Propagation for commercial production of sweet acacia (*Vachellia farnesiana*): a native plant with ornamental potential

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ABSTRACT

Sweet acacia (*Vachellia farnesiana* (L.) Wight & Arn. [Fabaceae]) is an evergreen or drought-deciduous tree with attractive foliage and fragrant yellow flowers. This Florida native has high drought tolerance and is underutilized in landscapes because of its limited availability and the limited knowledge of commercial production techniques. We conducted a series of 4 propagation studies for practical application by nurseries looking to grow sweet acacia. In Experiment 1, seeds were scarified with either sandpaper or boiling water treatments prior to soaking overnight. After 23 d, 62.7% and 76.0% emergence were achieved for the sandpaper and boiling water treatments, respectively, whereas the non-scarified control treatment resulted in only 1.3% emergence. For both the sandpaper and boiling water treatments, half of the seeds germinated by day 10.5 (T50). Two-thirds of the resultant seedlings were polycotyledonous, having 3 and 4 cotyledons and 6.8 times more branching when compared to those with 2 cotyledons. In Experiment 2, we scarified seeds with boiling water overnight and then sorted them by their appearance (imbibed versus non-imbibed). Initially, the visually imbibed seeds had the highest emergence followed by the visually non-imbibed seeds, and then the control seeds. Yet after 23 d, emergence was similar among imbibed (96.7%) and non-imbibed (87.8%) seeds and greater than the control (11.1%). We conducted Experiments 3 and 4 to determine if cutting propagation is a feasible alternative to seed propagation. In Experiment 3, the effects of liquid rooting hormone (auxin) concentrations on rooting were explored using semi-hardwood cuttings quick dipped with liquid Dip'N Grow (indole-3-butyric acid [IBA] + 1-naphthaleneacetic acid [NAA]) at concentrations of 4000:2000, 2000:1000, 1000:500, 500:250, and 0:0 mg/l (ppm) IBA:NAA. Regardless of treatment, few cuttings rooted and (or) survived the length of the experiment. In Experiment 4, the effects of talc rooting hormone concentrations on root formation were explored using younger stock plant cuttings and humidity domes placed within the mist house. When stuck with talc Hormex at 0, 8000, and 16,000 mg/l (ppm) IBA, 53% to 73% cutting survival was achieved with similar rooting percentage between treatments; however, cuttings treated with 16,000 mg/l (ppm) IBA had longer roots. Results confirm that asexual propagation of sweet acacia is possible by stem cuttings; however, the process is slow and not successful at rates necessary for commercial production. Instead, efficient sexual propagation can be reliably performed using a pre-sowing scarification treatment to alleviate physical seed dormancy.

CONVERSIONS

(°C x 1.8) + 32 = °F
0.3 m = 1 ft
2.54 cm = 1 in
25.4 mm = 1 in
0.43 kg = 1 lb
3.8 l = 1 gal

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KEY WORDS

seed, emergence, cuttings, landscapes, gardens, trees, Fabaceae

NOMENCLATURE

USDA NRCS (2022)
Wunderlin and others (2022)

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Native plants in residential and commercial landscapes have historically been underutilized because of limited availability of native plants in consumer markets, limited historical cultivation, and insufficient knowledge of the propagation techniques required for successful commercial propagation (Wilde and others 2015; Wilson 2020; Trigiano and others 2021). Many ornamental plants have been cultivated for thousands of years that are not native to the US (Access Science 2020). Only recently has there been a push for commercial-scale cultivation of native plants (Rupp and others 2018). Newfound understanding of ecosystem services and how native plants provide more than just aesthetic value have spurred the push toward native landscaping in residential and commercial landscapes. Native plants in the right place may require fewer external inputs (Helfand and others 2006) because they are locally adapted to the climate, soil conditions, and native pests. They also bring ecological value to a landscape by attracting pollinators (Kalaman and others 2022a), supporting native wildlife biodiversity (Burghardt and others 2009; Pardee and Philpott 2014), and providing important nectar and pollen resources (Kalaman and others 2022b). Providing more positive experiences with native plants can help curtail the traditional belief that native or "wild" plants do not look as ornamentally attractive when compared to exotic species (Wilde and others 2015). Recent research suggests that landscapes with a high proportion of native plants are appealing in appearance to people (Gillis and Swim 2020), and consumers are willing to pay more for well-designed yards that include native plants in place of lawns (Helfand and others 2006). Supply and demand for native plants influence their availability; although demand has increased, limited commercial availability hinders widespread use (Dumroese and others 2009). In a national survey, White and others (2018) identified slightly more than 800 active native plant vendors, selling only about 26% of all US native flora. By elucidating propagation techniques for native species and evaluating their potential use in landscapes, native plants can be integrated into more landscapes (Thetford and others 2008, 2012, 2018; Campbell-Martinez and others 2021, 2022).

Sweet acacia (*Vachellia farnesiana* (L.) Wight & Arn.) belongs to the third largest plant family, Fabaceae. This family contains many important agricultural crops and is known for its symbiotic relationship with nitrogen-fixing bacteria. Previously classified as *Acacia farnesiana*, this species is known by many names globally: huisache, needle-bush, sweet acacia, or *Mimosa farnesiana*. New taxonomic information now separates *Acacia* and *Vachellia* into 2 distinct genera (Kyalangaliwa and others 2013). Polymorphism in the historically defined genus, *Acacia,* is common, with many species exhibiting multiple growth forms. Polymorphism of plant cotyledons is relatively undocumented in all plant groups (Reddy and others 2000). Named for Odoardo Farnese, a noble Italian known for maintaining private botanical gardens, the first account of *V. farnesiana* was written by Tobias Aldini in Italy in 1625 from seeds collected in present-day Dominican Republic (Bell and others 2017).

