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Hybrid *Hibiscadelphus* (Malvaceae) in the Hawaiian Islands[1]

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ABSTRACT: First- and second-generation hybrids of *Hibiscadelphus giffardianus* Rock and *H. hualalaiensis* Rock have been found in Hawaii Volcanoes National Park, and elsewhere in the Hawaiian Islands. They are under cultivation from interspecifically cross-fertilized seed which occurred on parent trees within the park. A history of parent and hybrid species is given, and floral characteristics are analyzed. Hybrid occurrence and the implications to natural resource management in trying to preserve the integrity of native Hawaiian species and ecosystems are discussed.

HYBRID TREES OF TWO RARE, endemic Hawaiian species of *Hibiscadelphus* (Hau kuahiwi) are growing in Hawaii Volcanoes National Park, in arboreta and private gardens. These hybrids of *H. giffardianus* Rock and *H. hualalaiensis* Rock have been described as *H.* × *puakuahiwi* by Baker and Allen (1976*a*).

Hybridization occurred in the late 1950s or early 1960s, but went unnoticed for more than 10 years. Investigations of trees damaged by roof rats (*Rattus rattus*) revealed their presence in 1973. It had been noticed that rats were stripping bark from *Hibiscadelphus* trees, eating seed pods, and chewing holes in flowers to reach the quantities of nectar stored inside (Baker and Allen 1976*b*). Variations in morphology were noticed in flowers studied from different trees, which led to the discovery of first- and second-generation hybrids.

Hybridization probably originated in one of two localities where the parent species were brought together in cultivation. The most probable location is in Kipuka Puaulu (Bird Park) in Hawaii Volcanoes National Park, the type locality of *Hibiscadelphus giffardianus*. The type species was known from a single tree discovered in 1911 by Joseph F. Rock and W. M. Giffard. Rock (1911) described the species in honor of his friend Giffard.

Shortly before the tree died in 1930 others were grown from cuttings in the community of Volcano a few kilometers east of the type locality (Degener 1932, Fagerlund 1944). Only one cutting survived, but before it died in 1940, L. W. Bryan, Rock, and others succeeded in growing another cutting (Fagerlund 1944) which ultimately saved the species from extinction.

This cutting grew to maturity on the Keauhou Ranch of Herbert Shipman just east of Kipuka Puaulu. The 11 mature *Hibiscadelphus giffardianus* trees presently surviving in Hawaii are its descendents. Seven trees are growing at the type locality in Kipuka Puaulu, three in the Puu Mahoe Arboretum on Maui, and one in Wahiawa Arboretum on Oahu. On three occasions the species was reduced to a single tree, and today there are only 11 mature trees, which makes the species one of the world's rarest.

In the 1950s efforts were made to save the other very rare species, *Hibiscadelphus hualalaiensis*, from extinction. Its localized, allopatric distribution was 72 km from Kipuka Puaulu, on Mt. Hualalai. At the time of discovery in 1909, Rock (1911, 1913) estimated only a dozen trees were extant and since that time the number of wild trees has declined to two because of habitat deterioration by cattle ranching.

