

Chapter **54**

**Conservation of
Tropical Island Seeds:**
an example from Hawai'i



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Summary

Studies of seeds of Hawaiian native plants show a very low incidence of recalcitrance. Of 207 taxa screened so far, 74.7% are clearly not recalcitrant, and an additional 19.9% are probably not recalcitrant. The requirement for long-distance dispersal of original colonisers selects against recalcitrant seeds, and few recalcitrant seeds evolve from successful colonisers. Other oceanic islands are likely to show similar patterns. This suggests that seeds of many oceanic island species can be stored using conventional techniques for orthodox seeds. It is practical to establish seed conservation programmes both locally and through higher-level institutions even on islands with limited infrastructure.

Introduction

Although oceanic islands are homes to some of the world's most endangered floras (Whittaker, 1998), seed storage techniques are currently little used in island plant conservation. Our studies on native Hawaiian plants show that in a wet tropical oceanic island flora, the proportion of seed recalcitrance, or desiccation sensitivity, can be very low. In contrast, floras of continental wet tropical habitats are known for their high proportions of recalcitrant seeds. Factors leading to the high proportion of desiccation tolerant seeds in Hawai'i are common to many oceanic islands. This suggests that conventional seed storage techniques, i.e., desiccation followed by frozen storage in hermetically sealed containers, can be a valuable tool for conserving island floras.

Materials and Methods

This study combines results from three research groups working on developing seed storage methods for native Hawaiian plants: the U.S. Dept. of Agriculture National Seed Storage Laboratory (NSSL); the University of Hawai'i Center for Conservation Research and Training (CCRT); and the National Tropical Botanical Garden (NTBG) at Kalaheo, Hawai'i. The following describes how each group evaluated desiccation and temperature tolerance.

NSSL: Fresh seeds were germinated to confirm their viability. Seeds were dried at 13% relative humidity at 25°C for a week. After this, some seeds were frozen at -18°C for 16 h. Seeds that survived both drying and freezing were considered not recalcitrant.

CCRT: Fresh seeds were germinated to confirm their viability. Seeds were sown after 3+ months storage in sealed containers at 10% relative humidity or less and ambient temperature (13–29°C) or at -18°C after drying at 10–30% relative humidity at 4°C. Seeds that germinated after both treatments were considered orthodox; after neither, recalcitrant; after only the first test, intermediate. Seeds that germinated after both treatments, but displayed higher viability after 4°C storage than after being held at -18°C, were considered not recalcitrant.

NTBG: Fresh seeds were not tested. Seeds were stored at 15–30% relative humidity at ambient temperature (presumably 13–29°C). Seeds were considered not recalcitrant if more than 5% germinated after 1.5 + years of storage, and orthodox if they also survived the CCRT or NSSL freezing tests.

Results and Discussion

Table 54.1 gives seed storage category classifications for all native Hawaiian plant species for which there are data (ca. 207 taxa, or 17% of the known flora in Wagner *et al.*, 1999). A summary of the categories is as follows: Orthodox + probably Orthodox, 33.0; not Recalcitrant, 44.7%; probably not Recalcitrant, 19.9%; Intermediate + possibly Intermediate, 1.5%; and possibly Recalcitrant, 1.0%.

Most of the species in the ‘Not Recalcitrant’ and ‘Probably Not Recalcitrant’ categories will probably be reclassified as ‘Orthodox + probably Orthodox’ as further test results accumulate. Comparable figures for all seed plants worldwide for which there is storage information are: Orthodox + probably Orthodox, 88.7%; Intermediate + probably Intermediate, 1.9%; Recalcitrant + probably Recalcitrant, 7.3%; Uncertain, 2.1% (Hong *et al.*, 1996).

Both Hawaiian and worldwide figures are based on small, non-random samples of the total flora (17% and 2.9% respectively). At the family level, 63 of the 251 families in the IPGRI Compendium (Hong *et al.*, 1996), or 25.5% of the total, contain species known or believed to have recalcitrant seeds. However, many of these families are poorly studied. If the true incidence of recalcitrant seeds among species is 7.3%, it is possible to show, using the probability density function of the binomial distribution, that, in a random sample of 15 species from an infinitely large family, there is a 32.1% probability that at least one case of recalcitrance would be present within the family but not be present within the sample (Anonymous, 1993). If this as an acceptable error level it is possible to consider the 77 families for which 15 or more species have been screened

Table 54.1 Storage physiology classification of native Hawaiian plants by family. Numbers reflect species, subspecies and varieties. Classifications of individual taxa can be viewed on the World Wide Web at www2.hawaii.edu/scb/seed/seedtabl.html.