Sweet acacia is a small to medium tree or large shrub that is slow growing, but it will eventually reach a height between 4.6 and 7.6 m with a spread of 4.6 to 7.6 m wide (UF/IFAS 2018) (Figure 1A). Foliage is feathery in appearance, and the canopy creates an umbrella as the trunk and stems bend easily. Leaves are even, bi-pinnately compound and alternately arranged, whereas pinna and leaflets are opposite. Each leaf contains 2 to 8 pinna, and the attached leaflets are medium green and oblong. Stipular spines at each node are woody and large (Figure 1B). Stems are dark chocolate-brown to greenish-gray with prominent lenticels (TWC 2015; Erkovan and others 2016; UF/IFAS 2018). Leaflets exhibit nyctinasty and close together at night as a water conservation strategy that reduces leaf surface area to the air (Minorsky 2018; Odirile and others 2019). Flowers are yellow to orange or gold and highly fragrant, with highly visible exerted stamens on a globose head (Figure 1C). Flowering occurs in late winter or early spring; however, blooms can occur throughout the year after each new flush of growth. Bloom intensity varies depending on geographic location (TWC 2015; Erkovan and others 2016; UF/IFAS 2018). Fruits are long, dark brown leguminous pods that mature 4 to 6 mo after the flower is pollinated (Figure 1D). As fruit matures, it dries and hardens. When mature pods dehisce, anywhere from 5 to 30 small seeds are released (observational data) (Figure 1E).

Sweet acacia can be grown in cold hardiness zones 9 to 11 (USDA 2012) and has a pan-tropical distribution. Believed to be native to the southern US, Central America, and the Caribbean, sweet acacia can be found in a wide range of environmental conditions (Parrotta 2004; KRBG 2021). Characterized by high drought tolerance given its prominent taproot (Moura and Vieira 2020), this species is extremely hardy, preferring well-drained soils and bright direct sunlight (UF/IFAS 2018; Moura and Vieira 2020).

Despite its ornamental appeal, adaptive ability, and potential use as a wildlife attractant, sweet acacia is rarely utilized in the landscape and is difficult to find in the trade. Limited species propagation information is one obstacle to commercial production. Propagation by seed is relatively undocumented, and propagation by vegetative cuttings is not documented. As with many members of Fabaceae, seeds are reported to possess physical dormancy (Tadros and others 2011) imposed by the impermeability of the seedcoat (Davies and others 2018). Seeds of the closely related pineland sweet acacia (*V. farnesiana* (L.) Wight & Arn. var. *pinetorum* (F.J. Herm.) Siegler & Ebinger) are desiccant and freeze tolerant, suggesting the ability for long-term storage (Salazar and others 2018). Sweet acacia seeds stored for 15 y or more in dry, refrigerated conditions were found to be highly viable (Wilson, unpublished data). Manual scarification techniques may be used to overcome physical

