Cutting Propagation of ‘Coy’ Alder-leaf Mountain Mahogany

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Keywords. **callus, *Cercocarpus montanus*, plant growth regulator, subterminal cutting, terminal cutting, wound**

Abstract. **‘Coy’ alder-leaf mountain mahogany (*Cercocarpus montanus*) is a new cultivar developed from a species native to the western United States with potential for use in xeriscaping, rock gardens, and water-efficient landscaping. However, efficient propagation methods are not well developed for it. In this study, cutting propagation of ‘Coy’ alder-leaf mountain mahogany was investigated over 3 years to evaluate the effects of wounding method, rooting hormone, type of cuttings collected, and time for cutting collection on rooting. In May, Jul, and Sep 2020, 2021, and 2022, nondormant hardwood subterminal cuttings and/or semihardwood terminal cuttings were collected for wounding studies. Before the treatment with 3000 mg·L^{-1} indole-3-butyric acid (IBA) in powder, cuttings were wounded either by scraping one side (scrape) or by perpendicular cuts around the base (cut), and cuttings without additional wounding were used as the control. Similarly, subterminal and terminal cuttings of ‘Coy’ alder-leaf mountain mahogany were collected during the same time and were used for hormone treatments. Cuttings were treated with 1000 or 3000 mg·L^{-1} IBA in powder or 1000/500 or 3000/1500 mg·L^{-1} IBA/NAA (1-naphthaleneacetic acid) in solution. Wounding by cut or scrape increased the rooting percentage. In addition, most cuttings wounded by the scrape method had better rooting than those wounded with cuts. On the basis of hierarchical cluster analyses, cuttings treated with 3000 mg·L^{-1} IBA in powder had greater rooting than those treated with other hormones. Therefore, our research showed that successful rooting of subterminal or terminal stem cuttings of ‘Coy’ alder-leaf mountain mahogany can be achieved through wounding using scrape method and by treatment with 3000 mg·L^{-1} IBA in powder.**

There is a need to develop efficient propagation methods for many recommended drought-tolerant and native woody plants (Alberty 2023). For woody plants, vegetative propagation is often preferred over sexual propagation for commercial nursery production because it allows production of uniform plants (Davies et al. 2018; Dole and Gibson 2006). Several factors, including the timing of cutting collection, the selection of tissues for cuttings, cutting length, growing medium, methods of wounding, and the type and concentration of plant rooting hormones (such as auxins), significantly influence the process of root formation in cuttings (Davies et al. 2018; Dole and Gibson 2006).

Plants exhibit different seasonal physiological conditions, so the time of cutting collection impacts the success of cutting propagation. During the growing season, plants experience seasonal growth and development patterns with carbohydrate content, endogenous auxin, other rooting cofactors (phenolics, polyamines, etc.), and/or rooting inhibitors changing over time. Each of these plays important roles in rooting capability (Melcher 2016). Root formation and root quality of dwarf serviceberry (*Amelanchier spicata*) cuttings varied by collection date (Melcher 2016). Similarly, a higher rooting success rate (57%) was obtained on New Jersey tea (*Ceanothus americanus*) when softwood cuttings were collected in June compared with those collected in July and August (Cartabiano and Lubell 2013).

For vegetative propagation, different types of stem cuttings, including softwood, semihardwood, and hardwood, are used depending on the species. Softwood cuttings are used in the propagation of many species (Alsup 2001; Cartabiano and Lubell 2013; Smalley et al. 1987), and there is a high chance of achieving post-rooting growth with this method (Nair and Zhang 2010). On the other hand, softwood cuttings are delicate and wilt easily (Davies et al. 2018). Careful handling of softwood cuttings is required to prevent desiccation of leaves. In addition, they are rooted under high-humidity conditions to avoid excessive water loss from the leaves (Davies et al. 2018). Softwood and semihardwood cuttings were more effective in promoting the rooting of snowbrush ceanothus (*Ceanthous velutinus*) compared with hardwood cuttings (Paudel et al. 2022). Similarly, softwood cuttings were good compared with semiharwood cuttings in dwarf serviceberry propagation (Melcher 2016).

Wounding may enhance adventitious rooting on stem cuttings for some species like dwarf serviceberry, Greek strawberry tree (*Arbutus andrachne*), and Santa Cruz manzanita (*Arctostaphylos andersonii*) (Al-Salem and Karam 2001; Davies et al. 2018; Melcher 2016; Wisura 1980). Wounding increases cellular division near the vascular cambium and phloem, which promotes callus formation (Pijut et al. 2011). In some species, callus formation is a precursor of adventitious root formation (Karakurt et al. 2009). Furthermore, wounding speeds rooting because it increases the surface area of the basal part of cuttings where rooting hormone is predominately absorbed (Davies and Hartmann 1988).

