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Asexual Reproduction to Propel Recovery Efforts of the Critically Endangered Håyun Lågu Tree (*Serianthes nelsonii* Merr.)

Thomas E. Marler

Abstract

The natural distribution of the critically endangered tree *Serianthes nelsonii* (Håyun lågu) is restricted to 33 known individuals located on the islands of Rota and Guam, Mariana Islands. Major risks of extinction are a limited range, a minimal number of individuals, and a lack of recruitment. The potential for grafting and air-layering propagation was evaluated to reveal new approaches, by which species recovery efforts may be achieved. Root formation occurred on 100% of the air-layered *S. nelsonii* stems. Using *Serianthes kanehirae* as rootstock, graft success was 100% for approach graft and 25% for traditional veneer graft techniques. These results have shown that asexual reproduction is highly successful for this woody legume species and is available to address the restrictions on species recovery caused by limited seed availability. These propagation strategies open up new prospects for conserving contemporary genetic diversity and reversing the failures in *S. nelsonii* recovery efforts, since the 1994 recovery plan was published.

Keywords

air layer, endemic, graft, marcot, *Serianthes grandiflora*, *Serianthes kanehirae*

Background

Asexual plant reproduction is critical in some species for naturally retaining occupancy of habitats and expanding into new habitats (Niklas & Cobb, 2017). Asexual plant propagation has also been employed to augment seedling production systems during recovery efforts of rare plant species (Mng'omba & Sileshi, 2015; Ren et al., 2016). Asexual methods of reproduction are not universally successful among plants, and the protocols for air layer and grafting are not canonical among the species that can be cloned. Therefore, the precise approach for success requires research for each plant species (Hartmann, Kester, Davies, & Geneve, 2010).

Serianthes nelsonii Merr. (Håyun lågu) is a rare tree from the southern Mariana Islands (see map in Marler & Musser, 2015). It is a classic example of a critically endangered species with a limited endemic range, very few areas of occupancy, a limited number of adult individuals, and a contemporary failure to recruit (Marler, & Cascasan, 2015; Marler & Musser, 2015; Wiles, Schreiner, Nafus, Jurgensen, & Manglona, 1996). For plants with these traits, the mortality of even one mature individual may constitute considerable worldwide genetic erosion for the taxon.

The 1994 recovery plan for delisting the species (U.S. Fish & Wildlife Service [USFWS], 1994) called for artificial propagation of enough new plants to establish more than 4,000 mature trees among eight *in situ* populations on Guam and Rota. But limited seed availability has been one of the many impediments during pursuit of this goal. Asexual reproduction of existing *S. nelsonii* individuals could halt genetic erosion by cloning mature *in situ* trees before they die and could also enhance recovery efforts by adding new protocols for producing individuals ready for outplanting. Yet no published reports are available that demonstrate the potential for success of asexual

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propagation protocols. For the research reported here, two congenerics were employed for potential use as rootstocks for grafting *S. nelsonii*. These were *Serianthes kanehirae* Fosberg from the western Caroline Islands to the southwest of Guam and *Serianthes grandiflora* Benth from the Philippine islands.

Several objectives guided these conservation trials. First, under homogeneous shaded container nursery production, the growth rate of seedlings of the three *Serianthes* species was compared. Second, because removal of propagation material from plants in a conservation nursery requires stem pruning, the postpruning recovery of severely pruned *S. nelsonii* plants was assessed. Third, the potential for adventitious root formation using traditional air layer techniques was determined for *S. nelsonii*. Fourth, two protocols were tested for grafting *S. nelsonii* onto *S. kanehirae* rootstocks.

Implications for plant conservation are explored. Applications to *S. nelsonii* species recovery are discussed.

Study 1: Seedling Growth Rates

S. nelsonii seeds were collected under the U. S. Endangered Species Act (ESA) Recovery Permit TE-84876A-0 on November 20, 2012, from Guam's only known mature tree and were individually planted on September 30, 2014, in 0.625-L containers positioned on nursery benches under 45% sunlight transmission and protection from rain by a plexiglass roof. The container medium was 60% peat and 40% perlite. The plants were grown according to methods described by Marler and Musser (2016) until they were transplanted to 2.6-L containers on November 24, 2014. Thereafter, the plexiglass roof was removed, the sunlight transmission was 50%, and irrigation frequency was reduced to 1 time every 3 days. The plants were transplanted to 5.1-L containers on April 14, 2015.

S. kanehirae seeds originating from Palau and *S. grandiflora* seeds originating from Bohol Island were used to repeat the study outlined above for *S. nelsonii*. The *S. kanehirae* seeds were sown on January 14, 2015, and the resulting seedlings were transplanted to 2.6-L containers on March 3, 2015, then transplanted to 5.1-L containers on July 7, 2015. The *S. grandiflora* seeds were sown on March 15, 2015, and the resulting seedlings were transplanted to 2.6-L containers on May 13, 2015, then transplanted to 5.1-L containers on October 10, 2015.