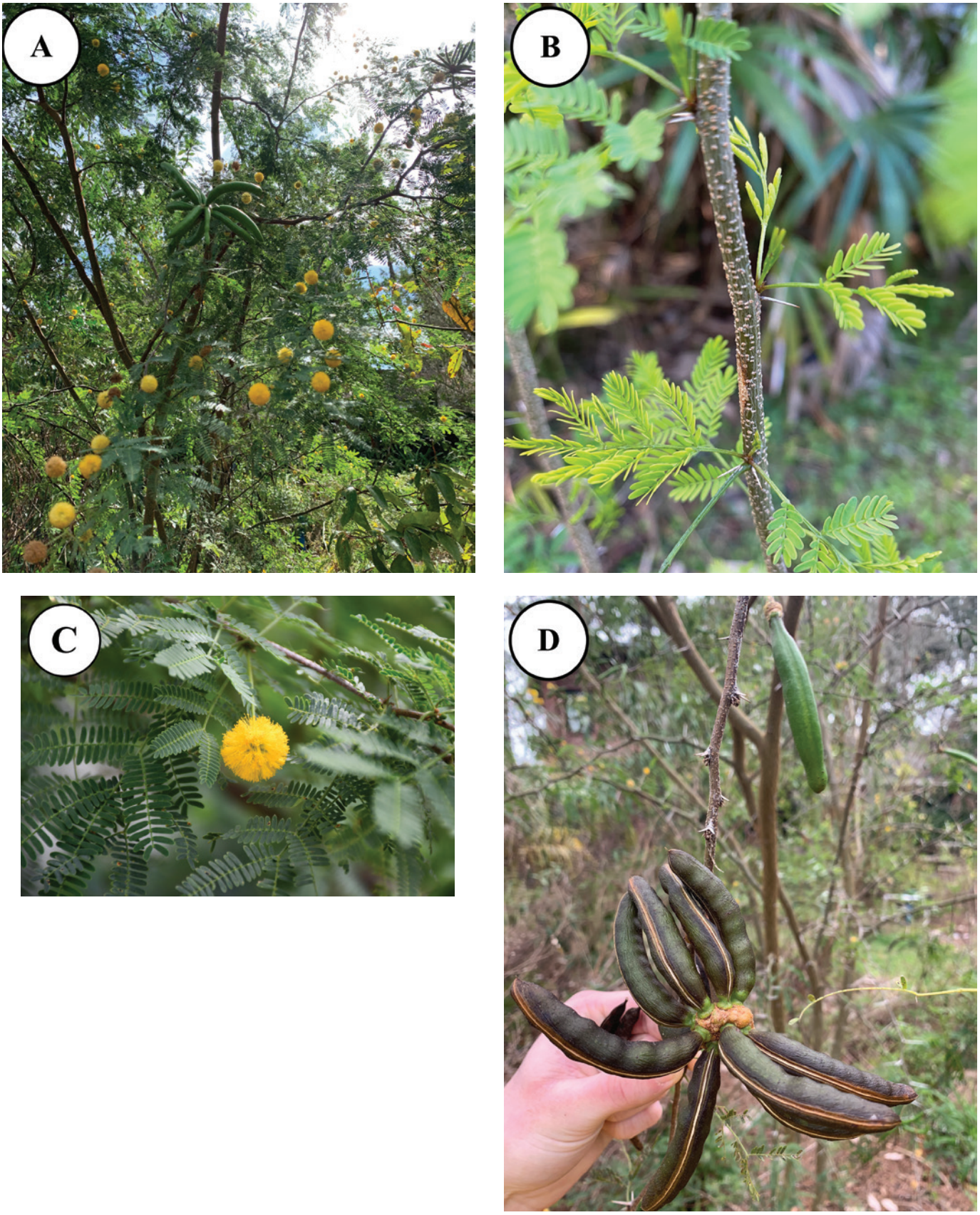

Figure 1. Plant form of sweet acacia seedlings (A) with bipinnately compound leaves and stipular spines (B), globose flower heads (C), and leguminous biserrate seed pods (D) splitting to reveal seeds (E) (on following page). Photos by Thomas Smith and Sandra Wilson

Figure 1. Split seed pods reveal seeds (E).

dormancy of the seeds (Baskin and others 2004; Dumroese and others 2009). Seeds treated with sulfuric acid for 15 min and 1 h dramatically improve germination of sweet acacia with 100% germination after 2 d compared to untreated seeds that did not germinate (Morales-Dominguez and others 2019). Disadvantages associated with acid scarification include the requirement of special safety equipment, the risk of thermal reactivity damaging the embryo, and hazardous waste disposal (Davies and others 2018). Sandpaper, hot water, and drum tumbling are common mechanical and thermal alternatives to chemical scarification. They are used by nursery professionals with similar results for a lower cost (Materechera and Materechera 2001; Davies and others 2018). In 2 closely related species, umbrella thorn acacia and porknut (*Vachellia macracantha (*Humb. & Bonpl. ex Willd.) Seigler & Ebinger), mechanical scarification resulted in higher germination rates than thermal or chemical scarification (Kruger and others 2018; Maldonado-Arciniegas and others 2018).

While seed propagation is generally preferred when propagating native plants for improving genetic diversity of local populations, cutting propagation has noted advantages. Most important, cutting propagation may serve as an alternative means when seeds are not available. Cutting propagation is also used to produce more uniform plants, maintain specific genotypes, or decrease production time (Dumroese and others 2009; Rupp and others 2011; Davies and others 2018). *Vachellia* species are considered difficult to root (Davies and others 2018) although branch cuttings have been reported on a small scale (Webb and others 1984). Min and others (2010) found IBA to be superior to other auxins in increasing root number and length of brown salwood (*Acacia mangium* Willd. [Fabaceae]). Efficient propagation systems for root cuttings of sweet acacia are unknown, although reports of *in vitro* shooting and rooting (Morales-Dominguez and others 2019) suggest it is possible.

The overall goal of this study is to widen the use of sweet acacia in landscapes by developing practical methods for propagation. Specific objectives were to determine 1) the effects of mechanical scarification and visual imbibition sorting on seed emergence, 2) comparison of seedling morphology and the effect of cotyledon number on later branching and plant height, and 3) the effects of liquid and talc auxin on rooting and quality of cuttings.

MATERIALS AND METHODS

Experiment 1: Emergence, Cotyledon Number, and Branching

We designed the first study to evaluate and compare sandpaper and boiling water seed treatments to each other and to nontreated (control) seeds. In late spring 2020, mature fruit (dark brown to black in color with a noticeably dehydrated exterior; seeds are loose and rattle if shaken) were collected from a 5-y-old specimen tree located in a teaching garden on University of Florida's campus (Gainesville, Florida). After collection, seeds were removed from fruits and stored at room temperature in a paper bag prior to experiments. Seeds were treated as a group and randomly divided into 3, 25 seed replicates for each treatment (N = 225) The first treatment was mechanical scarification, accomplished by positioning seeds between 2 pieces of sandpaper (60 Grit Sandblaster Pro, 3M Company, St Paul, Minnesota) and sanding in a circular motion, maintaining pressure and contact with seeds, for 5 min prior to soaking at room temperature water for 24 h. The second treatment was thermal scarification, accomplished by bringing water to a rapid boil, removing it from the heat source, and pouring the water over the seeds and allowing them to soak for 24 h as the water cools. As a control, seeds were not scarified but soaked in room temperature water for 24 h, the industry standard for hard-coated seeds (Davies and others 2018). Following the 24 h soaking interval, 3 replicates made up of 25 seeds each were sown into 30-cell seed trays (diameter 6.35 cm, depth 8.9 cm; Landmark Plastic, Akron, Ohio) filled with a commercial potting soil (Pro-Mix HP Biofungicide and Mycorrhizae media made up of peat moss, perlite, vermiculite, limestone, and wetting agent; Premier Horticulture, Quakertown, Pennsylvania) for each treatment. Seeds were planted 2 cm deep and lightly covered. Seedling trays were transferred into a mist house with overhead mist irrigation running for 5 s every 5 min by a Sterling 12 irrigation controller (Superior Controls, Seabrook, New Hampshire), with 12 zones of 6 Senninger upright Misters (Senninger Irrigation, Clermont, Florida) with 1.3 cm nozzles spaced 76.2 cm apart along each bench. Average temperature in the mist house was 25.1 °C with a maximum temperature

of 36.4 °C and a low temperature of 13.7 °C (HOBO Pendant MX Water Temperature Data Logger; Onset Computer Corporation, Bourne, Massachusetts). We collected data 3 times a week for a period of 22 d with emergence defined as any visible portion of the emerging stem rising above the soil line.