In 1953 and 1954, 12 seedlings of the

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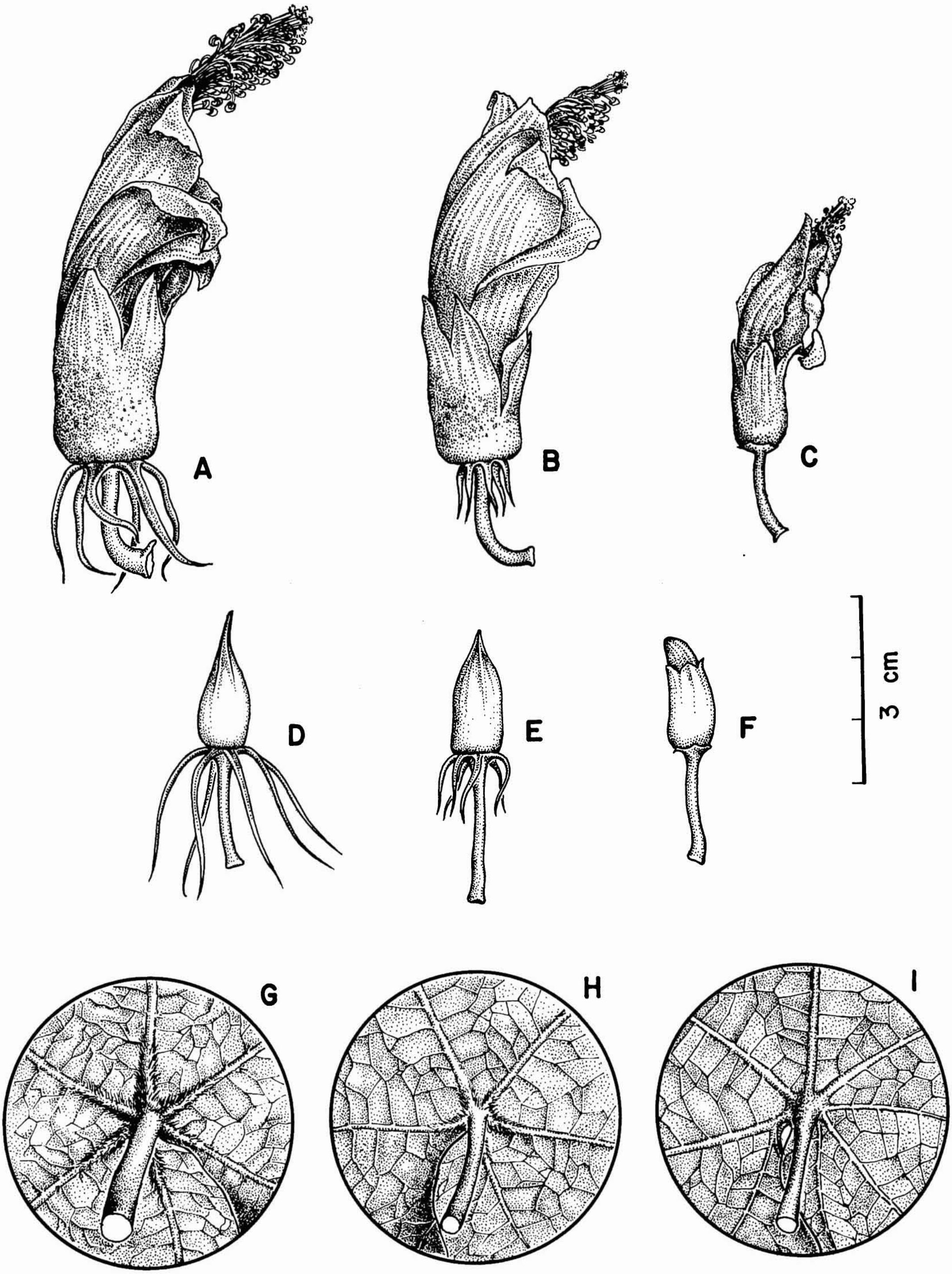

FIGURE 1. *A*, *Hibiscadelphus giffardianus*; *B*, hybrid *H.* × *puakuahiwi*; *C*, *H. hualalaiensis*; *D*, *E*, and *F*, buds of *A*, *B*, and *C*, respectively; *G*, *H*, and *I*, tomentum in angles of veins of *A*, *B*, and *C*, respectively.

Hualalai species were planted in Kipuka Puaulu (National Park Service planting records) in the belief that the national park was a proper refuge for rare and endangered island flora. Six of the 12 trees were planted within 30 meters of a *Hibiscadelphus giffardianus* tree which for a number of years had been a primary source of seed for that species, though relatively few seedlings survived.

We believe that the history of *H.* × *puakuahiwi* began when park management personnel unknowingly collected interspecifically cross-fertilized seed from this tree. Several seedlings were planted in nearby Kipuka Ki, but only two of the unsuspected hybrids survived. Both grew adjacent to a road.

Because of their easy roadside access and because the two F1 hybrids demonstrated such vigor in producing flowers and seed, both became primary sources for herbarium specimens, and seed for propagation of "*H. giffardianus*" trees. Consequently, many specimens were identified improperly, and numerous F2 hybrids were grown unknowingly in the park, Hawaii, and world arboreta (Baker and Allen 1977). On Maui a second-generation tree was used unwittingly to propagate a large number of F3 seedlings for perpetuation of *H. giffardianus* on that island. When this error was noted, the F3 seedlings were destroyed so as not to compound the hybrid dilemma.

The second, but less feasible source of the two F1 hybrids may have been trees from Puu Mahoe (Fleming/Vodtrock) Arboretum on Maui, where both parent species have been cultivated since the 1950s. In 1960, two seedling "*H. giffardianus*" trees were given to Hawaii Volcanoes National Park by the Territorial Division of Forestry, but existing records indicate only that the trees came from Maui. We assume they came from Puu Mahoe. These seedlings may have been hybrids, but the exact location of their origin and planting in the park is unknown.

As we know of no other F1 trees outside the two in Kipuka Ki, and since the plantings of seedlings in Kipuka Ki are well documented, we believe the origin of the two F1 trees to be cross-fertilized seed taken from Kipuka Puaulu.