Family	Orthodox	Not recalcitrant or possibly not recalcitrant	Intermediate or possibly intermediate	Possibly recalcitrant
<i>Amaranthaceae</i>	1	6		
<i>Apiaceae</i>		2		
<i>Apocynaceae</i>		1		
<i>Araliaceae</i>		1		
<i>Arecaceae</i>		3		
<i>Asteraceae</i>	9	29		
<i>Brassicaceae</i>	1			
<i>Campanulaceae</i>	6	23		
<i>Caryophyllaceae</i>	6	10		
<i>Chenopodiaceae</i>	1			
<i>Cucurbitaceae</i>		2		
<i>Cyperaceae</i>	1	6	1	
<i>Ericaceae</i>	1	1		
<i>Euphorbiaceae</i>		2		
<i>Fabaceae</i>	4	2		
<i>Gesneriaceae</i>		7		
<i>Goodeniaceae</i>	1	1		
<i>Hydrangeaceae</i>	1			
<i>Joinvilleaceae</i>		1		
<i>Juncaceae</i>	1			
<i>Lamiaceae</i>		2	1	
<i>Loganiaceae</i>		1		
<i>Malvaceae</i>		7		
<i>Myoporaceae</i>		1		
<i>Myrsinaceae</i>				1
<i>Myrtaceae</i>	2	1		1
<i>Oleaceae</i>		1		
<i>Papaveraceae</i>	1	1		
<i>Piperaceae</i>	4			
<i>Pittosporaceae</i>		1		
<i>Plantaginaceae</i>		2		
<i>Poaceae</i>	2	13		
<i>Polygonaceae</i>	1	1		
<i>Portulacaceae</i>	1	1		
<i>Rhamnaceae</i>		1		
<i>Rosaceae</i>	1			
<i>Rubiaceae</i>	2	10	1	
<i>Santalaceae</i>		1		
<i>Sapindaceae</i>		3		
<i>Solanaceae</i>		2		
<i>Thymelaeaceae</i>		2		
<i>Urticaceae</i>	3	2		
<i>Violaceae</i>	1			

worldwide. Of these families, 31 have known recalcitrant seeds (40.3%). Fifty of the 77 families have Hawaiian species. Though few Hawaiian species with recalcitrant seeds are known, 22 of the 50 families have species with known recalcitrant seeds elsewhere (44%), a proportion not greatly different from the worldwide proportion. The lack of recalcitrant seeds in Hawaiian species has several possible causes:

- **Recalcitrant seeds are poor colonisers of oceanic islands.**

Typical agents of long-distance dispersal over water select against recalcitrant seeds. Such seeds are shorter-lived and less desiccation-tolerant than orthodox seeds and tend to be larger and heavier. Carlquist (1974) noted that the entire native Hawaiian flora could be derived from ancestors with no single-seeded fruits larger than 10 mm in diameter. Table 54.2 compares colonisation rates for the 10 families with the highest known percentages of recalcitrance worldwide and for the 10 largest families with no known recalcitrant or intermediate seeds. The recalcitrant families total 7,375 species, and have accounted for an estimated 6 colonists to the Hawaiian Islands, or 1 colonist per 1,229 species. The families without known recalcitrant or intermediate seeds total 50,370 species, and have accounted for an estimated 67 colonists, or 1 per 752 species. (Total numbers of species and distribution of recalcitrance are from Hong *et al.*, 1996. Numbers of colonists are from Sakai *et al.*, 1995).

- **Successful colonists from families with high incidences of recalcitrant or intermediate seeds have not speciated after establishment.** The 6 colonists from the 10 families with highest incidence of recalcitrance worldwide have contributed 6 species to the present-day Hawaiian flora. The 67 colonists from the 10 largest families with no known recalcitrant or intermediate species worldwide have contributed 244 species. Adding the 11th family, *Campanulaceae*, would bring this figure to 68 colonists and 368 species. (Number of species and colonists from Sakai *et al.*, 1995. Figures for *Campanulaceae* adjusted from Wagner *et al.*, 1999.)

