A HISTORY OF HAWAIIAN PLANT PROPAGATION

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ABSTRACT

The National Tropical Botanical Garden (NTBG) has been a leader in the propagation and cultivation of rare native Hawaiian plants for several decades. The organisation's work in rare plant conservation started primarily with field research and has evolved into a large-scale nursery operation. The NTBG now produces thousands of plants a year for *ex situ* conservation, garden collections and restoration projects. Here a number of Hawaiian species are reviewed, and appropriate propagation and cultural methods for each are discussed.

INTRODUCTION

The NTBG is a not-for-profit, non-governmental organisation created by US Congressional charter in 1964. The charter dedicated the institution to tropical plant research, conservation and education. The mission of the NTBG is to enrich life through discovery, scientific research, conservation and education by perpetuating the survival of plants, ecosystems and cultural knowledge of tropical regions.

Today, the NTBG is made up of a series of gardens on the islands of Kauai and Maui in the Hawaiian Islands and a garden in Florida. The island of Kauai is where the administrative offices are located. Also on Kauai, in Lawai Valley, are the Allerton Garden and McBryde Garden, and on Kauai's north shore is Limahuli Garden. In Hana on the island of Maui is Kahanu Garden and in Florida, the Kampong.

As a result of wide-ranging field research programmes and collaborations with other gardens and organisations, the NTBG has developed an extensive Living Collection in all its gardens. In a few cases, the collections have a particular focus. Kahanu Garden, for example, has a focused collection of Hawaiian ethnobotanical plants. The recent completion of the Juliet Rice Wichman Botanical Research Center (BRC) has given the Garden the ability to expand its non-living collections and to provide modern facilities to visiting scientists. In addition to the herbarium, our BRC houses the botanical book collection as well as archaeological artifacts collected on Kauai.

In the spirit of discovery, a rigorous field research programme has been developed at the NTBG. It started with a basic curiosity and concern for the disappearing native flora of Hawaii. In time, this quest for knowledge evolved into a much celebrated field botany programme that had NTBG researchers like Steve Perlman and Ken Wood developing techniques that would enable them to access the dangerous terrain in Hawaii. Whether

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high in the volcanic mountains of Kauai or on sheer-sided offshore islets, the NTBG field crew surveyed areas not easily worked before. During this time, new species were discovered, and species thought to be extinct were rediscovered. Valuable collections of voucher material were made for herbarium specimens and propagules were sent to the NTBG nursery. As a result of this intense fieldwork, NTBG became a leader in native Hawaiian plant propagation and cultivation.

The native flora of Hawaii consists of about 1,200 species of flowering plants and ferns. Since Hawaii is the most isolated island group in the world, the original colonisers were species that had to be capable of long-distance dispersal. When a new species survived the transpacific crossing, it arrived in a land with no mammalian herbivores. This, coupled with a diversity of environments ranging from the coastal strand to alpine scrublands, meant that plant species evolved to fill every niche possible. This has led to an evolved flora unique in the world with more than 90 per cent of native species being endemic.

The Hawaiian flora has been highly impacted since the arrival of Polynesians a millennium ago. When the first Polynesians arrived, they brought with them plants that they used as food, fibre or medicinal sources. They also brought chickens, dogs and pigs and the Polynesian rat as a stowaway. Prior to this, the Hawaiian hoary bat was the only native land mammal. Early human activity resulted in dramatic changes to the native forest, particularly the lowland forest where archaeological evidence seems to indicate the disappearance not only of plant species but also of many bird species, including large flightless birds (Burney *et al*., 2001). The pressure on the native forest grew once western civilisation arrived with large-scale agriculture. Ranching brought large ungulates to the high forests where overgrazing resulted in excessive run-off and erosion, which continues today. Tens of thousands of acres of native ecosystems were cleared to make way for sugar and pineapple plantations in the lowlands. This habitat degradation due to human activities coupled with the introduction of feral ungulates and invasive plants and insects has made the Hawaiian Islands the endangered species capital of the United States. It is believed that Hawaii has lost more than half its native vegetation and is home to 37 per cent of all endangered plants in the United States (State of Hawaii, 2010).