Furthermore, basal treatment of stem cuttings with rooting hormones such as indole-3-butyric acid (IBA)

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can enhance rooting and increase the quantity of adventitious roots (Davies et al. 2018). Rupp et al. (2011) reported a significant effect of auxin on the rooting of cuttings of little leaf mountain mahogany (*Cercocarpus intricatus*). However, the success of rooting depends on the type and concentration of auxin and plant species. High doses of auxin can lead to foliar senescence, chloroplast damage, destruction of membranes, necrosis, and even plant death (Blythe et al. 2007). The use of IBA improved both the rooting percentage and the number of adventitious roots per rooted cutting in the eucalypt hybrid (*Corymbia torelliana* × *Corymbia citriodora*) but also led to increased defoliation (Kilkenny et al. 2012).

'Coy' alder-leaf mountain mahogany (*Cercocarpus montanus*) is an evergreen selection with small leaves that has been selected for landscape use (Paudel et al. 2020a). It is a slow-growing shrub that typically reaches a height of 1.5 m at maturity. 'Coy' alder-leaf mountain mahogany flourishes in low-water landscapes. However, few studies have been conducted on the propagation of this landscape-worthy species. Alder-leaf mountain mahogany is generally propagated through seeds (Rupp and Wheaton 2014). Similarly, seed propagation methods have been investigated for alder-leaf mountain mahogany (Paudel et al. 2020b). However, off-type plants with genetic variability are produced from seeds (Dole and Gibson 2006). Therefore, vegetative propagation through cuttings is a more promising alternative for the propagation of 'Coy' alder-leaf mountain mahogany. Gucker (2006) mentioned that vegetative regeneration is possible from root crowns and rhizomes of alder-leaf mountain mahogany. Furthermore, successful results in rooting stem cuttings of 'Coy' alder-leaf mountain mahogany were reported by Paudel et al. (2020a). However, there are still questions as to the correct time for cutting collection, types of auxins and their concentrations, and suitability of terminal and subterminal cuttings for propagating 'Coy' alder-leaf mountain mahogany. The purpose of this study was to develop an efficient protocol to propagate 'Coy' alder-leaf mountain mahogany successfully via stem cuttings. We evaluated wounding methods, rooting hormone treatments, use of terminal and subterminal cuttings, and timing of cutting collection during the propagation of 'Coy' alder-leaf mountain mahogany.

Materials and methods

Wounding, type of cuttings, time of cutting collection. Propagation experiments were conducted for 'Coy' alder-leaf mountain mahogany using cuttings collected from five plants located in a landscape in Hyde Park, UT, USA. Those plants are clones of the 'Coy' alder-leaf mountain mahogany that were previously introduced to the landscape (Paudel et al. 2020a). The cuttings were collected in May, Jul, and Sep in 2020, 2021, and 2022; wrapped in moist paper towels; and stored in a cooler at 4 °C until used (Table 1). Terminal cuttings included the shoot tips, whereas subterminal cuttings were positioned below. At all collection time points, subterminal cuttings were nondormant hardwood (previous season growth) and terminal cuttings were semihardwood. In May, only subterminal cuttings

Table 1. General information for propagation experiments (2020–22) of 'Coy' alder-leaf mountain mahogany (*Cercocarpus montanus*) with initiation and end dates, number of cuttings, type of cuttings, wounding method, and rooting hormone used. Cuttings treated with liquid-based (Dip'N Grow, Clackamas, OR, USA) or talc-based (Hormodin® 1 and 2; OHP, Inc., Mainland, PA, USA) hormone.

Month	Initiation date	End date	Cuttings (no./treatment)	Total cuttings (no.)	Type of cuttings[i]	Wounding method[ii]	Rooting hormone[iii]
			Wounding studies				
May	11 May 2020	4 Jul 2020	36	108	Subterminal	Control, cut, and scrape	H2
	14 May 2021	14 Jul 2021	36	108			
	9 May 2022	11 Jul 2022	64	192			
July	31 Jul 2020	27 Sep 2020	27	108	Subterminal and terminal	Cut and scrape	H2
	26 Jul 2021	30 Sep 2021	36	144			
	18 Jul 2022	20 Sep 2022	54	216			
September	11 Sep 2020	10 Nov 2020	36	144	Subterminal and terminal	Cut and scrape	H2
	16 Sep 2021	17 Nov 2021	24	96			
	8 Sep 2022	17 Nov 2022	48	192			
			Plant growth regulator studies				
May	14 May 2021	14 Jul 2021	36	144	Subterminal	Scrape	H1, H2, 1K, and 3K
	9 May 2022	11 Jul 2022	64	192			
July	26 Jul 2021	30 Sep 2021	36	288	Subterminal and terminal	Scrape	H1, H2, 1K, and 3K
	18 Jul 2022	20 Sep 2022	54	432			
September	18 Sep 2020	12 Nov 2020	27	216	Subterminal and terminal	Scrape	H1, H2, 1K, and 3K
	16 Sep 2021	17 Nov 2021	24	192			
	8 Sep 2022	17 Nov 2022	54	432			