Stem height was measured daily for the first month, then was measured monthly. Stem height measurements were terminated when the mean for each species reached 2 m. There were six replications for *S. nelsonii* and eight replications for the other two species.

Serianthes nelsonii and *S. kanehirae* seeds were similar in shape and proportional dimensions, but *S. kanehirae* seeds were larger in size (Figure 1). In contrast, *S. grandiflora* seeds were more elongated and angular than seeds of the other two species. Germination behavior was similar among the three species. Epigeal germination occurred with expansion of the hypocotyl and first node of the epicotyl occurring simultaneously (see Supplemental File 1). Expansion in height of the seedling exhibited one smooth process until the first set of true leaves above the cotyledons reached its maximum height. Thereafter, no more height growth occurred for several days before resuming growth of the epicotyl. For *S. nelsonii*, the expansion in height of the hypocotyl and first node of the epicotyl required 6 days and then the rest period also required 6 days. General appearance of young seedlings was similar among the three species for the first two months, with *S. kanehirae* seedlings exhibiting more rapid growth than the other two species (Figure 1).

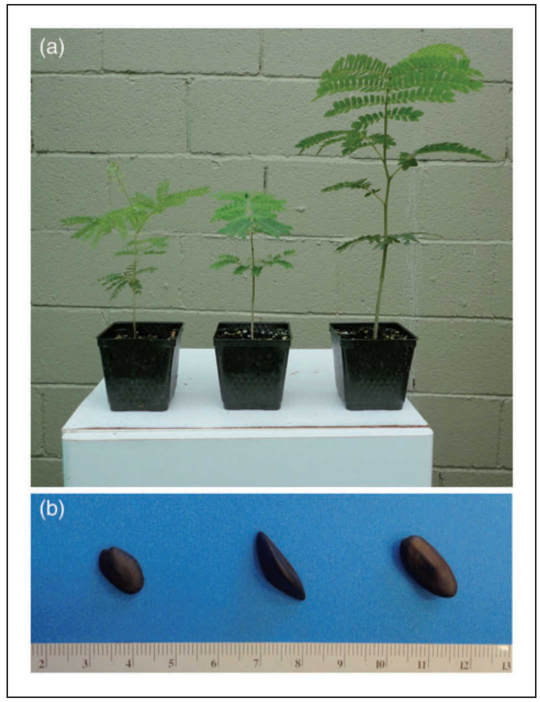

Figure 1. (a) Appearance of *Serianthes nelsonii*, *Serianthes grandiflora*, and *Serianthes kanehirae* seedlings (left to right) following 2 months of growth. (b) Appearance of *S. nelsonii*, *S. grandiflora*, and *S. kanehirae* seeds (left to right). Numbers on scale are centimeter.

The rapid initial growth of *S. kanehirae* seedlings compared to the other two species was sustained and the plants reached 1 m in height after 5.5 months and 2-m in height after 9.5 months (Figure 2(a)). *S. nelsonii* seedlings sustained growth such that they reached 1 m in height after 8 months and 2 m in height after 12.5 months (Figure 2(a)). *S. grandiflora* exhibited the slowest seedling height growth and reached 1 m in height after 9.5 months and 2 m in height after 14 months (Figure 2(a)).