PLANT CONSERVATION IN HAWAII

With an extensive history of botanical surveys and field research in the Hawaiian Islands, the NTBG could be considered to be the leader in native plant conservation. This effort has focused on several fronts: nursery stock, *ex situ* collections and restoration projects. Our nursery maintains specimens of some of the rarest plants in Hawaii. In many cases, we have three or four times more plants in our nursery than are growing in the wild. These plants are maintained for scientific research and for the production of propagules to supply restoration efforts with our government and private collaborators. We maintain *ex situ* collections in both our McBryde Garden Native Section and Limahuli Garden and Preserve. *Ex situ* collections provide us with the opportunity to preserve the genetic diversity of species that

are becoming rare in the wild. We are also able to establish best horticultural practices for many of the species that have previously never been in cultivation.

Restorations, which can be found in all our Hawaii gardens and in collaborations with landowners and government agencies, bolster degraded native plant communities or establish new ones in areas where they no longer exist. In this case, we rely on historical botanical surveys and relictual native plant communities, if they exist, to guide us in our plant selections. We also refer to archaeological evidence of the botanical history of an area and attempt to recreate the forest that the evidence says existed (Burney and Burney, 2007). The re-establishment of native forest based on the archaeological record is referred to as *inter situ* conservation and is applied to our restoration work in Lawai Valley and Limahuli Preserve as well as other collaborations on Kauai and beyond (Burney, 2009).

PROPAGATION OF NATIVE SPECIES

The NTBG has had many opportunities to work with the rarest of Hawaii's native plants. For the most part, when propagules of a new species are brought to the nursery, we depend on our experience with other members of the same family to guide us in our efforts to grow the new material. Although exceptions are made when necessary, all seed plantings are subject to the same nursery conditions, which are:

- an open greenhouse with 75 per cent shaded light conditions
- a year-round average temperature of 24°C
- each nursery bench irrigated daily for seven minutes.

Since irrigation run times are standard for the whole nursery, the primary growing medium is pure volcanic cinders. This provides optimal drainage and air circulation around the seeds. Further, since the cinders are heavier than perlite, they will not blow out of the propagation flats on windier days. If cinders are not readily available, a perlite and vermiculite mixture can also be used. Propagation notes on eight rare native Hawaiian species are detailed below.

This rare member of Malvaceae (Fig. 1) has been collected in dry forest on the islands of Hawaii, Lanai and Oahu.

Abutilon menziesii Seem. Malvaceae
Kooloa ula

Seeds: Soak in fresh water for 24 hours to hasten germination. Soaking also means that most seeds germinate within a few days of each other. Sow on the surface of the growing medium.

Germination: Occurs in 35 to 40 days. Seedlings are allowed to grow until they have produced their third or fourth true leaf before pricking out into individual pots.

Fig. 1 *Abutilon menziesii* flower. Photo: Michael De Motta.

Potting medium: Commercial potting mixes can be used but should drain well. We often use pure cinders in the first pot after initially separating seedlings. Our ideal mix as a final potting medium to harden off plants is one part peat moss, one part coco coir and two parts perlite. This mixture provides for good drainage and allows the plants to develop a vigorous root system before being planted out in the heavy clay soils of our dry lowlands.

Planting out: Kooloa ula is ideally planted in full sun and can tolerate hot, dry and windy conditions. Under these circumstances, the pubescent foliage will become silvery green. The soil should have good structure and be well drained. The plant should be irrigated as required in the first year. Once established, it should never need irrigation.

Fertiliser and pests: Any balanced fertiliser works well for this species. We find it beneficial to till the planting site with compost and also to work in organic fertiliser. Excessive nitrogen tends to make the more mature plants top heavy and prone to toppling over. It also stimulates soft growth, which makes the plant attractive to insects such as mealy bugs (family Pseudococcidae) and aphids (Aphidoidea). Rose beetles (*Macrodactylus subspinosus*) can also be a problem for this species. If the infestation isn't too severe, they will not affect the health of the plant.

Fig. 2 *Brighamia insignis*. Photo: Michael De Motta.

Fig. 3 *Brighamia insignis* habitat. Photo: Michael De Motta.

Brighamia insignis A. Gray Campanulaceae
Alula

This species (Fig. 2) was once found on steep slopes on the islands of Niihau and Kauai. Today, the population has been reduced to one known individual in the wild, on a sea cliff on Kauai's Napali Coast (Fig. 3).

Seeds: Mature seeds disperse readily from dehiscent capsules and can be surface sown with no additional preparation. The first sets of cotyledons will appear thirty days later and seeds will continue to germinate for another three to five weeks. Using a large seed flat will allow the seeds to be spread out so that they can be pricked out from the community flat without disturbing seedlings that are not ready to be moved. We wait for the seedlings to be at least 2.5cm tall before moving them, taking special care not to break any roots.