[i] Subterminal cuttings, positioned below the shoot tips, were nondormant hardwood (previous season growth) and terminal cuttings, including the shoot tips, were semihardwood.
[ii] Control: no additional wound; cut: wounded by making three to five perpendicular cuts (0.2 cm) on both stem sides at the base; scrape: wounded by scraping the bark (1 cm) on one stem side at the base; 1 cm = 0.3937 inch.
[iii] H1: Hormodin 1 [1000 $mg \cdot L^{-1}$ indole-3-butyric acid (IBA)]; H2: Hormodin 2 (3000 $mg \cdot L^{-1}$ IBA); 1K: 1000 $mg \cdot L^{-1}$ IBA and 500 $mg \cdot L^{-1}$ 1-naphthaleneacetic acid (NAA) Dip'N Grow; 3K: 3000 $mg \cdot L^{-1}$ IBA and 1500 $mg \cdot L^{-1}$ NAA Dip'N Grow; 1 $mg \cdot L^{-1}$ = 1 ppm.

Fig. 1. 'Coy' alder-leaf mountain mahogany (*Cercocarpus montanus*) subterminal cuttings without additional wounding (control) and wounded by making three to five perpendicular cuts (0.2 cm) on both stem sides at the base (cuts), or by scraping the bark (1 cm) on one stem side at the base (scrape). Subterminal cuttings, positioned below the shoot tips, were nondormant hardwood (previous season growth). 1 cm = 0.3937 inch.

(7–9 cm) were used by removing the tips ~2 to 3 cm long. In July and September, terminal and subterminal cuttings (7–9 cm) were used. In May, three treatments were designed to assess the best wounding method. Cuttings with no additional wounds were used as the control. For wounding treatments, cuttings were wounded by scraping the bark (1 cm) on one stem side at the base (scrape) or making three to five perpendicular cuts (0.2 cm) on both stem sides around the base (cut) by a sharp grafting knife (Fig. 1). For other collection times, all cuttings were wounded using the scrape or cut methods.

Leaves were removed from the bottom of each cutting which was then dipped in 1% broad-spectrum algaecide/bactericide/fungicide [27.1% hydrogen dioxide, 2.0% peroxyacetic acid (ZeroTol® BioSafe Systems, Hartford, CT, USA)] for disinfestation and then allowed to dry. The cuttings were wounded as described above and quickly dipped in distilled water and then in talc-based formulation of 3000 mg·L^{-1} IBA (Hormodin® 2; OHP, Inc., Mainland, PA, USA). The cuttings were then laid on paper towels for about 1 min and stuck vertically into 3 inch deep, 11 cubic inch insert cells (Landmark Plastic Corporation, Akron, OH, USA) that contained a 4:1 (vol.) mixture of moist perlite (Hess perlite, Malad City, ID, USA) and sphagnum peatmoss (SunGro Horticulture, Agawam, MA, USA). Cuttings were placed on a white-cloth-covered intermittent mist bench and supplied with bottom heat at 23 °C using a heating mat (Propagation Mat; Grower's Nursery Supply, Salem, OR, USA). Cuttings were misted at a frequency set to maintain conditions at 60 vapor pressure deficit (VPD) units using a mist controller (Water Plus VPD; Phytotronics, Inc., Earth City, MO, USA) in a USU research greenhouse in Logan, UT, USA. Cuttings were drenched with fosetyl aluminum fungicide (Aliette®; Bayer CropScience, Research Triangle, NC, USA) within 1 week of insertion at a rate of 0.7 g·L^{-1}. After ~8 weeks, we evaluated the callus and root formation, number of roots per cutting, and the longest root's length (centimeters) (Fig. 2). Calluses were visually inspected as slightly swollen tissue that were light in color. Callus and rooting percentage were calculated. The types of cuttings and the timing for cutting collection were evaluated alongside the experiments.