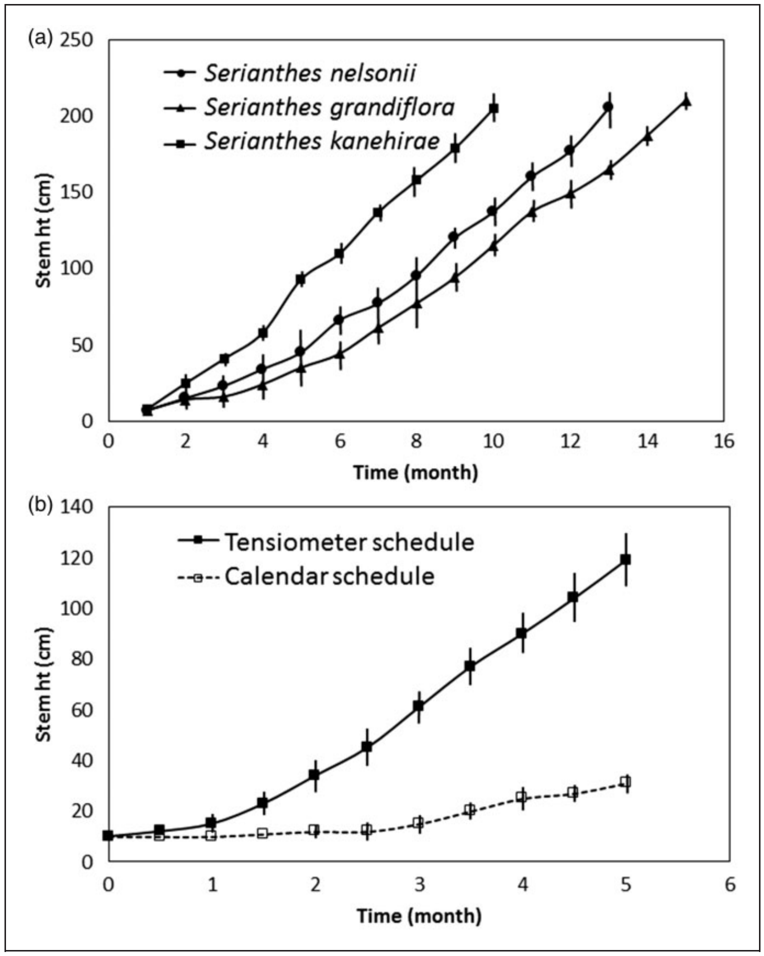

Figure 2. (a) Height of container-grown seedlings for three *Serianthes* species under 50% shaded conditions as influenced by time. Mean ± standard deviation. $n = 6$ for *S. nelsonii*, $n = 8$ for *S. kanehirae*, and *Serianthes grandiflora*. (b) Height of container-grown *S. nelsonii* plants following bare rooting and severe pruning to 10-cm in height. Tensiometer scheduling of irrigation was based on container medium reaching −22 kPa matric potential, and calendar schedule was based on watering every 3 days regardless of weather or container water relations, $n = 6$.

Study 2: Growth Following Severe Pruning

S. nelsonii seeds were collected on February 20, 2013, from Guam and were planted individually in 0.625-L containers on October 23, 2013. The plants were transplanted to 2.6-L containers on December 20, 2013. Maintenance and nursery conditions were as previously described. Twelve healthy plants were bare rooted and severely pruned to 10 cm in stem height on January 20, 2015 when the plant height was 31 ± 3 cm (mean ± *SE*). The plants were established in 2.6-L containers and placed back under the plexiglass roof (45% sunlight transmission). Half of the plants continued to receive the same irrigation frequency of every 3 days, the other half received irrigation when medium matric potential reached −22 kPa (measured by Model R6 tensiometers, Irrometer, Inc., Salinas, CA, USA). Every container for the six replications that were irrigated based on matric potential contained a tensiometer, and each plant was irrigated based on its own medium matric potential. The value of −22 kPa was derived by averaging matric potential at the time of watering each of the *S. nelsonii* plants near the end of Study 1.

The most vigorous developing shoot that subtended the heading back pruning cut was retained, and all other lateral shoots were thinned when they reached ca. 4 cm in length. This generated one central leader on each plant. Plant height was recorded every 2 weeks, and the study was terminated when the regrowth reached 1 m in length.

Irrigation management exerted a profound influence on regrowth of *S. nelsonii* plants after they were bare rooted, then pruned to 10 cm in height (Figure 2(b)). The plants that were watered when medium matric potential reached −22 kPa initiated regrowth within 2 weeks and established growth rates that exceeded growth rates of newly planted seedlings of similar height. These plants added 1 m of new stem growth in 4.5 months. Irrigation frequency was 18–20 days intervals initially and gradually decreased to 3–5 days intervals by 5 months. In contrast, the plants that were watered on a fixed schedule initiated regrowth after 2.5 months, and the growth rate was stunted throughout the study. These plants exhibited a mean of only 20 cm of new growth during the 4.5 months following the pruning treatment.

Study 3: Air Layer Trials

Guam-sourced *S. nelsonii* plants growing in a container nursery were used as stock plants to attempt traditional air layer techniques (Hartmann et al., 2010). The plants had multiple leaders and were 0.90–1.3 m tall with vigorous stem growth. A total of 20 air layers were installed from January to April 2015. Hormodin #2 commercial rooting powder (0.3% indole-3-butyric acid; OHP, Inc., Mainland, PA, USA) was applied to the bark before affixing moistened sphagnum moss as the rooting substrate. The moss was covered by plastic to retain moisture and then aluminum foil to exclude light. The aluminum foil was opened periodically beginning at 8 weeks to observe root proliferation, and the rooted air layers were removed from the stock plants 10–12 weeks after air layer installation. After removal, the aluminum foil and plastic were removed and the sphagnum moss with comingled adventitious roots was carefully planted into 2.6-L containers with 60% peat, 40% perlite medium. The plants were placed on raised benches under 50% sunlight transmission and watered as needed.

Adventitious root initiation and growth occurred for 100% of the air layers (Figure 3(a)). Under the conditions of this study, 45% of the detached air-layered plants