Additionally, we recorded observations noting the differences in cotyledon numbers per seedling after emergence. At 22 d after sowing, seedlings were transplanted to 3.8-l pots and kept in a greenhouse. Each pot contained 2 seedlings that were grouped together by numbers of cotyledons. Seedlings were visually assessed and classified as either 2, 3, or 4 cotyledons per seedling. Some seedlings had cotyledons that were lobed or cleft, therefore a full division in cotyledon tissue, to the hypocotyl, differentiated seedlings with more than 2 cotyledons. While in the greenhouse, seedlings were fertilized with 14.8 ml (1 tbsp) of extended-release 15-9-12 (N-P-K) fertilizer (Osmocote; The Scotts Company, Marysville, Ohio). After 60 d in the greenhouse, plants were moved outdoors and maintained in containers for an additional 7 wk. Total height and the height of the first 2 branches (if present) were recorded to determine if cotyledon number affected plant growth form. The presence of branching (yes/no) was also assessed. Plants were measured from the crown to the tallest stem tip, and branches were measured from the crown to the abaxial stem branch point.

Experiment 2: Emergence of Visually Imbibed versus Non-imbibed Seed

We exposed an additional group of seeds collected from the same tree as Experiment 1, during spring through summer 2020, to either the boiling water scarification (described previously) or soaked in water at room temperature for 24 h, as described for the first experiment. Prior to planting, we visually sorted seeds depending on if they had imbibed (swelled) or not. Seeds that imbibed water were visibly swollen with the hard seedcoat becoming gelatinous and rubbery. Seeds were then grouped according to their initial scarification treatment; classifying them as "scarified and imbibed," "scarified and not imbibed," or "non-scarified" (control). Three replications of 30 seeds each were selected in a completely randomized fashion (by imbibed or scarification pre-treatment) for emergence evaluation, totaling 90 seeds per treatment (N = 270). Seeds were sown into 30-cell seed trays using the same potting mix as described in Experiment 1 and monitored for 27 d in the mist house. We recorded simple emergence counts and cotyledon numbers used in the total representation of plant cotyledon frequency.

Experiment 3: Cutting Propagation with Liquid Rooting Hormone

We conducted vegetative propagation with sweet acacia using a commercial liquid rooting hormone (DipN'Grow, Clackamas, Oregon). The DipN'Grow concentrated formulation contains IBA (indole-3-butyric acid) at twice the rate of NAA (1-naphthaleneacetic acid) (10,000 mg/l [ppm] IBA + 5000 mg/l [ppm] NAA). Auxin solutions were prepared per manufacturer instruction with subsequent serial dilutions to achieve the following treatments: Control (0:0), 4000:2000, 2000:1000, 1000:500, and 500:250 mg/l (ppm), IBA:NAA, respectively. Semi-hardwood, sub-terminally wounded, stem cuttings were prepared by collecting large branches nearest to the crown. These branches were stored in a large walk-in refrigerator, with the cut end submerged in water, while preparing individual cuttings. We subdivided the branches into cuttings with 2 to 3 nodes, 5 to 7 cm in length, with a majority of the leaf tissue removed. Wounding was achieved by cutting diagonally below the basal node to create a heel. We dipped cuttings in the control treatment in water, while other cuttings received a 3 s basal quick-dip to a depth of 2 cm in their respective IBA:NAA treatments, as a group. After treatment application, cuttings were stuck into the same 30-cell trays used in Experiment 1 and filled with a media mixture made up of 50% Pro-Mix HP Biofungicide and Mycorrhizae media and 50% perlite by volume as described in Experiment 1. Overhead mist was provided within the mist house as described previously. Maximum photosynthetically active radiation in the enclosure at the level of the cuttings was 342 $\mu mol \cdot m^{-2}/s$ PPF (LI-250A Light Meter; LI-COR Biosciences, Lincoln, Nebraska). Temperature was monitored with a data logger placed among the cuttings, recording a daily average of 25.3 °C for the duration of this experiment.

We utilized a randomized block design for this experiment. Blocks were randomly placed on the greenhouse benches. Each block contained 6 cuttings from each of the 5 treatments. The randomized block was replicated 3 times totaling 18 cuttings per treatment. We assigned treatments in a randomized fashion to 1 of 5 columns in a 30-cell tray representing a block. Cuttings were observed weekly with the presence or absence of foliage recorded each month. At 119 d after treatment, we evaluated surviving cuttings using a visual root quality scale (DAT) from 0 to 5 with 0 = dead cuttings; 1 = alive cuttings with no roots; 2 = roots beginning to form; 3 = roots forming but do not hold medium; 4 = rootball partially holds plug medium; and 5 = fully formed rootball entirely holding the plug medium when removed from the tray.

Experiment 4: Cutting Propagation with Talc Powder Rooting Hormone

We conducted a subsequent cutting experiment using a commercial talc rooting hormone (Hormex, OHP Inc, Mainland, Pennsylvania) containing either 8000 or 16,000 mg/l (ppm) IBA. Longer terminal semi-hardwood cuttings 15 to 20 cm with 4 to 6 nodes were made and wounded toward the 1.3 cm basal end of the cutting. Cuttings were dipped in water prior to receiving 1 of 3 treatments: 0, 8000, and 16,000 mg/l

(ppm) IBA. After talc hormone application, we immediately stuck cuttings in 6-cell trays (width 3.8 cm × length 3.8 cm × depth 5.8 cm (T.O. Plastics, Clearwater, Minnesota) using the same potting media as described in the third experiment (Pro-Mix HP Biofungicide and Mycorrhizae media). Cuttings were placed in the same mist house as previously described with overhead mist set for 5 s every 5 min and covered with vented humidity domes. An experimental unit consisted of a 6-cell pack with 6 cuttings randomly assigned to each of 3 flats (replicates). We observed cuttings weekly and the presence or absence of foliage and (or) roots were recorded each month. At 94 d after treatment (DAT), surviving cuttings were evaluated using a visual root quality scale from 0 to 4, where 0 = dead; 1 = foliage but no roots; 2 = roots forming; 3 = roots present and holds little to no media; and 4 = well-formed rootball holding a majority of the plug media.