ANALYSIS OF *Hibiscadelphus* HYBRIDS

Comparative morphology of parent species and F1 hybrids is shown in Figure 1. The following floral characteristics were examined: (1) number of bracts, (2) length of shortest bract, (3) length of longest bract, (4) length of calyx, (5) length of peduncle, (6) length of corolla, (7) length of staminal column, (8) lengths of styles and stigmas, (9) length of longest petal, (10) length of shortest petal, (11) width of shortest petal, (12) width of longest petal, and (13) direction of corolla whorl.

Criteria 3–7 were selected to plot potential key characters to separate parents from hybrids. The plots of criteria 4–7 in Figure 2 show that the degree of overlap of these measurements make them unreliable characters. Criterion 3 is reliable but caution must be taken to determine that longest bracts are not stunted or shortened due to necrosis or insect damage.

Figures 1 and 3 show that *Hibiscadelphus giffardianus* bracts are the longest of the three taxa, while *H. hualalaiensis* flowers nearly lack them. Figure 3 shows no overlap in twice the standard deviations in lengths of longest bracts, and this character alone will usually separate parents and hybrids.

A peculiarity of bract morphology of *Hibiscadelphus distans* Bishop and Herbst (1973), will easily distinguish this other extant taxon. Bracts of *H. distans* are connate through one-third their length, while bracts of the other taxa are not.

In analyzing the direction of corolla whorl, we found the following (c, clockwise; cc, counterclockwise):

H. giffardianus	*H. hualalaiensis*
38 percent c	63 percent c
62 percent cc	37 percent cc

F1 hybrids	F2 hybrids
43 percent c	53 percent c
57 percent cc	47 percent cc

When viewed apically, a flower is considered left-handed if the petals overlap in a clockwise direction, and right-handed if the petals overlap in a counterclockwise direction (compare parts *B* and *C*, Figure 1).

