Restoring Hawaiian dry forests with direct seeding: the effects of light, water, and weeding.

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Although the destruction of the world's tropical rain forests continues to receive more attention, tropical dry forests are as a whole far more threatened and endangered (Janzen, 1988). In the Hawaiian Islands, for example, over 90% of the original dry forests are now gone, compared to only 42% of the original rain forests. Today, the remnants of Hawaii's once extensive and diverse native dry forests have been severely fragmented and degraded by deforestation and land development, fire, nonnative ungulate grazing, and invasions by alien plant species. Our general observations of native dry forest communities throughout the State of Hawaii suggest there is little hope these systems can recover without intensive management and reintroduction of native species.

In a previous study (Cabin et al., in press) within one of the best remaining dry forest fragments (the Kaupulehu Preserve on the island of Hawaii), we found virtually no regeneration of native canopy trees despite over 40 years of protection from human and ungulate disturbances. Since our efforts in 1996-1997 to control the dominant alien specie within this preserve (fountain grass [*Pennisetum setaceum*], an aggressive perennial African bunchgrass) appeared to facilitate the regeneration of mainly herbaceous native species, in May 1998 we sowed seeds of 6 native woody species into 64, 1-m^2 plots within the Kaupulehu Preserve. We used 30 seeds per plot per species for the shrubs ‘a‘ali‘i (*Dodonaea viscosa*) and mamane (*Sophora chrysophylla*), 20 seeds per plot for the locally abundant trees lama (*Diospyros sandwicensis*) and ‘iliahi or sandalwood (*Santalum paniculatum*), and 10 seeds per plot for the federally endangered trees kauila (*Colubrina oppositifolia*) and koki‘o (*Kokia drynarioides*). The experimental plots were established under factorial combinations of sub-canopy shade/inter-canopy full sunlight, weeding of emerging non-native species/no weeding, and supplemental water/ambient water treatments. The supplemental water treatment consisted of 5.3 gallons per plot (20 liters) three times a week for the first six months of the experiment, and once a week thereafter. Here we present data collected approximately one year after the seeds were sown.

We found significantly more native species in the shade vs. sun plots (7.0 and 2.2 plants per plot, respectively, $p < 0.01$, t-test). Conversely, there were slightly but not significantly fewer alien species in the shade plots (8.3 and 11.3, respectively, $p > 0.71$). Surprisingly, we found slightly more native species in the non-weeded vs. weeded plots (5.4 and 3.8 plants per plot, respectively, $p > 0.38$). Despite initially promising germination of the seeded species in the ambient water plots, a severe drought in the summer of 1998 eventually led to virtually 100% mortality of these seedlings.

Three of the six native species produced considerable numbers of seedlings surviving to one year after sowing (there were 37, 34, and 246 individuals of kauila, koki‘o, and mamane, respectively), while seeds from the remaining three species virtually or completely failed to germinate. Although there were more surviving plants of all native species in the shade vs. sun plots, there were no significant differences in the height, width, or number of leaves of plants growing within these two treatments. There were also fewer surviving individuals of each species in the weeded vs. non-weeded plots, but with the exception of mamane (mean height was 9.0 [22.9 cm] and 6.7 [17.0 cm] inches, mean number of leaves 17.1 and 13.3 in the weeded and non-weeded plots, respectively, $p < 0.05$ in each case), there were no significant plant size differences between the weeded and non-weeded treatments.

Our results to date suggest that if adequate water and shade are provided, at least some native Hawaiian dry forest species may be successfully regenerated using *in situ* direct-seeding techniques. Weeding emerging alien species in general did not appear to significantly affect the growth or survival of the natives, although it is important to point out that this experiment began under initially weed-free conditions. Nevertheless, we found this result surprising, given the aggressiveness of some of the alien species that invaded the plots (e.g. lantana [*Lantana camara*]and milkweed [*Asclepias physocarpa*]) and the alleged competitive inferiority of native Hawaiian species. Indeed, in some plots we observed apparently healthy kauila and koki‘o individuals surrounded by dense alien species foliage. This result suggests that given the right micro-environmental conditions and care, successful regeneration of rare native dry forest species can occur, and Hawaii’s remaining dry forest fragments need not be gradually lost to senescence.

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