Potting medium: Since this species is a cliff dweller, a well-drained potting mix is especially important. The plants can tolerate moist potting mix but only if there is adequate air circulation among the roots and the mix never becomes saturated with water.

Planting out: This plant is now rare in the wild; however, it is rather easy to care for. It can be planted in full sun but seems to thrive equally well if it is in full shade for part of the day then full sun for part of the day. This seems to replicate the sunlight regime of its natural cliff habitat. If there is no possible well-drained location, soil could be mounded up and mixed with perlite or cinders to enhance drainage. This species also does well in the long term in pots.

Fertiliser and pests: Slow-release and organic fertilisers work best for alula. When used at half strength, foliar fertilisers also work very well if applied on a regular basis. Mites, red spider mites (*Tetranychus urticae*) in particular, are lethal enemies and can kill a plant in a short time if a major infestation is allowed to take hold. Slugs and snails are attracted to alula and can eat the meristem, girdle it and eat holes right through the stem.

Hillebrandia sandwicensis Oliver Begoniaceae
Akaakawa

A monotypic, endemic genus, our native begonia (Fig. 4) can be found on hillsides in wet forest on most of the main islands. Its distribution is rather localised and so it is not a common sight. It is an annual and emerges in early spring to produce large clusters of pink flowers.

Seeds: The tiny seeds (Fig. 5) are spread over the surface of the medium and germinate in about two weeks. The seedlings are so tiny that there is little we can do with them

Fig. 4 *Hillebrandia sandwicensis.* Photo: Michael De Motta.

Fig. 5 Seeds of *Hillebrandia sandwicensis.* Photo: Michael De Motta.

until they are large enough to handle. This takes about eight months. The plants can then be potted up separately.

Potting medium: Pure, fine, screened cinders are used as the growing medium for this species. Since the seedlings will need to stay in the community flat for a long time, it is important to control mosses and algae that can smother out small seedlings.

Planting out: This species has been planted out for the first time on the restoration site at Limahuli Preserve. The site is a shaded, moist gulch (a large gully created by erosion) with brown, granular soil which is similar to the type of soil found in the species' preferred habitat.

Fertiliser and pests: Slow-release fertiliser seems to be adequate. Our nursery plants have been maintained in the long term using pure cinder, but the plants eventually develop chlorosis (yellowing of the leaves). Adding some peat moss to the mix seems to reduce this. We have observed spider mites and aphids on our nursery plants in the past.

Ochrosia Kauaiensis St John Apocynaceae
Holei

This rare, attractive tree is found in scattered locations along Kauai's Napali Coast (Fig. 6). With its dark green leaves (Fig. 7) it is an outstanding specimen in the forest. Seedlings are rarely seen and it is thought that this is because rodents eat the seeds (Fig. 8) before they germinate or feral goats eat the seedlings.

Seeds: The fruits are large, up to 57mm long. The soft, mature pulp should be cleaned off and the seeds washed in fresh water and air dried. The seeds should then be half-buried in the planting mix. Initial germination may occur in two months but can take as long as seven months (Fig. 8). Seeds may continue to germinate for more than a year after sowing.

Fig. 6 *Ochrosia kauaiensis* seedling. Photo: Michael De Motta.

Fig. 7 *Ochrosia kauaiensis* foliage. Photo: Michael De Motta.

Fig. 8 *Ochrosia kauaiensis* habitat on the Na Pali coast. Photo: Michael De Motta.

Potting medium: We have used different mixes ranging from black cinders to coconut fibre chunks with the best results coming from the mixes that allow for good air circulation around the seeds.

Planting out: Holei tolerates most soil types. We have successfully established plants in heavy red clay soils as well as richer forest soils that contain a lot of organic matter. Ideally, the clay soil should be well tilled and composted.

Fertiliser and pests: In well-composted soil, holei will grow well with additional fertiliser added. Should nutrient deficiency occur, the soil should be top-dressed with fresh compost or slow-release fertilisers should be used. This plant species should be checked for mealy bugs and scales as they can check growth.

Fig. 9 *Phyllostegia renovans* flower. Photo: Michael De Motta.

Phyllostegia renovans W.L. Wagner Lamiaceae

Recently discovered, this Kauai island endemic member of the mint family is found in shaded and sunny locations in wet *Metrosideros polymorpha* (Ohia) forests. Often found growing on the edges of landslides, the plant is a sprawling scandent shrub with white flowers on a long inflorescence (Fig. 9).