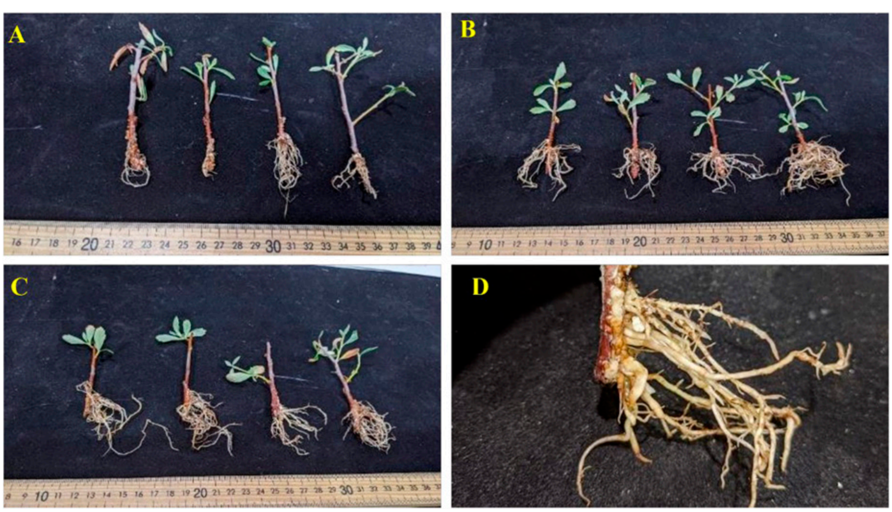

Fig. 2. 'Coy' alder-leaf mountain mahogany (*Cercocarpus montanus*) rooted subterminal cuttings treated with 3000 mg·L^{-1} indole-3-butyric acid (Hormodin® 2; OHP, Inc., Mainland, PA, USA). Rooted cuttings: (A) without additional wounding or (B) wounded with three to five perpendicular cuts (0.2 cm) on both stem sides at the base or (C) scraping the bark (1 cm) on one stem side at the base, and (D) closer view of a rooted cutting wounded with scrape. Subterminal cuttings, positioned below the shoot tips, were nondormant hardwood (previous season growth). 1 mg·L^{-1} = 1 ppm; 1 cm = 0.3937 inch.

Plant growth regulator, type of cuttings, time of cutting collection. Cuttings (7–9 cm) were collected in May and Jul of 2021 and 2022, and Sep in 2020, 2021, and 2022 and handled as previously described. Subterminal and terminal cuttings were collected in July and September, whereas only subterminal cuttings were collected in May. Experiments were performed to determine the best type and rate of plant growth regulators (rooting hormones). Cuttings were wounded at the base using the scrape method. They were quickly dipped in distilled water and subsequently treated with a talc-based rooting hormone 1000 mg·L^{-1} IBA (Hormodin 1) or 3000 mg·L^{-1} IBA (Hormodin 2), or liquid-based rooting hormone at a concentration of 1000 mg·L^{-1} IBA plus 500 mg·L^{-1} NAA or 3000 mg·L^{-1} IBA plus 1500 mg·L^{-1} NAA, in 25% ethanol as Dip'n Grow (0.1% IBA/0.05% NAA or 0.3% IBA/0.15% NAA, Dip'n Grow, Clackamas, OR, USA). The cuttings were stuck vertically into inserts and cared for as described earlier. The types of cuttings and the timing for cutting collection were evaluated alongside the experiments.

Experimental design and statistical analyses. The experiments were conducted using a randomized complete block design. Year of cutting collection was used as a block. Analysis of variance was conducted on all data. Callus formation and rooting on cuttings were treated as binary data (0, 1). Log transformation was performed for the number of roots and the length of the longest root formed. To assess the influence of types of cuttings and the time for cutting collection, rooting percentage data from July and September were analyzed because only subterminal cuttings were used in May. Neither the types of cuttings nor the time of cutting collection showed a significant effect on rooting percentage. In wounding studies, the interaction between the time of cutting collection and wounding method was significant ($P = 0.03$), but rooting percentage was unaffected by the types of cuttings. In rooting hormone studies, the interaction among the type of cuttings, time of cutting collection, and rooting hormone was significant ($P = 0.04$). Therefore, all data presented are based on timing for wounding studies and type and timing for rooting hormone studies.

Statistical analyses were conducted using PROC GLIMMIX procedures for callus and rooting data or PROC MIXED procedures for the number of roots and length of the longest roots formed in SAS OnDemand for Academics: Studio (version 3.8; SAS Institute Inc., Cary, NC, USA). Mean separation among treatments was adjusted using Tukey–Kramer method for multiplicity at $\alpha = 0.05$. Hierarchical cluster analyses were conducted using the Ward method in JMP (version 13.2.1; SAS Institute Inc.) for plant growth regulator experiments using mean values of percent of cuttings that rooted, number of roots per cutting, and length of the longest root to compare hormone treatments for rooting of cuttings.