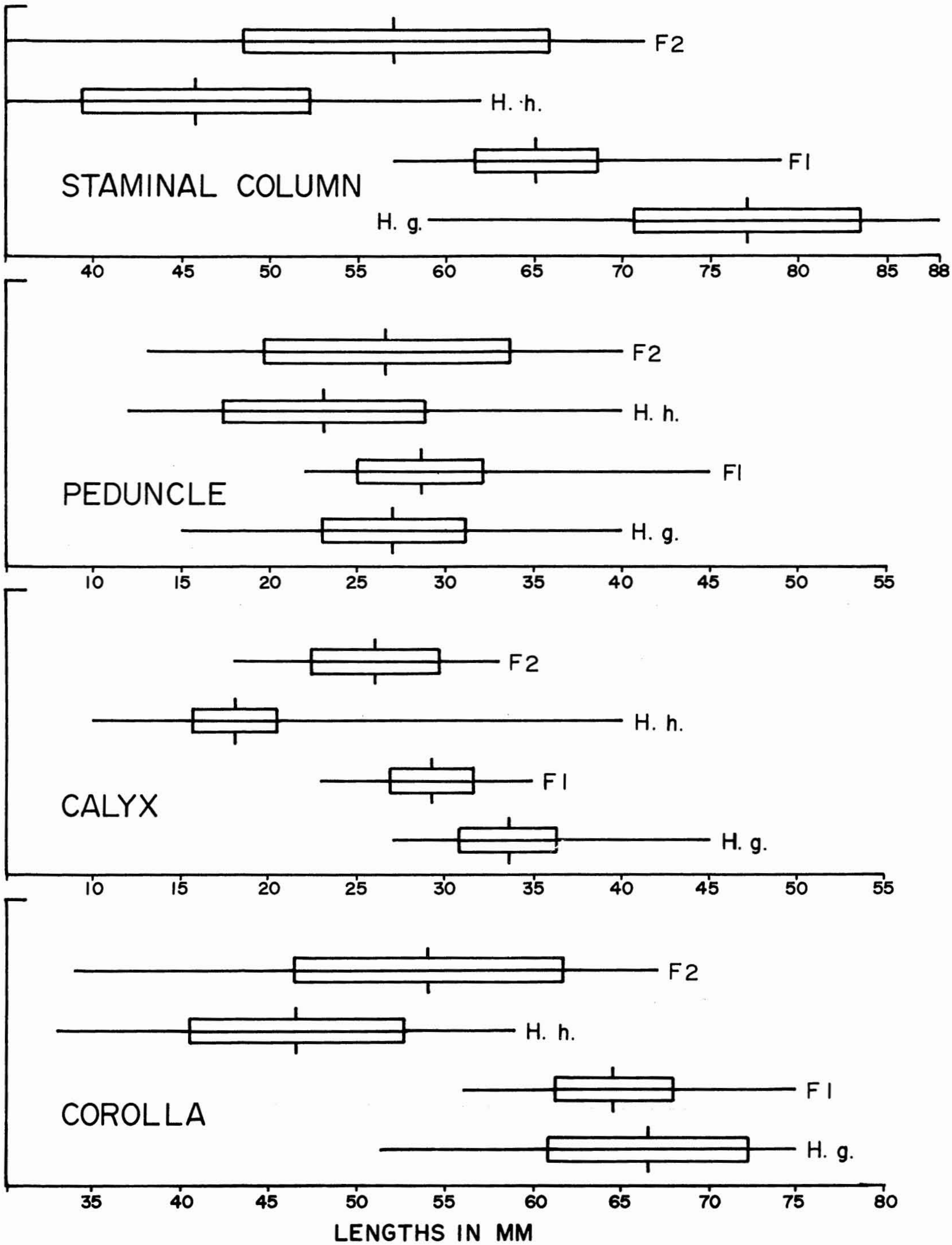

FIGURE 2. Ranges, means, and one standard deviation of measurements for staminal column, peduncle, calyx, and corolla lengths. Horizontal lines are ranges, vertical lines are means, and boxes are one standard deviation on either side of the mean. H. g., *Hibiscadelphus giffardianus*; H. h., *H. hualalaiensis*; F1, first-generation hybrid; F2, second-generation hybrid.