Seeds: The seeds are small, hard, greenish black nutlets and can be sown on the surface. Germination begins at about six weeks and continues for several weeks. Though small when they sprout, seedlings grow quickly.

Potting medium: Any well-drained potting mix will be suitable for this species. Once the young plants become established in their own individual pots, growth is rapid and repotting becomes necessary every couple of weeks.

Fig. 10 *Solanum nelsonii* flower. Photo: Michael De Motta.

Planting out: *P. renovans* will tolerate most soil types, but excessively sandy soil is the least desirable. It will even grow well in heavy red clay soils as long as it is tilled, compost is added and it drains well.

Fertiliser and pests: This species does well with slow-release and organic fertilisers. It seems that if this species is given a lot of nitrogen, it becomes more attractive to mealy bugs and thrips (*Frankliniella* sp.).

Fig. 11 *Spermolepis hawaiiensis* flower. Photo: Michael De Motta.

***Solanum nelsonii* Dunal Solanaceae**
Popolo

Popolo is a shrub that was once common on all the main islands (Fig. 10), but now only a vine form remains on the sand dunes of Moomomi Preserve on the island of Molokai. Shrub forms can still be found on the islets and coral atolls of the north-west Hawaiian Islands where they provide food and cover for rare endemic finches such as the Nihoa finch (*Telespiza ultima*).

Seeds: The seeds should be separated from the fruits, rinsed in fresh water and thoroughly air dried before sowing. Fully mature fruits will yield viable seeds that will germinate in 30 to 40 days and continue to sprout over an additional two-month period.

Potting medium: If the mature plants are to be kept in pots for a long period of time, this species requires a rather coarse and especially well-drained medium as it appears to be susceptible to root diseases.

Planting out: This species will tolerate most soil types if they are well drained. Allow soil to thoroughly dry out before watering again. The species thrives in full sun and is drought tolerant once established.

Fig. 12 *Vigna o-wahuensis* flower. Photo: Michael De Motta.

Fertiliser and pests: Slow-release fertilisers work best for popolo. Composting and mulching often provides all the nutrients the plant needs. Mites are the main insect pest affecting popolo.

Spermolepis hawaiiensis Wolff Apiaceae

Ephemeral in nature, this rare species can be found in dry shrubland where seeds will sprout after heavy, drenching rains. It is inconspicuous in its growth habit and is easily overlooked (Fig. 11).

Seeds: It is surprising to note that relatively large seeds are produced by such a small plant. Mature seeds harvested from drying plants germinate quickly. First sprouts can be observed in about six weeks.

Potting medium: Though we use our pure cinders, any commercially available medium will work for this species.

Planting out: This species is so short lived that planting out into the collection almost seems unreasonable. Still, we have done this with the intention of initiating regeneration and germination of second-generation seed.

Fertiliser and pests: We have not observed any pests on *S. hawaiiensis* and, because of its short life span, a slow-release fertiliser works well.

Vigna o-wahuensis Vogel Fabaceae
Vigna

This delicate vine has disappeared from its former range over the years and is now known only from a few sites on the island of Maui (Fig. 12).

Seeds: The seeds are hard and dark brown in colour. Fully mature seeds should be nicked before sowing. This can be done with a large nail clipper. A small bit of the seed coat should be clipped off. When planted, this nicking allows the seed to take up water immediately, hastening germination. If sown unclipped, germination could take many months. Nicked seeds will sprout in about two weeks and germination among nicked seeds is virtually simultaneous.

Potting medium: A well-drained medium that provides good air circulation is crucial for this plant. Since the seeds are nicked, excess moisture around the seeds could provide a good environment for diseases that may kill the seed. Once sprouted, the seeds grow very quickly.

Planting out: This species requires full sun and a well-drained location. It is known to

grow on old, relatively barren lava flows. It will simply spread over boulders and other plants if not provided with any support to climb up.

Fertiliser and pests: As a nitrogen fixer, this plant is quite self-sustaining. Any foliar fertiliser used at half strength will work well. Twig borers (Tortricidae) can be a problem for this species as they can cause an entire stem to die back.

CONCLUSION

The extreme isolation of the Hawaiian Islands has led to the evolution of a unique flora that is now threatened by habitat destruction and invasive species. In fulfilling its mission, the NTBG has endeavoured to be a conservation and horticultural resource and leader in the state of Hawaii.

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