Results

Wounding. 'Coy' alder-leaf mountain mahogany cuttings formed callus in 4 to 5 weeks after cuttings were placed in the mist bench. In May, the wounding method affected visible callus formation ($P = 0.03$). A greater percentage of cuttings wounded by the scrape method (71%) produced calluses than did cuttings in the control treatment (55%) (Table 2). Similarly, the wounding method affected root formation ($P < 0.001$), the number of roots formed per cutting ($P = 0.004$), and the length of the longest root formed ($P = 0.005$). Cuttings collected in May had the highest rooting percentage of 71% when wounded using the scrape method, compared with cuttings wounded by cut method or the control (Table 2). In addition, cuttings wounded by the scrape method had a greater number of roots and longest root produced compared with control (both P values < 0.01). However, cuttings wounded by the cut method were not different compared with cuttings wounded by scraping or control group in terms of callus percentage, number of roots, and longest roots produced.

In July experiments, the wounding method affected root formation ($P = 0.03$). Cuttings wounded by the cut and scrape methods had 49% and 57% rooting, respectively (Table 2). However, the wounding method did not impact callus percentage, number of roots, and longest roots produced.

In September experiments, the wounding method had significant effects on callus formation ($P = 0.01$). The percentage of callused cuttings wounded by the cutting method and the scrape method were 68% and 79%, respectively (Table 2). Similarly, wounding method affected root formation, number of roots, and longest root formed (all P values < 0.001). The rooting percentage of cuttings was higher when the scrape method (71%) was used, compared with the cut method (49%) (Table 2). Furthermore, a greater number of roots were observed on cuttings that were scraped (7.1) compared with those wounded by the cut method (5.1). Moreover, the length of the longest roots were 4.8 and 3.1 cm when cuttings were wounded by the scrape and cut methods, respectively.

Plant growth regulator. A higher percentage of cuttings treated with 3000 $mg \cdot L^{-1}$ IBA callused (75%) and rooted (69%) compared with other rooting hormone treatments for the experiments conducted in May (all P values ≤ 0.05, Fig. 3). Similarly, rooting hormone affected the number of roots and longest root formed (both P values < 0.001). Cuttings treated with 3000 $mg \cdot L^{-1}$ IBA produced a greater number of roots (8.6) compared with cuttings treated with 1000 $mg \cdot L^{-1}$ IBA (5.3) and liquid-based rooting hormone at a concentration of 1000 $mg \cdot L^{-1}$ of IBA plus 500 $mg \cdot L^{-1}$ NAA (3.0). Cuttings treated with 3000 $mg \cdot L^{-1}$ IBA also had greater length of the longest root (4.9 cm) compared with cuttings treated with liquid-based rooting hormone at a concentration of 1000 $mg \cdot L^{-1}$ of IBA plus 500 $mg \cdot L^{-1}$ NAA (2.2 cm).

The percentage of callused cuttings was unaffected by rooting hormones in the experiments conducted in July, with 36% to 53% of cuttings showing callusing (Fig. 3). Subterminal cuttings treated with 3000 $mg \cdot L^{-1}$ IBA had the highest rooting percentage (72%) compared with cuttings treated with 1000 $mg \cdot L^{-1}$ IBA or liquid-based rooting hormone at a concentration of 1000 or 3000 $mg \cdot L^{-1}$ IBA plus 500 or 1500 $mg \cdot L^{-1}$ NAA (all P values < 0.01). Terminal cuttings also had a greater number of cuttings rooted (63%) after 3000 $mg \cdot L^{-1}$ IBA treatment compared with cuttings treated with liquid-based rooting hormone at a concentration of 1000 or 3000 $mg \cdot L^{-1}$ IBA plus 500 or 1500 $mg \cdot L^{-1}$ NAA (both P values ≤ 0.001). The rooted cuttings consisted of 3 to 10 roots, with the longest root measuring 2 to 4 cm in length.

In September experiments, the rooting hormone and type of cuttings had significant effects on root formation (both P values ≤ 0.03). Subterminal cuttings treated with 3000 $mg \cdot L^{-1}$ IBA had a rooting percentage of 55%, which is greater than those cuttings treated with liquid-based rooting hormone at a concentration of 1000 or 3000 $mg \cdot L^{-1}$ IBA plus 500 or 1500 $mg \cdot L^{-1}$ NAA (Fig. 3). More rooted cuttings were observed when terminal cuttings were treated with 3000 $mg \cdot L^{-1}$ IBA (62%) compared with liquid-based rooting hormone at a concentration of 1000 or 3000 $mg \cdot L^{-1}$ IBA plus 500 or 1500 $mg \cdot L^{-1}$ NAA. Terminal cuttings treated with 1000 $mg \cdot L^{-1}$ IBA also had a greater number of cuttings rooted (56%) compared with cuttings treated with liquid-based rooting hormone at a concentration of 3000 $mg \cdot L^{-1}$ IBA plus 1500 $mg \cdot L^{-1}$ NAA. In addition, the number of roots per cutting and length of the longest roots formed did not differ among treatments. According to hierarchical cluster analysis using mean values of percent rooted cuttings, number of roots per cutting, and length of the longest root, 3000 $mg \cdot L^{-1}$ IBA was found to be more effective as a