Experiment Design and Statistical Analysis

Experiments utilized a completely randomized block design. Prior to analysis, all data were tested for normality using the Shapiro Wilk test to ensure that the assumptions of ANOVA were met. All data were analyzed using JMP Pro Software (ver. 14, SAS Institute, Cary, North Carolina) or SAS (ver. 9.4, SAS Institute). Seed emergence data were subjected to mixed model analysis of variance with replication as a random effect and all other effects as fixed. Post hoc means comparisons were accomplished using Tukey's Honest Significant Differences (HSD) at a 0.05 significance level to compare pre-sowing stratification treatments and to determine emergence differences in imbibed versus non-imbibed seed. We evaluated cotyledon effects on growth by comparing mean stem height for each cotyledon number using Tukey's HSD test (P = 0.05) while branching (yes/no) data were analyzed using a chi-squared test to determine if cotyledon number had an effect on seedlings breaking apical dominance. Rooting hormone data from surviving cuttings were analyzed using orthogonal contrasts to determine linear or quadratic trends of rooting success by hormone rate. Contrast coefficients were determined using PROC IML in SAS when hormone concentrations were unequally spaced. Post hoc mean separation was also performed in order to make individual treatment comparisons using Tukey's HSD as described previously.

RESULTS

Experiment 1

At 7 d after sowing (DAS), the highest emergence rate observed was in seeds that were scarified with sandpaper (19% emergence), while minimal emergence was observed in seeds scarified with boiling water and the control group (1% and 0% emergence, respectively, $P \leq 0.05$) (Figure 2). By 10 DAS, no difference was observed between scarification treatment of seeds scarified with sandpaper or boiling water, which reached 49% and 47% emergence, respectively. Compared with the non-scarified control, which had a low emergence of 1.3%, both sandpaper and boiling water had significantly higher rates of emergence after treatment ($P \leq 0.05$). This trend continued through the conclusion of the study at 22 DAS with seeds

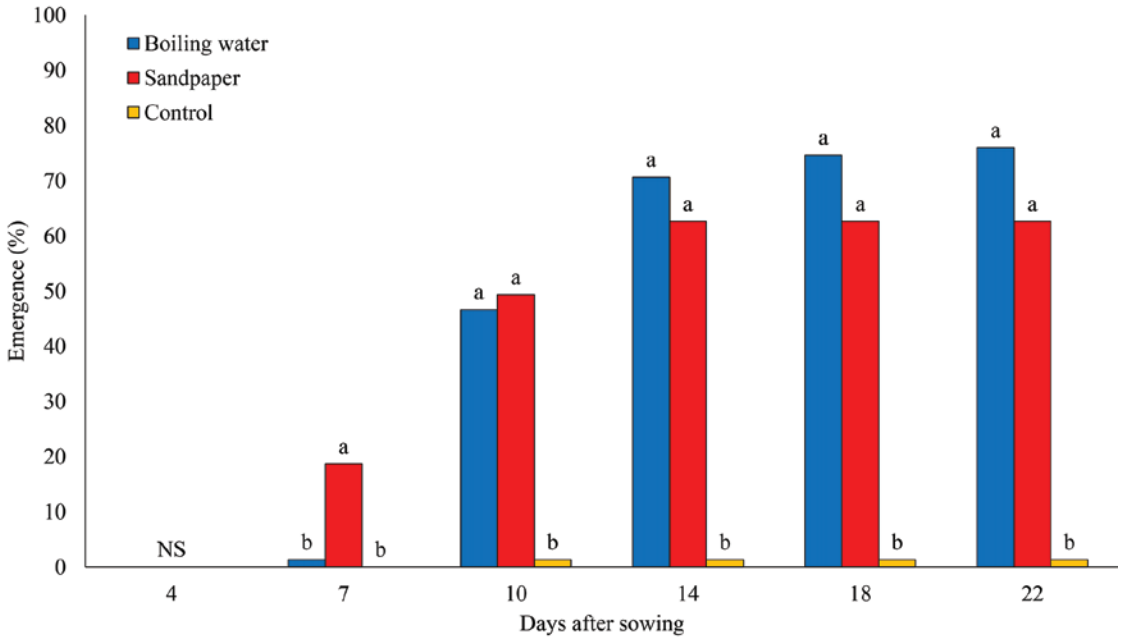

Figure 2. Emergence percentage of sweet acacia across time (days after sowing [DAS]) with seeds that were non-scarified (control), scarified with sandpaper, or scarified with boiling water. Within each DAS, columns followed by the same letter do not statistically differ ($P \leq 0.05$), NS = nonsignificant.

scarified by either boiling water or sandpaper reaching 76% and 73% emergence while non-scarified seeds never exceeded 1.3% emergence ($P \leq 0.05$).

Seedlings displayed 2, 3, or 4 cotyledons making up 33%, 43%, and 23% of the population ($N = 343$), respectively (Figure 3A–D). A single plant was observed to have 5 cotyledons. Initial scarification treatment (sandpaper, boiling water, or no scarification) had no effect on plant cotyledon number ($P = 0.599$) (data not shown). Abnormal cotyledon morphology (some were lobed) appeared to also affect the first true leaves, with leaves being whorled or in a mass at the first node instead of alternate. When comparing growth characteristics of plants with different numbers of cotyledons, data showed 3- and 4-cotyledon plants had a significantly higher incidence of branching when compared with 2-cotyledon plants but there was no difference in plant height 119 d after planting (Table 1). While plants with 2 cotyledons had an overall lower frequency of branching when compared to plants with 3 or 4 cotyledons, polycotyledonous plants had significantly lower branching points with no difference between those with 3 or 4 cotyledons ($P = 0.021$). Approximately 90% of plants with 2 cotyledons did not branch over the course of the experiment, whereas branching of polycotyledonous plants was on average 6.8 times higher when compared to plants with only 2 cotyledons (Table 1).