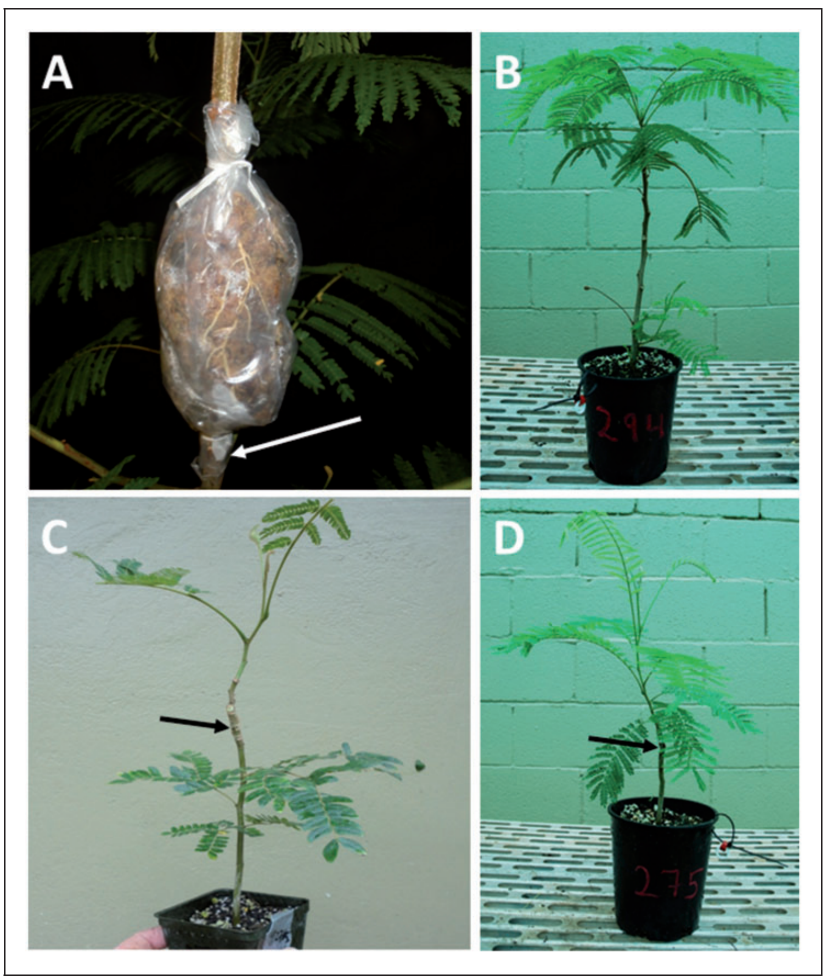

Figure 3. (a) Air layers installed on *Serianthes nelsonii* stems began to reveal adventitious roots in 8 weeks. White arrow depicts site of pruning to remove the propagule from the source plant. (b) A 53-cm tall air-layered *S. nelsonii* plant 6 weeks after removal from the source plant. (c) An approach graft propagule immediately after removal from the source plant exhibits *Serianthes kanehirae* leaves below the graft union (black arrow) and *S. nelsonii* leaves above the graft union. (d) A 34-cm tall veneer graft propagule exhibits robust growth 2 months after the grafting procedure.

established in containers and initiated robust growth (Figure 3(b)). The remaining plants slowly declined and died.

Study 4: Grafting Trials

S. kanehirae seeds from Palau were planted on January 20, 2015, and *S. kanehirae* seeds from Yap were planted on April 5, 2015. The plants were used as rootstocks for grafting trials when each seedling was growing in a 0.625-L container and was 2–4 months in age. For approach grafts (Hartmann et al., 2010), the containers were suspended in the canopy of containerized *S. nelsonii* plants to position the rootstock stem adjacent to a *S. nelsonii* stem of similar diameter (Figure 4). For veneer grafts (Hartmann et al., 2010), budwood was detached from the containerized *S. nelsonii* plants and grafted onto *S. kanehirae* plants where the stem diameters matched.

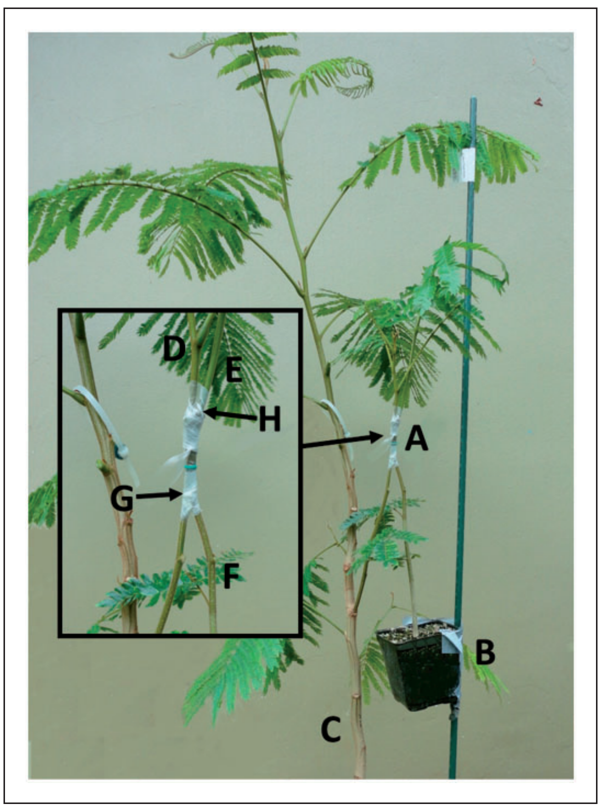

Figure 4. Pictorial depiction of approach graft technique used to propagate *Serianthes nelsonii* plants with *Serianthes kanehirae* as rootstocks. Graft union (a) was made possible by suspending small containers (b) with *S. kanehirae* seedlings. Water and nutrient needs of *S. nelsonii* stem and leaves distal to graft union were supported by intact connection to *S. nelsonii* roots (c). Following graft union, *S. nelsonii* stem (d) was retained and *S. kanehirae* stem (e) was removed above the union. The grafted plant was removed from the source plant by retaining *S. kanehirae* stem (f) and pruning *S. nelsonii* stem (g) below the graft union.