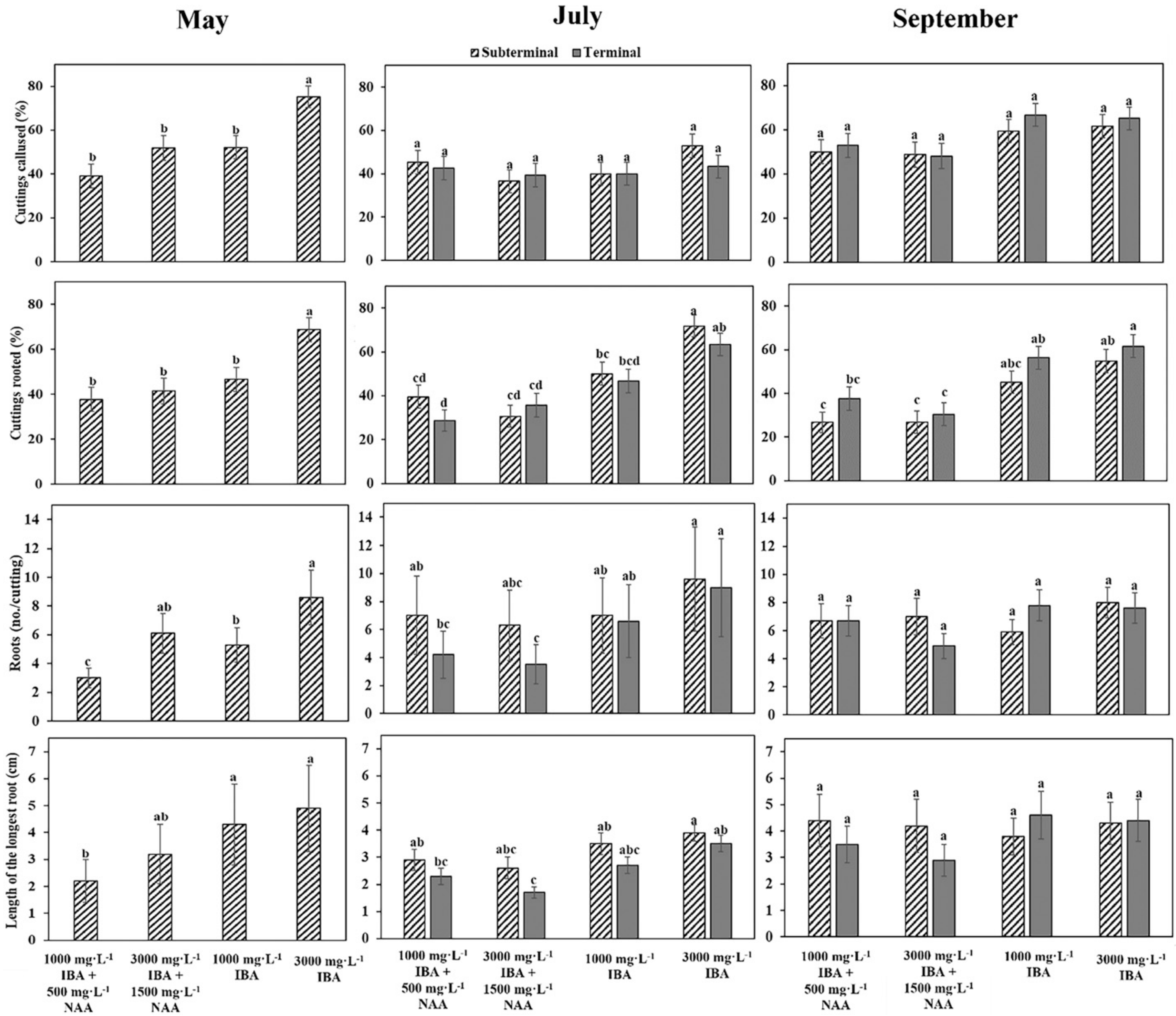

Fig. 3. Callus percentage, rooting percentage, number of roots, and length of the longest root of 'Coy' alder-leaf mountain mahogany (*Cercocarpus montanus*) subterminal and terminal cuttings collected in May, July, and September and treated with different concentrations of rooting hormones. Cuttings were treated with rooting hormone as liquid-based 1000 mg·L^{-1} indole-3-butyric acid (IBA) plus 500 mg·L^{-1} 1-naphthaleneacetic acid (NAA) or 3000 mg·L^{-1} IBA plus 1500 mg·L^{-1} NAA as Dip'N Grow (Dip'N Grow; Clackamas, OR, USA) and talc-based 1000 mg·L^{-1} and 3000 mg·L^{-1} IBA (Hormodin® 1 and 2; OHP, Inc., Mainland, PA, USA). Cuttings were wounded by scraping the bark (1 cm) on one stem side at the base. Subterminal cuttings, positioned below the shoot tips, were nondormant hardwood (previous season growth) and terminal cuttings, including the shoot tips, were semihardwood. Vertical bars represent standard errors of mean values of replications. The same letters above column bars within the same month represent no significance among the combination of cutting types and rooting hormone, as determined by Tukey–Kramer method for multiplicity at $\alpha \leq 0.05$. Only subterminal cuttings were used in May. 1 mg·L^{-1} = 1 ppm; 1 cm = 0.3937 inch.

