significance at $P<0.05$ (*), 0.01 (**) or 0.001 (***), F-test.

after May 2. Since the time of floral bud initiation has not been examined anatomically, it requires further studies. Increase in the number of lateral shoots and flowers were increased as the pinching frequencies in *Sedum rotundifolium* D.B. was increased (Jeong, 2000). The length of shoots exceeding 30 cm following pinching is considered excessive for producing *Corylopsis* in a 10 cm pot.

Flowering of *C. sinensis* var. *calvescens* plants treated with ancymidol, chlormequat, and daminozide that produced higher than 60% plants with inflorescences regardless of treatment concentrations did not differ significantly from that of control. The longest shoot length (A) on Jan. 16 responding linear effect to ancymidol, chlormequat and daminozide was the shortest, especially when treated with 80 ppm ancymidol. Ancymidol is,therefore, recommended for *C. sinensis* var. *calvescens* in 10 cm pot. Since the length of new shoot (B) on May 16 was not affected, the effect of these three plant growth retardants may not last long when compared with paclobutrazol. A single application of ancymidol is not effective and may require two treatments to produce quality *Mussaenda* 'Queen Sirikit' as a short-stemmed potted plant without reducing the number of flowers per plant and delaying the flowering (Cramer and Bridgen, 1998). Application of ancymidol requires further testing since growth retarding effects of ancymidol do not persist as reported in *L. lancifolium* Thunb. (Roh, 1979) and shoot length is increased under a long day photoperiod during June or July as observed in *L. longiflorum* (Roh and Wilkins, 1977).

Soil drench treatment with paclobutrazol 20 mg/L or higher concentrations which took longer than 36 days to flower (Table 4) compared with 22 days with the control. When treated with 20 mg/L of paclobutrazol, the extension of peduncle-bearing inflorescence was severely inhibited resulting in the death of inflorescence immediately following leaf emergence, thus lowering the flowering rate from 60% to 10% (Fig. 3). Shoot length was arrested under any paclobutrazol treatment which is undesirable.

Although 10-20 mg/L paclobutrazol as a soil drench is considered effective to reduce shoot length, the growth of new shoots and inflorescence development is significantly arrested even a year later, which may require double treatments at low concentrations, i. e., 5 mg/L to avoid severe growth retardation and malformation of inflorescence. A single foliar spray of 500 mg/L paclobutrazol may be used to test produce compact flowering plants as reported in *Rhododendron* hybrids, which is a woody ornamental (Wilkinson and Richards, 1991).

Generally paclobutrazol was not effective in *Mussaenda* at 0.125-0.25 mg a.i. per pot as a soil drench compared with ancymidol and daminozide (Cramer and Bridgen, 1998), which is considered effective in producing compact plants with accelerated flowering although 0.4 g a.i. per pot increased the number of flowers, producing malformed and unacceptable of *Rhododendron* 'Sir Robert Peel' (Wilkinson and Richards, 1991). Shoot length of poinsettia (*Euphorbis pucherrima* Wild. ex Klotzch) was reduced by daminozide and chlormequat treatments without affecting the flowering (Lewis *et al*., 2004). Combined treatment with chlormequat and daminozide can also be considered as reported to be effective to retard stem elongation of zonal (cutting) geraniums [*Pelargonium ×hortorum* (L.H. Bailey)] (Tayama and Carver, 1990).

Due to the long-lasting inhibitory effect of paclobutrazol on shoot elongation and reduction in leaf size when applied as a soil drench, a malformation of inflorescence and formation of inflorescences after leaf emergence result in a lower percentage of plants with inflorescences in both species in this study and in other woody ornamentals such as *Dissotis rotundifolia* (Sm.) Triana and *Tibouchina forthergillae ×pilosa* (Hawkins *et al*., 2015). Therefore, paclobutrazol is not recommended to use as a soil drench in *Corylopsis.* The optimum dosages require further study comparing the effect of soil drench and foliar spray. A spray treatment of paclobutrazol may be considered as the quality of *Dianthus caryophyllus* L., cv. Mondriaan was improved (Bañón *et al*., 2002).

This is the first report providing practical and horticultural strategies to produce flowering *Corylopsis* plants in small pots with a great potential to utilize under-utilized native plants as ornamental and nursery plant starting from seeds. *Corylopsis sinensis* var. *calvescens* indigenous to China is a suitable species as compared to *C. coreana* native to Korea to produce from seeds with application of slow release fertilizer at 0.5 g per pot and pinching for four times at 2-week interval before May 16 to reduce shoot elongation, to increase flowering percentage, and to accelerate flowering with increased number of inflorescences.

Treatments with ancymidol as a soil drench and daminozide and chlormequat as a foliar spray at all concentrations evaluated in this study were not effective to produce compact plants as compared to paclobutrazol treatment. Soil drench treatment with paclobutrazol at 10-20 mg/L is considered effective in reducing shoot elongation the first year. However, the inhibitory effects of paclobutrazol last longer than a year, and appear resulting in malformation of inflorescences in the second year. Therefore, investigation on selecting appropriate treatment methods andconcentrations of paclobutrazol to reduce shoot elongation without triggering malformation of inflorescence is needed. The time of floral initiation and development in relation to pinching treatment needs to be determined as well.

References

BAÑÓN S., GONZALEZ A., CANO E.A., FRANCO J.A., 2002 - *Growth, development and colour response of potted* Dianthus caryophyllus *cv. Mondriaan to paclobutrazol treatment.* - Scientia Hort., 94: 371-377.