Each scion for the veneer grafts contained one lateral bud. A total of 34 grafts were executed between April and June 2015. Approach grafted plants were removed from the source *S. nelsonii* plants by pruning the *S. nelsonii* stem below the graft union and the *S. kanehirae* stem above the graft union (Figure 4). All plants were transplanted to 2.6-L containers the same day they were removed from the source plants. Successful veneer grafted plants did not require a procedure to force the *S. nelsonii* scion to initiate growth. The *S. kanehirae* stem above the veneer graft was pruned when the *S. nelsonii* scion's stem growth reached 4–5 cm in length, and the plants were transplanted to 2.6-L containers.

The approach graft protocol led to 100% success, and the merged grafted plants were removed from the source *S. nelsonii* plants 4–5 weeks after the propagation procedure (Figure 3(c)). The veneer graft protocol led to 25% success. The new stem growth from the *S. nelsonii* scions occurred within 3 weeks of grafting, and the top of the *S. kanehirae* rootstocks was pruned after 4 weeks. Successfully grafted plants rapidly resumed robust stem growth (Figure 3(d)).

Discussion

S. nelsonii is listed as endangered under the U. S. ESA (USFWS, 1987) and as critically endangered under the International Union for Conservation of Nature (IUCN) Red List (Wiles, 1998). The published targets for recovery of Guam's *S. nelsonii* population set a lofty goal of establishing at least four *in situ* populations, with each population containing 500 or more reproductive plants (USFWS, 1994). Therefore, more than 2,000 propagated individuals are required for Guam alone, especially if mortality of small outplanted individuals is factored in to the process of achieving 2,000 mature plants. A single outplanting project was funded in the late 1990s, which resulted in 67 seedlings being planted in two in situ locations (Heidi Hirsh, personal communication 23 October 2012). As of today, one juvenile tree remains alive from this single in situ conservation project (USFWS, 2016).

The global population of *S. nelsonii* was about 120 adult trees (Wiles, 1996; Wiles, Aguon, Davis, & Grout, 1995) at the time the 1994 recovery plan was formulated (USFWS, 1994). Attrition of these mature trees generated an estimate of 60–80 live trees in 2012 (USFWS, 2012) and 33 live trees in 2016 (USFWS, 2016). This trend illuminates some of the reasons that research was defined as a major component of the recovery plan for *S. nelsonii* (USFWS, 1994). Unfortunately, the conservation community did not immediately respond to the need for research, and little effort was invested into adhering to the recommendations of the recovery plan until recently.

The results presented here verify the potential for use of air layer propagation techniques to improve *S. nelsonii* recovery efforts. The 100% success in rooting then the failure of some plants to establish after removal of the propagules indicates that more research is warranted to determine optimum nursery care to establish the rooted propagules. Leaving the rooted air layers on the stock plants much longer may improve the vascular connections between the newly formed adventitious roots and the leaves that are distal to the air layer and thereby improve establishment of the propagules. Alternatively, more shaded conditions, intermittent mist systems, or any means by which relative humidity may be controlled to reduce transpiration of the removed air layer plants may improve transplant success.

The 25% success rate for a grafting protocol that used detached scions was not unexpected, as nothing was known about grafting of *S. nelsonii*. To improve traditional graft success, future research should focus on how to prepare the budwood section prior to removal from the source tree. Some species require the budwood to be fully dormant or fully quiescent, yet other species require budwood that is ready to initiate primary growth from the bud(s) on the scion. Techniques such as tip pruning about 1 week prior to removal of the budwood have been successfully used with other tropical tree species. More trials to determine the stage of growth that is most appropriate for removing *S. nelsonii* budwood will enable an experienced grafter to greatly improve grafting success.

The ESA places no limits on the number of cuttings removed from endangered plants growing in a conservation nursery. However, when all propagules under an ESA permit are being grown for outplanting, any nondestructive manipulations imposed in the nursery should not negatively affect the subsequent plant growth. The production of new plants by air layer or grafting protocols cannot be accomplished without excision of plant material from the source plants. Woody tree species respond differently to severe heading back pruning cuts; and to date, nothing is known about how *Serianthes* species recover from severe pruning. These results revealed that a pruning procedure that removed 2/3 of the canopy and reduced the plant to a 10-cm leafless stem caused no lasting influence on plant growth. Initiation of subtending latent bud growth was rapid and height growth during the 5 months after this pruning treatment (Figure 2(b)) greatly exceeded the corresponding height growth after *S. nelsonii* seedlings reach 10 cm in height (Figure 2(a)).