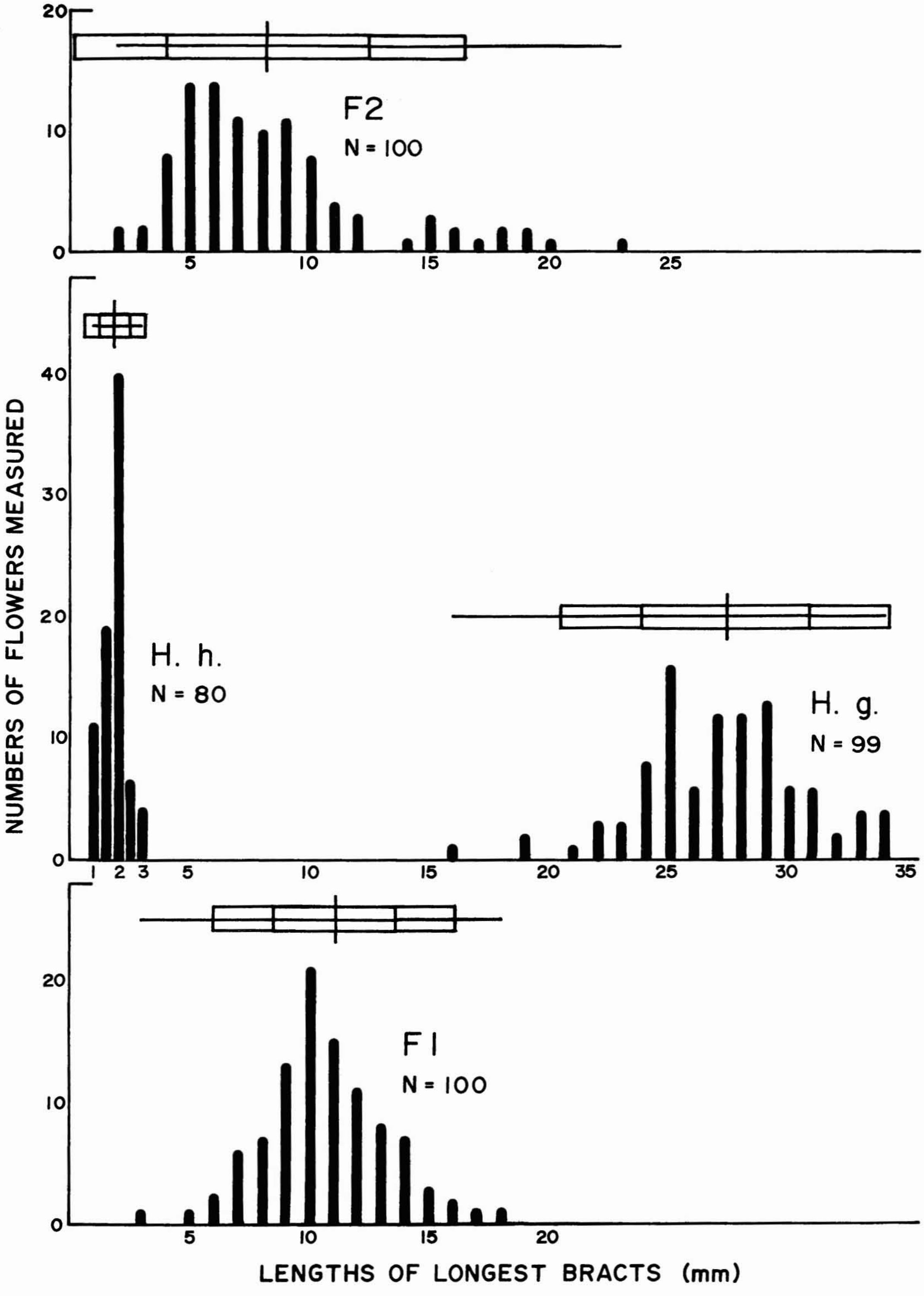

FIGURE 3. Ranges, means, and two standard deviations of measurements for lengths of longest bracts. Horizontal lines are ranges, vertical lines are means, and boxes are two standard deviations on either side of the mean. Bar graphs represent numbers of flowers. H. g., *Hibiscadelphus giffardianus*; H. h., *H. hualalaiensis*; F1, first-generation hybrid; F2, second-generation hybrid; *N*, sample size.

Davis (1964) and Davis and Selvaraj (1964) showed that among 34 species of 12 genera (11 species of *Hibiscus*), only three species could be considered predominantly left-handed and none could be considered right-handed. The others simply showed no specific tendency. In view of these data, petal asymmetry in *Hibiscadelphus* is of interest.

In Figure 1 it can be seen that tomentum is located in the angles of veins on the undersides of leaves, which can be useful in keying species when buds or flowers are not available. Rock (1911, 1913), Degener (1932), and Bishop and Herbst (1973) also mention this characteristic. Leaves of *Hibiscadelphus giffardianus* have more tomentum than F1 leaves, whereas the tomentum is almost nonexistent on leaves of *H. hualalaiensis*. However, the presence of tomentum should not be used to key leaves from young trees, sucker growth, or limbs of any aged tree not producing flowers.

Coloration of petals can be used to distinguish between parent and F1 taxa but not F2s. Flowers of *Hibiscadelphus giffardianus* are magenta (rarely splotched with green) throughout the 3 to 5 day life-span of the blossom. Flowers of *H. hualalaiensis* are yellow-green when 1 to 3 days old but may tend to turn purplish in 4- to 5-day-old flowers. Flower color of F1 hybrids is usually magenta with greenish splotches in petals at the apex. Flower colors of F2 hybrids range from magenta to yellow-green.

The appearance or condition of anthers and pollen may sometimes distinguish F2 hybrids which closely resemble parent species. Anthers of parent and F1 taxa fully dehisce, exposing amber-colored pollen, whereas anthers of some F2 flowers may not dehisce and contain abnormally small, colorless pollen grains that lack cytoplasm.

This may be a further indication of reduced fertility in some F2 flowers, a situation already documented in hybrid *Hibiscadelphus* by Carr and Baker (1977). Meiotic analyses showed some F2 trees to be little affected by hybrid breakdown, while others exhibited moderate to severe meiotic disturbances.

DISCUSSION OF HYBRID PROBLEMS

In view of the apparent fertility of some F2 hybrids, and occurrence of some F3s, it appears that gene flow between *Hibiscadelphus* species is possible. These factors must be taken into consideration in any program designed to protect the genetic integrity of *Hibiscadelphus* taxa. In other words, the taxa should not be grown together.

Discovery of hybrid *Hibiscadelphus*, and the situation that brought about their occurrence, has created much interest and controversy among those interested in maintaining native species and ecosystem integrity. *Hibiscadelphus* hybrids have become a case in point of problems of hybridization and genetic swamping brought about by man.

Hybridization of *Hibiscadelphus* occurred when species were cultivated outside their natural distributions in close proximity to one another, whereas their natural allopatric distributions would have prevented interspecific cross-fertilization of seed. Throughout Hawaii numerous native species, many with very limited natural ranges, are being brought together under artificial conditions in gardens, arboreta, and parks.

Persons concerned with propagation of native plants for perpetuation of species should be cautious or suspicious of seeds or seedlings produced from genetically compatible taxa when grown together unnaturally. Propagation should always be through cuttings or pollination under controlled conditions.

In the case of *Hibiscadelphus*, the unsuspected gathering of cross-fertilized seed and the transplanting of seedlings gathered from beneath hybrid trees have compounded the hybrid problem.

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