plant growth regulator for promoting root formation in 'Coy' alder-leaf mountain mahogany compared with other rooting hormone treatments (data not shown).

Discussion

Propagation by stem cuttings can be done in both woody and herbaceous plants. It is important to consider factors including cutting collection time, type of cuttings, cutting length, growing medium, wounding methods, and rooting hormones to enhance rooting success (Davies et al. 2018; Dole and Gibson 2006). In the current study, we have evaluated the impact of wounding, hormones, type of cuttings, and time of cutting collection on 'Coy' alder-leaf mountain mahogany.

Wounding can be beneficial for some plant species during cutting propagation but also is detrimental to rooting success in other species because it creates a site of entry for harmful microorganisms (Dirr and Heuser 1987). In the current study, wounding had a positive effect on 'Coy' alder-leaf mountain mahogany cuttings in terms of the callus formation,

Table 2. Callus and root formation of stem cuttings of 'Coy' alder-leaf mountain mahogany (*Cercocarpus montanus*) that were collected in May, July, and September and received no additional wounding (control) or wounded by cutting or scraping. Cuttings were treated with 3000 mg·L^{-1} indole-3-butyric acid (Hormodin® 2; OHP, Inc., Mainland, PA, USA).[i]

Month	Wounding method[ii]	Cuttings callused (%)	Cuttings rooted (%)	Roots (no./cutting)	Length of the longest root (cm[i])
		Mean ± *SE*			
May	Control	55.2 ± 4.3 b[iii]	46.3 ± 4.3 b	5.5 ± 0.8 b	3.0 ± 0.5 b
	Cut	66.7 ± 4.2 ab	47.3 ± 4.4 b	7.3 ± 1.1 ab	4.1 ± 0.7 ab
	Scrape	71.3 ± 4.1 a	70.5 ± 4.1 a	8.8 ± 1.2 a	4.7 ± 0.7 a
July	Cut	45.2 ± 3.3 a	49.1 ± 3.3 b	9.6 ± 1.8 a	4.6 ± 0.3 a
	Scrape	49.1 ± 3.3 a	57.1 ± 3.3 a	10.1 ± 1.8 a	5.3 ± 0.3 a
September	Cut	67.5 ± 3.3 b	48.5 ± 3.5 b	5.1 ± 0.4 b	3.1 ± 0.4 b
	Scrape	78.5 ± 2.9 a	70.8 ± 3.2 a	7.1 ± 0.4 a	4.8 ± 0.7 a

[i] 1 mg·L^{-1} = 1 ppm; 1 cm = 0.3937 inch.
[ii] Control, cut, scrape: no additional wound, wounded by making three to five perpendicular cuts (0.2 cm) on both stem sides at the base, and wounded by scraping the bark (1 cm) on one stem side at the base, respectively.
[iii] Same lowercase letters within a column and month are not different among wounding methods by Tukey–Kramer method for multiplicity at $\alpha \leq 0.05$.

rooting, number of roots, and root length. This may be attributed to the stimulation of cellular division in the areas near the vascular cambium and phloem, which facilitated callus formation and subsequent adventitious root growth (Pijut et al. 2011). Additionally, wounding can remove tough tissue that hinders the outward growth of roots from the cutting (Zhou 2007). Davies et al. (2018) also reported that wounding positively affected root production on stem cuttings. In some hard-to-root species, adventitious root quantity and uniformity also increase when cuttings are wounded and treated with an auxin (Alsup et al. 2001). Furthermore, wounding increases the tissue responsiveness to rooting hormones in cuttings (Davies and Hartmann 1988). The adventitious root formation and root quality of dwarf serviceberry were enhanced by wounding (Melcher 2016). Similarly, Santa Cruz manzanita, which are difficult to root, showed beneficial effects following wounding along the bottom (1 cm) of the cutting (Wisura 1980).