One caveat to this success, however, relates to functional equilibrium among plant organs. When a horticultural manipulation alters the root:shoot quotient, the nursery manager must invoke an understanding of plant physiology and anaerobiosis for managing container media water relations. The importance of these issues for *S. nelsonii* was suspected based on two observations. First, this species is currently restricted to highly drained coralline substrates. Some other sympatric native species exhibit a greater range of habitat types such as littoral and riparian habitats, but *S. nelsonii* is not known to have occurred in these wet habitats. Second, our past use of a 10-hr water soak to imbibe seeds of other Guam native tree species was severely inhibitory of *S. nelsonii* seed germination, and a 1- to 2-hr imbibition treatment was more successful (USFWS, 2012). Clearly, competent nursery management for this species must refrain from using a fixed irrigation schedule, and plants with limited transpiring surface should be protected from rainfall. Daily inspection of each plant to irrigate only when leaf wilting is initiated will ensure optimum plant health. The species is highly intolerant of overwatering (Figure 2(b)) and highly resilient following inadvertent underwatering.

Implications for Conservation

These results present new insights into the potential for cloning *S. nelsonii* plants as a means of dismantling one of the key barriers to recovery efforts, the acute limitation of seed availability. First, the unlimited availability of seeds from *S. kanehirae* (and potentially *S. grandiflora*) means that thousands of new *S. nelsonii* plants can be produced without consuming any *S. nelsonii* seeds. Second, the two genotypes that comprise a grafted plant can be exploited by a competent propagator to build custom trees with unique root traits. For example, *S. grandiflora* plants are commonly found as coastal vegetation. As rootstocks, these plants may be more tolerant of saline or flooded sites. Moreover, *S. kanehirae* plants are found in schist soils from Yap. As rootstocks, these plants may be more tolerant of acid soils. Conservationists may be able to maintain healthy grafted *S. nelsonii* collections on various marginal substrates simply by selecting the best rootstock species in a manner that proves more successful than plantings using seedling *S. nelsonii* plants. Similarly, if the *S. kanehirae* roots impart increased vigor to grafted *S. nelsonii* plants as a result of their more rapid growth rate as seedlings, the plantings would likely begin producing larger quantities of seeds at an earlier age. Other conservationists have recently used this approach with grafted plants for endangered plant recovery efforts (Ren et al., 2016). Third, if mature stems from mature *S. nelsonii* trees are used as the scion source for grafting, the newly propagated plants will likely be able to produce flowers, fruits, and seeds in nursery containers. This would rapidly boost Guam *S. nelsonii* seed production for addressing needs of the recovery plan. It would also mean that these containerized source trees could be protected during Guam's frequent tropical cyclones because they could be moved inside of buildings during each disturbance event.

Demonstration of the ability for *S. nelsonii* stems to develop adventitious roots by way of air layer techniques could also generate small plants capable of producing flowers if mature tree stem sections are used to generate the air layers. Moreover, air-layered plants are usually highly branched and compact in growth habit when compared to seedling or grafted plants. This compact growth habit may prove beneficial in nursery container production of stock plants for seed production. One negative trait of air-layered plants is the adventitious root system is not as proficient at anchoring the tree as the zygotic root system that develops from a seed. Therefore, seedling trees and grafted trees may be more desirable in a geographic region like Guam that has frequent tropical cyclones.

A combination of air layering and grafting could also be exploited to propagate a large number of *S. nelsonii* propagules. A fairly large stem section is required to produce an air layer propagule, but only one node on a stem is needed to produce a grafted propagule. Therefore, current ESA-permitting restrictions would not allow many air layers on in situ trees each year. But juvenile nursery stock could be maintained for the sole purpose of producing numerous air-layered plants. These plants would retain the juvenile traits of the stock plants. In order to enjoy the benefit of a mature clonally propagated plant, budwood from mature trees could be used as scions to graft onto the air-layered plants. These grafted plants on an adventitious root system would be able to produce flowers at a young age and small size.

Although the value of using asexual propagation for furtherance of species recovery efforts by increasing the number of plants that can be produced is clear, employing grafting and air layering to clone the existing global population is arguably a higher priority. The ongoing and rapid decline of the population indicates using these techniques immediately is needed to stop the genetic erosion.