Three seeming exceptions to this pattern are *Areaceae*, *Rutaceae*, and *Thymelaeaceae*, which have high percentages of species with recalcitrant or intermediate seeds worldwide. Each has apparently colonized the Hawaiian Islands once, giving rise to 19, 55, and 12 Hawaiian species respectively. The original palm colonizer may have been from a non-recalcitrant species. Hawaiian species of *Areaceae* appear to be not recalcitrant. Tests of seed physiology of Hawaiian species from the other two families are still in early stages.

Table 54.2 Representation in the Hawaiian flora of families with high and low incidences of recalcitrance worldwide

Family	Number of species worldwide	Incidence of recalcitrance among tested species	Number of Hawaiian species	Number of founding colonists
<i>Hippocastanaceae</i>	15	100.0%	0	
<i>Dipterocarpaceae</i>	530	100.0%	0	
<i>Rhizophoraceae</i>	130	93.2%	0	
<i>Fagaceae</i>	1,050	88.5%	0	
<i>Lauraceae</i>	2,200	74.3%	2	2
<i>Podocarpaceae</i>	155	70.0%	0	
<i>Sapotaceae</i>	1,000	66.7%	2	2
<i>Theaceae</i>	520	55.6%	1	1
<i>Moraceae</i>	1,200	48.4%	1	1
<i>Meliaceae</i>	575	47.6%	0	
<i>Asteraceae</i>	21,000	0%	92	11
<i>Lamiaceae</i>	5,600	0%	54	3
<i>Scrophulariaceae</i>	4,450	0%	1	1
<i>Cyperaceae</i>	3,600	0%	45	37
<i>Ericaceae</i>	3,350	0%	3	1
<i>Apiaceae</i>	3,100	0%	6	5
<i>Solanaceae</i>	2,600	0%	9	4
<i>Boraginaceae</i>	2,500	0%	2	2
<i>Bromeliaceae</i>	2,100	0%	0	
<i>Caryophyllaceae</i>	2,070	0%	32	3

Upper: 10 families with the highest observed percentage of recalcitrance worldwide (families with fewer than 8 tested species excluded). Lower: 10 largest families with no known recalcitrant or intermediate species.

Worldwide species numbers and incidence of recalcitrance from Hong *et al.* (1996); Hawaiian species numbers from Wagner *et al.* (1999); number of colonists to Hawaiian Islands from Sakai *et al.* (1995).

- **The Hawaiian flora appears to have been derived primarily from moderately dry regions.** Most Hawaiian wet forest species have evolved from ancestors adapted to drier habitats (Carlquist, 1974). Even in wet forest species, there are few signs of a trend towards the evolution of recalcitrant seeds. Molecular evidence shows that the two *Campanulaceae* genera, *Clermontia* and *Cyanea*, diverged sometime between 8.7 and 17.4 million years ago (Givnish *et al.*, 1995), on a now non-existent high island. Seed physiology data exists for 10 species from each genus. Most are wet forest species. All are orthodox. The oldest extant high island is 5.1 million years old. These evolutionary lines must have had to colonize newer islands as older islands eroded away. This would have selected against species with recalcitrant seeds, which are less adapted for over-water dispersal than orthodox seeds.

Although the Hawaiian Islands are the most isolated large islands in the world, the factors which lead to low incidence of recalcitrance there should be present on other oceanic islands as well. For less isolated islands, seed dispersal from outside sources is less difficult, so the selection pressure against recalcitrant and intermediate behavior may be correspondingly reduced. If orthodox seed physiology turns out to be widespread among seeds from plants of oceanic islands, seed storage will be a valuable tool for conservation of island plants.

Preliminary screening to determine whether seeds are orthodox is simple. Even basic storage facilities can greatly extend storage lives of orthodox seeds. Much can be done with simple equipment available to local plant conservationists without access to a central facility. Seed screening programmes for seeds of threatened floras of oceanic islands should be started soon so that seed conservation measures can be taken while seed sources are still available from rapidly dwindling environments.

Acknowledgements

The CCRT and NSSL studies were supported by grants from the Packard Foundation and the US Fish and Wildlife Service. We would like to thank Peter Tausend for providing the NTBG data. The Hawai'i State Department of Land and Natural Resources issued a permit to allow collection of seeds from Federally listed endangered plants.

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