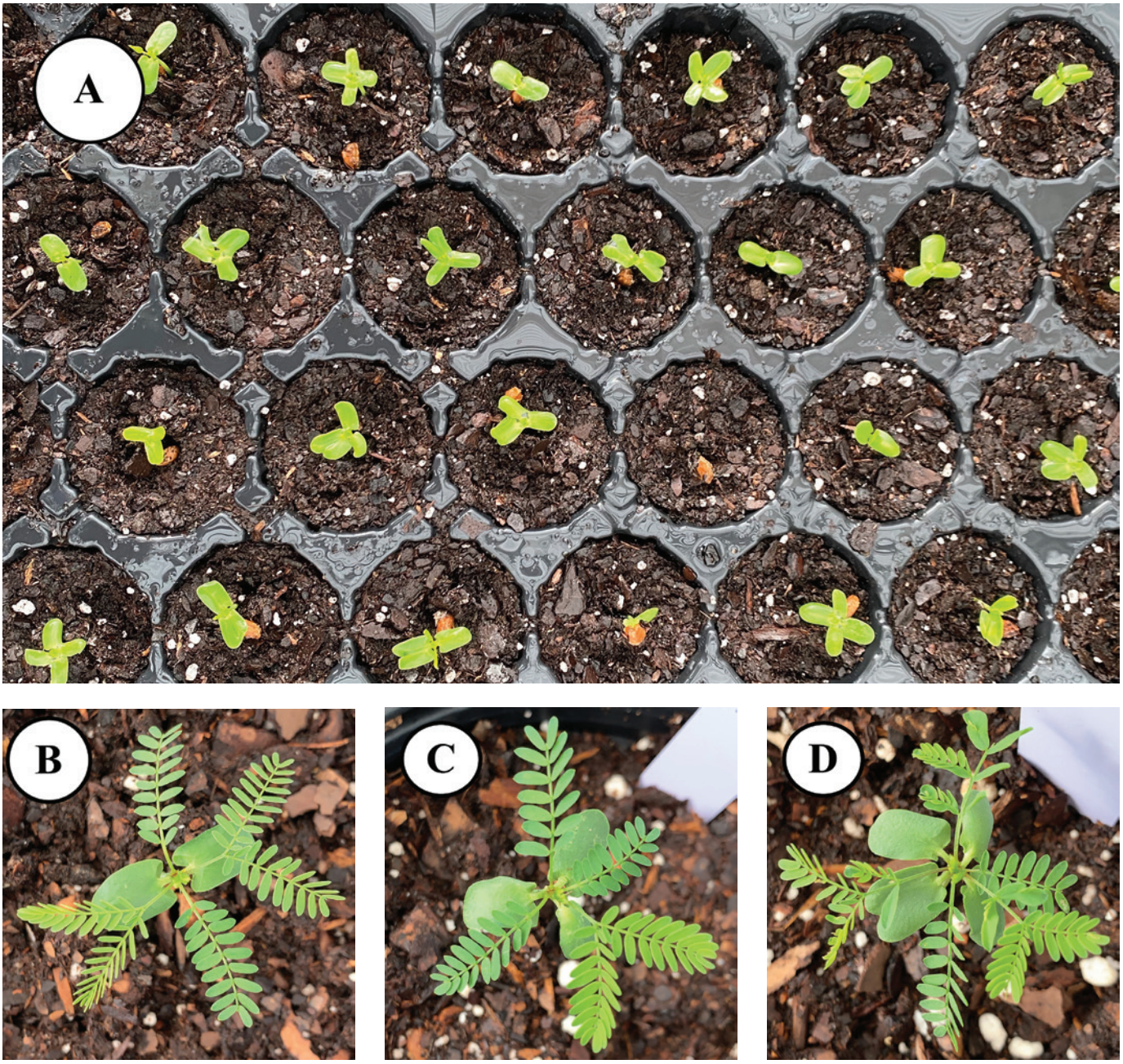

Figure 3. Polycotyledonous behavior of sweet acacia seedlings (A) having 2 (B), 3 (C), or 4 (D) cotyledons. Photos by Thomas Smith

TABLE 1

*Effect of the total number of cotyledons on the subsequent plant height and branching after transplanting, from germinated sweet acacia (*V. farnesiana*) seeds, to 3.8 l (1 gal) pots and grown for an additional 119 d.*

		Branching (%)[z]	
Cotyledon number	Plant height (mm)	Yes	No
2	44.4 a[y]	10 b	90 b
3	41.2 a	68 a	32 a
4	45.6 a	67 a	33 a

[z]Branching shows percentage of seedlings that formed branches based on cotyledon number and were analyzed using chi-squared contingency analysis ($P \leq 0.05$).

[y]Means followed by the same letter are not significantly different according to Tukey's HSD test ($P \leq 0.05$).

TABLE 2

Effect of rooting hormone level (0:0, 500:250, 1000:500, 2000:1000, 4000:2000 mg/l [ppm] indole-3-butyric acid [IBA]): 1-naphthaleneacetic acid [NAA]) on survival of sweet acacia stem cuttings 34, 71, and 98 d after treatment (DAT).

	% Survival		
Contrasts[z]	34 DAT	71 DAT	98 DAT
Quadratic	0.0006	0.0239	0.0036

Notes: Survival was assessed based on cuttings that contained green leaves.

[z]Quadratic response were determined using orthogonal contrasts and considered significant at $P = 0.05$.