One issue of relevance is how the USFWS will approach permitting requests for outplanting grafted plants with a nonnative rootstock. If grafted plants with *S. kanehirae* or *S. grandiflora* roots will not be approved for use as in situ reintroduction plantings, there are three other potential applications for the grafted plants. First, maintaining these grafted plants in a permanent nursery exclusively for seed production would be one means of exploiting grafted plants for species recovery. Other recent case studies of rare plants have shown the value of using air-layered and grafted plants in a controlled planting for the purpose of increasing seed production (Atsatt & O'Dowd, 1976). Second, the use of grafted plants in circa situ plantings as a component of the recovery efforts would possibly be approved. Circa situ conservation is the conservation of species in plantings, where they previously existed naturally but in systems altered by man with agriculture or other managed systems. For example, *S. nelsonii* trees have been planted on the Guam National Wildlife Refuge as roadside trees, and these trees may be considered circa situ conservation. In these highly monitored circa situ settings, removal of the exotic *S. kanehirae* or *S. grandiflora* rootstocks could be easily accomplished for individuals where the *S. nelsonii* canopy declined and died. Third, an immediate ability to produce flowers is potentially the greatest benefit of using grafted plants when the budwood for the grafted plant is acquired from mature trees. To exploit this ability, *S. nelsonii* seedlings could be used as rootstocks for grafting mature budwood of *S. nelsonii* in order to generate native rootstock and native canopy plants that could produce flowers at a young age and small size. There should be no restriction on use of these grafted plants for in situ plantings.

The ESA permits place limits on how many vegetative cuttings can be taken from protected mature *S. nelsonii* trees. Therefore, large-scale cloning of in situ trees appears to be unachievable. But the permits place no restrictions on collection of soil and litterfall which is comprised of fallen leaf, stem, and fruit tissues. The lack of restrictions on litter samples can be successfully exploited to greatly enhance recovery plan success because this species resides in the most active tropical cyclone basin in the world (Marler, 2014). Field observations indicate that a high volume of green stem and leaf material is commonly dislodged from *S. nelsonii* trees during tropical cyclones. This vegetative material would not be under any restrictions of collection under the ESA. Therefore, conservation agencies would benefit by hiring a skilled propagator to maintain a large nursery of suitable rootstocks during each annual typhoon season. Conservationists with grafting skills could collect the dislodged fresh stem tissue from the posttyphoon litter and produce numerous new clones of each tree by grafting onto the rootstocks maintained ready for grafting.

The results presented herein also illuminate a conservation research approach that could be used with greater frequency. The three *Serianthes* species behaved similarly in all nursery trials, with height growth rate always adhering to the order *S. grandiflora*, *S. nelsonii*, and *S. kanehirae* (shortest to tallest). Destructive sampling techniques such as increase in dry weight among organs are required to quantify the most reliable growth traits in horticultural trials. These destructive response traits are not compatible with species recovery efforts, where each individual within a conservation nursery should go toward recovery efforts. But experiments with *S. nelsonii* and the other two species using nondestructive techniques to generate response traits for all three species could be augmented with destructive sampling techniques for the other two species. In effect, the other two species would be analogues of *S. nelsonii* with these experimental approaches. Indeed, when limited data are available on a species of interest, more informed conservation decisions can be made from data gleaned from information across species in the same genus (Pritchard, 2014).

When *S. kanehirae* and *S. nelsonii* seedlings were comingled in our nursery, *Eurema blanda* Boisduval butterfly adults preferentially ovipositioned on *S. kanehirae* leaves. This observation may be used to exploit the nonnative *S. kanehirae* as a trap crop in a *S. nelsonii* nursery. Trap cropping is a strategy where a grower plants a small percentage of the planting with a separate species that a pest is highly attracted to, leading to a response whereby the valued crop species is less damaged by the pest. The concept is founded in the attractant-decoy hypothesis, which indicates that plants may be able to avoid consumption by herbivores if they exist near more preferred, highly palatable plants (Erickson, Bell, & Dawes, 2012; Tahvanainen & Root, 1972). These decoy plants provide alternative food choices and draw the herbivore away from the less-palatable plant (Atsatt & O'Dowd, 1976; Ruttan & Lortie, 2015). With more research, these observations may lead to a valuable approach for minimizing *E. blanda* damage to *S. nelsonii* in managed plantings with less reliance on pesticides.

The anecdotal literature and communications concerning, *S. nelsonii* indicate the species is difficult to grow in a conservation nursery. Numerous past attempts to grow the species in a container nursery were minimally successful. The results from this study contradict these assertions. The species is easy to propagate by seed and production of 2-m tall plants ready for outplanting is easily achieved in about 1 year in a well-managed nursery. The species is also highly responsive to horticultural manipulations and inputs. Treatments such as barerooting, defoliating, and severe pruning do not lead to a setback in subsequent growth or health of the plants if knowledge of plant physiology by the nursery manager is employed to refine aftercare protocols. Future conservation success may be maximized if funding agencies require potential nursery managers to first meet minimum experience and academic performance qualifications, then demonstrate their ability to grow a robust nursery plant in a short trial period. This trial period may delay the initiation of large scale production of plant material for outplanting. But considering the thousands of plants that are required and the decades of failures to advance the recovery of *S. nelsonii* by the conservation community, a trial period to confirm nursery management skills would greatly shorten the time required to ultimately satisfy the total number of plants for outplanting by restricting funds to competent nursery managers.

Author's Note

Serianthes grandiflora seeds were provided by the Soil & Water Conservation Foundation Inc., Bohol Island. *Serianthes kanehirae* seeds were provided by the Botanical Collections Department of Waimea Valley and National Tropical Botanical Garden. Seed take was conducted under Recovery Permit TE-84876A-0.