Moreover, in the case of 'Coy' alder-leaf mountain mahogany, superior rooting success was observed when the scrape method of wounding was employed, compared with the cut method, despite the experiments being conducted in different years. In a study conducted in 2016, the authors noted the highest rooting rate of 51% when terminal cuttings of 'Coy' alder-leaf mountain mahogany were treated with 3000 mg·L^{-1} IBA and subjected to the scrape method for wounding (Paudel et al. 2020a). On the other hand, during an experiment in 2019, the highest observed rooting rate was only 37% for cuttings treated with 3000 mg·L^{-1} IBA and subjected to the cut method for wounding (Paudel et al. 2020a). Furthermore, the current study found the scrape method of wounding to be more effective than the cut method, potentially because of the increased surface area exposed to hormones in the scrape method. However, root formation was primarily observed on one side of the stem. This asymmetric root formation may decrease the stability of cuttings and plant growth efficiency due to uneven resource utilization.

Auxins are produced in plant apical meristems and other actively growing tissues such as developing leaves, fruits, flowers, and seeds (MacAdam 2009). Indole-3-acetic acid is a potentially valuable auxin for use in propagation that is naturally occurring and found abundantly in plants; but it is sensitive to light and unstable in solutions (Dunlap and Robacker 1988; Tanimoto 2005). Therefore, stable exogenous auxins, such as IBA and NAA in liquid or powder form, are mostly used as root-inducing hormones. The right concentration of auxin is necessary for root formation. IBA and NAA are the most commonly used growth regulators for root induction (Nair and Zhang 2010) and mixtures of IBA and NAA are often efficacious for rooting (Yusnita et al. 2018). In this study, talc-based rooting hormone, 3000 mg·L^{-1} IBA induced more rooting compared with other hormone treatments. Similarly, Paudel et al. (2020a) reported that 3000 mg·L^{-1} IBA was better rooting hormone for rooting of 'Coy' alder-leaf mountain mahogany. Similar results were observed previously, in which talc-based rooting hormone was mentioned to be effective for cutting propagation of snowbrush ceanothus (Paudel et al. 2022). This consistency across studies for western native species underscores the effectiveness of 3000 mg·L^{-1} IBA in promoting successful rooting. Additionally, talc-based rooting hormone at a concentration of 3000 mg·L^{-1} IBA has been recommended for the propagation of semihardwood cuttings of native woody plant fourwing saltbush (*Atriplex canescens*) (Rupp and Wheaton 2014).

The success of rooting cuttings depends on the seasonal growth phase of the plant from which the cuttings are collected (Still and Zanon 1991). However, the timing of cutting collection can vary depending on the plant species. In the current study, it was observed that the rooting rates of 'Coy' alder-leaf mountain mahogany cuttings in July and September were similar but varied between experiments. The timing of cutting collection did not play a significant role in influencing the rooting process. These results suggest that cuttings collected in both July and September are good for propagation, although different results may be obtained if cuttings were collected in winter or spring.

The type of cuttings used for propagation also affects rooting (Davies et al. 2018). In this study, both the subterminal and terminal cuttings of 'Coy' alder-leaf mountain mahogany had similar rooting responses. Similarly, in a previous study, 11% of subterminal cuttings (referred to as stems) and 5% of terminal cuttings of 'Coy' alder-leaf mountain mahogany produced roots (Paudel et al. 2020a). Furthermore, Rosner et al. (2003) reported less than

1% of rooting in alder-leaf mountain mahogany when cuttings of current season growth were used. In the current research, terminal cuttings were semihardwood and subterminal cuttings were nondormant hardwood cuttings as 'Coy' alder-leaf mountain mahogany is a slow-growing species. Nondormant hardwood cuttings were from previous season growth. Both semihardwood and nondormant hardwood cuttings are acceptable for propagating 'Coy' alder-leaf mountain mahogany. Similarly, Everett et al. (1978) reported that semihardwood cuttings of bud sagebrush (*Artemisia spinescens*), big saltbush (*Atriplex lentiformis*), common winterfat (*Ceratoides lanata*), spiny hopsage (*Grayia spinosa*), wooly scalybroom (*Lepidospartum latisquamum*), Anderson peachbrush (*Prunus andersonii*), rose (*Rosa woodsii*), sage (*Salvia dorrii*), and canyon grape (*Vitis arizonica*) rooted successfully.

To summarize, our study has demonstrated that the successful rooting of 'Coy' alder-leaf mountain mahogany subterminal or terminal cuttings can be effectively accomplished by wounding using the scrape method and by treatment with 3000 $mg \cdot L^{-1}$ IBA as a talc-based hormone. Additionally, the timing of cutting collection did unaffected the rooting rate. Although the highest rooting success rate observed in the current study was 72%, these findings still offer valuable insights into the propagation of 'Coy' alder-leaf mountain mahogany and could potentially help to improve the cultivation of this plant. It is important to note that the stock plants in this study were growing in a landscape. However, maintaining stock plants in nursery containers might lead to even greater rooting success.

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