BEAN E., ANISKO T., 2014 - *Captivating* Corylopsis. - *https://www.amerinursery.com/growing/captivating -corylopsis/*.

CRAMER C.S., BRIDGEN M.P., 1998 - *Growth regulator effects on plant height of potted* Mussaenda *'Queen Sirikit'*. - HortScience, 33: 78-81.

CURREY C.J., LOPEZ R.G., 2016 - *Commercial greenhouse and nursery production. Applying plant growth retardants for height control*. - Purdue Extension. HD-248-W. Purdue University. https://www. extension.purdue.edu/extmedia/ho/ho-248-w.pdf.

HAWKINS S.M., RUTER J.M., ROBACKER C.D., 2015 - *Spray and drench treatments of paclobutrazol influence of growth of* Dissotis *and* Tibouchina. - HortScience, 50: 1514-1517.

JEONG J.H., 2000 - *Effects of pinching and growth regulators on growth and flowering of* Sedum rotundifolium. - J. Korean Soc. Hort. Sci., 41: 105-108 (In Korean with English summary).

KIM J.H., KIM K.O., LEE A.K., ROH M.S., SUH J.K., 2017 - *Germination of* Corylopsis *seeds evaluated by X-ray imaging and cold stratification*. - Hort. Sci., (Prague), 44:105-111.

KIM J.H., LEE A.K., SUH J.K., 2015 - *Effect of warm and cold stratification, ethanol treatment on germination of Corylopsis seeds*. - Hort. Sci. (Prague), 43: 84-92.

KIM J.H., SUH J.K., YOON S-T., JOURDAN P., ROH M.S., 2018 - *Germination of fully developed* Corylopsis *seeds influenced by harvest date and cold stratification*. - HortScience, 53: 1360-1363.

KOH G.C., LIM D.K., 2006 - In vitro *propagation of Korean native winter hazel* (Corylopsis coreana). - Kor. J. Hort. Sci. Technol., 24: 272-278.

KWON S.T., KIM J.C., JEONG J.H., 2011 - *Change of root potential as affected by rooting promoter treatment in cuttings of* Corylopsis coreana. - Kor. Soc. Floric. Sci., 19(4): 202-205 (In Korean with English abstract).

LATIMER J., WHIPKER B., 2013 - *Selecting and using plant growth regulators on floricultural crops*. - Virginia Polytechnic Institute and State University, Blacksburg, VA, USA, Publication 430-102 (HORT-43P), pp. 32.

LEE J.H., KIM K.S., SONG C.Y., 2006 - *Effects of pinching and retardants on growth and flowering of* Celosia argentea *native to Korea*. - Kor. J. Plant Res., 19: 573-579 (In Korean with English abstract).

LEWIS K.P., FAUSTAND J.E., SPARKMAN IV J.D., 2004 - *The effect of daminozide and chlormequat on the growth and flowering of poinsettia and pansy*. - HortScience, 39: 1315-1318.

MOON H.K., NOH E.W., HA Y.M., SHIM K.K., 2002 - *Micropropagation of juvenile and mature tree of* Corylopsis coreana *by axillary bud culture*. - Kor. J. Plant Biotechnol., 29: 117-121 (in Korean with English abstract).

ROH M.S., 1992 - *A method for producing* Lilium elegans. - U.S. Patent No. 5,138,794.

ROH M.S., 1996 - *New production technology of* Lilium. - *A review on propagation and forcing*. - Acta Horticulturae, 414: 219-228.

ROH M.S., LEE A.K., SUH J.K., BORDELON C.M., 2008 a - *Interspecific variations in seed germination of* Corylopsis. - Scientia Hort., 118: 347-350.

ROH M.S., McNAMARA W.A., PICTON D., YIN K., WANG Q., 2008 b - *Assessment of genetic variation in* Acer pentaphyllum *based on amplified fragment length polymorphisms*. - J. Hort. Sci.& Biotech., 83: 725-731.

ROH S.M., 1979 - *Various factors influencing the growth and flowering of* Lilium lancifolium *Thunb.* - J. Kor. Soc. Hort. Sci., 20: 72-83.

ROH S.M., WILKINS H.F., 1977 - *The influence and interaction of ancymidol and photoperiod on growth of* Lilium longiflorum *Thunb*. - J. Amer. Soc. Hort. Sci., 102: 255-257.

SAS, 2002 - *SAS proprietary software version 9.00*. - Statistical Analysis System Institute, Inc., Cary, NC, USA.

SON S.-W., KIM H., KIM Y.-S., 2016 - *Corylopsis coreana. The IUCN Red List of Threatened Species 2016*: e.T72136190A72136238.- http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T72136190A72136238.en.

TAYAMA H.K., CARVER S.A., 1990 - *Zonal geranium growth and flowering responses to six growth regulators*. - HortScience, 25: 82-83.

WILKINSON R.I., RICHARDS D., 1991 - *Influence of paclobutrazol on growth and flowering of* Rhododendron *'Sir Robert Peel'*. - HortScience, 26:282-284.

ZHANG Z., ZHANG H., ENDRES P.K., 2003 - *Hamalelidaceae*. - Flora of China, 9: 18-42. 16. http://flora.huh.harvard.edu/china/mss/volume09/Hamamelidaceae.pdf.