Experiment 2

Seeds that appeared visually imbibed (swollen) following boiling water scarification reached 96% emergence at 3 DAS ($P < 0.0001$) (Figure 4). At this time, non-imbibed seeds showed a 30% emergence rate whereas the control group had 0% emergence. This trend continued with the highest emergence being observed in treated imbibed seeds followed by treated not imbibed seeds for 21 DAS. At 23 DAS and for the remaining duration of the experiment, no difference displayed between seeds that had imbibed (97% emergence) and not imbibed (86% emergence) at planting, with both treatments displaying significantly higher emergence compared with the control (10% emergence) ($P < 0.0001$).

Experiments 3 and 4

In Experiment 3, liquid rooting hormone (IBA:NAA) did not affect root formation regardless of concentration applied, with low survivability in all treatments (Table 2). At 34 and 71 d after treatment (DAT), survivability was variable, revealing a significant quadratic response. At 98 DAT, survivability decreased as rooting hormone concentration increased ($P = 0.0237$).

In Experiment 4, talc rooting hormone (IBA) did not affect root score or root count but did affect root length. As IBA concentration increased from 0 to 16,000 ppm, the length of the longest and second longest roots and average root length increased linearly (Table 3) ($P \leq 0.0189$). Cutting survival rate was 73%, 70%, and 53% at the 0, 8000, and 16,000 ppm IBA concentration, respectively, but nonsignificant among treatments ($P = 0.5403$, data not shown).

DISCUSSION

We collected seeds used in both Experiment 1 and Experiment 2 from a single specimen, which should provide a representative sample for the species; however, the use of different genotypes may influence outcomes. Seed scarification

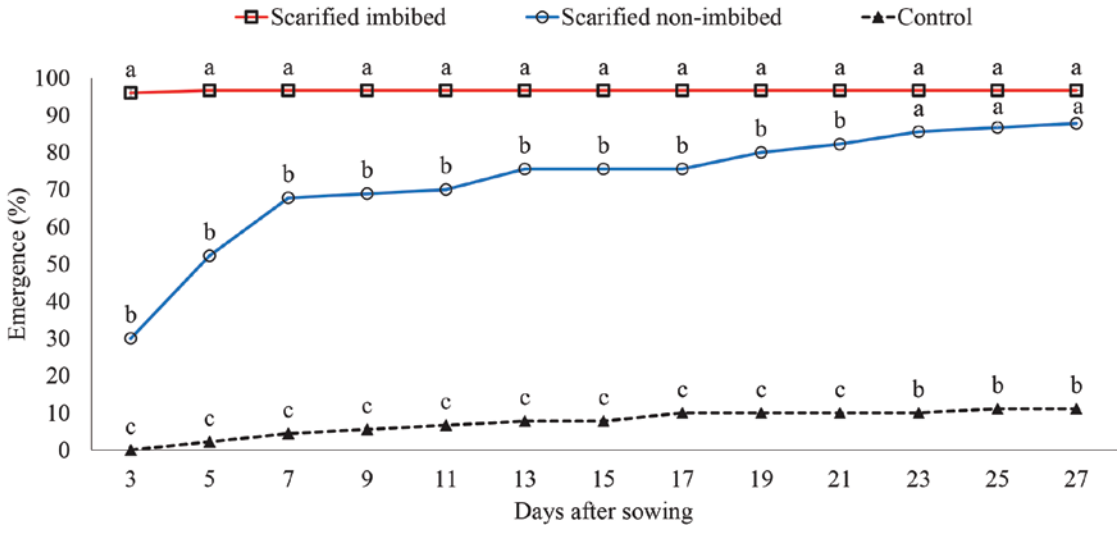

Figure 4. Comparison of emergence (%) between non-scarified (control), boiling water scarified (visibly imbibed), and boiling water scarified (non-visibly imbibed) seeds placed in a mist house for 27 d. Means within a time interval followed by the same letter are not significantly different according to Tukey's HSD ($P = 0.05$).

TABLE 3

Effect of talc powder rooting hormone (0, 8000, and 16,000 mg/l [ppm] indole-3-butyric acid [IBA]) treatment on rooting of sweet acacia stem cuttings at 94 d after treatment (DAT).

			Root length (cm)[z]		
IBA conc. (ppm)[z]	Root score (0 to 4)[y]	Root count	Longest root (cm)	2nd longest root (cm)	Mean root length (cm)
0	1.7	2.0	0.5	0.2	0.4
8000	2.1	3.9	2.2	1.3	1.7
16,000	2.5	7.1	2.6	2.1	2.4
Contrasts					
Linear	0.0523	0.060	0.0364	0.0093	0.0189

Notes: Linear responses are shown for root score, root count, longest root, second longest root, and mean root length across the 3 IBA levels and based on orthogonal contrasts. Responses were considered significant at $P = 0.05$.

[z]Talc powder rooting hormone = (indole-3-butyric acid [IBA]). Cuttings were dipped in hormone and immediately stuck.

[y]Root score was based on a scale of 0 to 4 with 0 = no visible roots or living shoot tissue; 1 = visible foliage but no root formation; 2 = roots beginning to form; 3 = roots present but small and did not hold potting media; and 4 = roots present and held potting media. Only cuttings with living shoot tissue were included in the analysis.

experiments conducted during Experiment 1 indicated that a physical dormancy must be overcome before sweet acacia seeds can germinate. Similar findings with other hard-coated species indicate seedcoat scarification is either required or improves germination (Baskin and others 2004; Odirile and others 2019). Although sandpaper-scarified seeds initially germinated faster than seeds treated with boiling water, both treatments reached 50% emergence by day 10.5 (T50), suggesting either method can be used for scarifying sweet acacia seeds. While sandpaper scarification was ideal for small batches of seed in this study, drum tumblers should be considered for larger-scale seed processing to achieve the same effect. As with any seed scarification process, care should be taken to avoid damaging the embryo (Davies and others 2018). Likewise, boiling water scarification was an effective way to soften the hard seedcoat. By denaturing proteins in the seedcoat, germination of sweet acacia is induced when the embryo has sufficient access to water. Choudhury and others (2009) and Kildisheva and others (2013) found this technique to be suitable also for Himalayan soap pod tree (*Gymnocladus assamicus* [Fabaceae or Leguminosae]) and large quantities of Munro's globemallow (*Sphaeralcea munroana* (Douglas) Spach [Malvaceae]). In Experiment 2, we found that after scarified seeds are soaked overnight, they can be further visually sorted based on the presence or absence of seed swelling (imbibition). While this practice of seed selection increased emergence speed and initial seedling tray uniformity, total emergence was similar for both visually imbibed and visually non-imbibed seeds after 3 wk. Thus, the added time and expense needed to preselect seeds may or may not be warranted, depending on one's production schedule.