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Declaration of Conflicting Interests

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References

Atsatt, P. R., & O'Dowd, D. J. (1976). Plant defense guilds. *Science*, *193*, 24–29.

Erickson, A. A., Bell, S. S., & Dawes, C. J. (2012). Associational resistance protects mangrove leaves from crab herbivory. *Acta Oecologia*, *41*, 46–57.

Hartmann, H. T., Kester, D. E., Davies, F. T. Jr., & Geneve, R. L. (2010). *Hartmann and Kester s plant propagation: Principles and practices* (7th ed., p. 928). London, UK: Pearson.

Marler, T., & Musser, C. (2015). Potential stressors leading to seedling mortality in the endemic Hayun lagu tree (*Serianthes nelsonii* Merr.) in the island of Guam. *Tropical Conservation Science*, *8*(3): 738–744.

Marler, T., & Musser, C. (2016). Chemical and air pruning of roots influence posttransplant root traits of the critically endangered *Serianthes nelsonii*. *Plant Root*, *10*, 21–25.

Marler, T. E., & Cascasan, A. N. (2015). Number of emerged seedlings and seedling longevity of the non-recruiting, critically endangered Håyun lågu tree *Serianthes nelsonii* Merr. (Fabales: Leguminosae) are influenced by month of emergence. *Journal of Threatened Taxa*, *15*, 8221–8225.

Marler, T. E. (2014). Pacific island tropical cyclones are more frequent and globally relevant, yet less studied. *Frontiers in Environmental Science*, *2*, 421–426.

Marler, T. E., Cascasan, A. N., & Lawrence, J. H. (2015). Threatened native trees in Guam: Short-term seed storage and shade conditions influence emergence and growth of seedlings. *HortScience*, *50*, 1049–1054.

Mng'omba, S. A., & Sileshi, G. W. (2015). Effect of propagule type and fruiting time on *Uapaca kirkiana* fruit and seed size, seed germination and seedling growth. *Trees*, *29*, 655–662.

Niklas, K. J., & Cobb, E. D. (2017). The evolutionary ecology (evo-eco) of plant asexual reproduction. *Evolutionary Ecology*. doi:10.1007/s10682-016-9828-5

Pritchard, H. W., Moat, J. F., Ferraz, J. B. S., Marks, T. R., Camargo, J. L. C., Nadarajan, J., & Ferraz, I. D. K. (2014). Innovative approaches to the preservation of forest trees. *Forest Ecology and Management*, *333*, 88–98.

Ren, H., Liu, H., Wang, J., Yuan, L., Cui, X., Zhang, Q., . . . Guo, Q. (2016). The use of grafted seedlings increases the success of conservation translocations of *Manglietia longipedunculata* (Magnoliaceae), a Critically Endangered tree. *Oryx*, *50*, 437–445.

Ruttan, A., & Lortie, C. J. (2015). A systematic review of the attractant-decoy and repellent-plant hypotheses: Do plants with heterospecific neighbours escape herbivory? *Journal of Plant Ecology*, *8*, 337–346.

Tahvanainen, J. O., & Root, R. B. (1972). The influence of vegetational diversity on the population ecology of a specialized herbivore. *Phyllotreta cruciferae* (Coleoptera: Chrysomelidae). *Oecologia*, *10*, 321–346.

U.S. Fish & Wildlife Service. (1987). Determination of endangered status for *Serianthes nelsonii* Merr. (Hayun lagu or Tronkon Guafi). *Federal Register*, *52*(32): 4907–4910.

U.S. Fish & Wildlife Service. (1994). *Recovery plan for Serianthes nelsonii* (p. 60). Portland, Oregon: Author. Retrieved from http://www.fws.gov/pacificislands/recoveryplans.html.

U.S. Fish & Wildlife Service. (2012). *Serianthes nelsonii (Hayun lagu) 5-year review summary and evaluation*. Honolulu, HI: Author. Retrieved from http://ecos.fws.gov/docs/five_year_review/doc4060.pdf

U.S. Fish & Wildlife Service. (2016). *Serianthes nelsonii (Hayun lagu or Tronkon guafi) 5-year review summary and evaluation*. Honolulu, HI: Author. Retrieved from http://ecos.fws.gov/ecp0/profile/speciesProfile?sId=8521

Wiles, G. (1998). *Serianthes nelsonii*. *The IUCN Red List of Threatened Species. Version 2015.1.* Retrieved from http://www.iucnredlist.org

Wiles, G. J., Aguon, C. F., Davis, G. W., & Grout, D. J. (1995). The status and distribution of endangered animals and plants in northern Guam. *Micronesica*, *28*, 31–49.

Wiles, G. J., Schreiner, I. H., Nafus, D., Jurgensen, L. K., & Manglona, J. C. (1996). The status, biology, and conservation of *Serianthes nelsonii* (Fabaceae), an endangered Micronesian tree. *Biological Conservation*, *76*, 229–239.