Curiously, approximately two-thirds of the germinated seedlings of sweet acacia had 3 or 4 cotyledons, rather than the expected 2 cotyledons typical within Fabaceae (eudicots) (Magallon and others 1999; Narantsetseg 2014). Several other *Vachellia* species (previously classified as *Acacia*) showed a higher proportion of tricotyledonous seeds when found in polluted soils compared to those growing in non-polluted soils (Weiersbye and Witkowski 2000). This finding serves as a first report of this unusual phenomenon for sweet acacia. The ecological benefit associated with multiple cotyledons is not well known. Reports of altered physiological and (or) morphological characteristics have been associated with this phenomenon in other plants. In one study, polycotyledonous garden tomatoes (*Solanum lycopersicum* L.) displayed changes throughout embryogenesis, vegetative, and reproductive life stages, resulting in increased flowering, as well as abnormal leaves and flowers (Al-Hammadi and others 2003; Chandler 2008). A study with blackthorn acacia (*Senegalia mellifera* (Vahl) L.A. Silva & J.Freitas [Fabaceae]) identified a single plant with 3 cotyledons that had noticeably slower growth compared to dicotyledonous plants (Reddy and others 2000). In our study, we found polycotyledonous plants had greater branching than dicotyledonous plants, but differences in plant height were not observed. Differences in plant flowering could not be ascertained during the time frame of this study as plants did not flower while in containers. Of interest, we did not observe the polycotyledonous behavior in other labeled sweet acacia seed sources we randomly tested from unknown parents/origins, including seeds shipped to us from California and Arizona or seeds collected from another landscape specimen we found in Florida (Smith and others, unpublished data). The origin of polycotyledony may be attributable to genetic variability, as sweet acacia has the greatest natural distribution of all acacia species. For a pantropical species like sweet acacia, found across varying biomes with distribution resulting from both natural and human-driven establishment events, hybridization between closely related species or the formation of distinct ecotypes within the species is plausible (Clarke and others 1989). The difference

in branching between dicotyledonous and polycotyledonous plants has potential application as a pre-sorting technique for trees and shrubs. Since polycotyledonous seedlings showed significantly more branching, they would be used as shrubs while 2 cotyledon plants with less overall branching could be grown as standards, potentially reducing total time spent pruning trees.

Under the experimental conditions discussed, cutting propagation does not appear to be a reliable means of producing sweet acacia, regardless of cutting length, moisture control, and use of a range of auxin formulations. Our fourth study utilized the highest talc IBA concentration commercially available (16,000 mg/l [ppm]), typically reserved for very difficult to root evergreen conifers. While only the response of root length was significant at $P \leq 0.0189$, both root scale ($P = 0.0523$) and root number ($P = 0.0603$) responses were nearly significant, suggesting a positive linear relationship between rooting and auxin concentration. Throughout the cutting experiments, plants regularly defoliated because of environmental stress, but many sprouted new foliage. Plants did respond somewhat to the use of humidity domes with air exchange to avoid direct mist contact, suggesting that if available, fog systems may be favorable for cutting propagation of this species. Numerous other tree species respond favorably to fog including black walnut (*Juglans nigra* L. [Juglandaceae]) and persimmons (*Diospyros kaki* Thunb. [Ebenaceae]) (Tetsumura and others 2017; Davies and others 2018). As an example, Stevens and Pijut (2017) found fog chamber–rooted cuttings formed roots at a higher frequency and had a greater number of roots overall compared to mist-rooted cuttings. Although rooting was low in both cutting propagation experiments, it should also be noted that cutting survival was higher in Experiment 4 with 70% to 73% survivability at 94 DAT compared with survival of 0% to 27% survivability at 98 DAT as observed in Experiment 3. This finding could have been attributable to the use of larger terminal cuttings in Experiment 4 compared with smaller subterminal cuttings in Experiment 3. Likewise, it is possible that seasonality and (or) cutting maturity affects rooting success of sweet acacia. Because of the timing of the studies, non-lignified spring growth was not attainable but could be explored for future work. Anecdotally, semi-hardwood (intermediate) cuttings have been suggested for sweet acacia (Gann and others 2021). Plants from our study cut in late fall showed multiple new shoot tips below the cut the following spring, thus plants were actively growing. Appropriate stock plant management timed to maximize rooting efficiency may be advantageous for sweet acacia.

CONCLUSION

In addition to sweet acacia's many desirable traits for Florida landscapes, such as drought tolerance, ornamental appeal, diverse growth form, and as a wildlife attractant, results from this study show that it is relatively easy to produce from seed using standard scarification practices. Given its high ornamental value, sweet acacia is an ideal candidate for year-round production through tissue culture. Work is currently underway to establish a reliable micropropagation system for this species. Additionally, the occurrence of multiple cotyledon seedlings of sweet acacia is of interest, perhaps warranting future phylogenetic research to help discern differences among widespread geographical populations. Through continued advances in propagation knowledge of this species and others, we anticipate increased nursery production and widened use of sweet acacia in landscapes and gardens.

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