Revegetation Strategies for Kaho‘olawe Island, Hawaii

by
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Over the past 2 centuries, the island of Kaho‘olawe has suffered the ravages of war, slash-and-burn agriculture, and overgrazing. Today, much of the island is barren and severely eroded. A research project initiated in 1988 sought to identify effective, economical techniques to revegetate portions of the island.

Treatments included drill seeding plus several rates of fertilization with monoammonium phosphate. Some treatments also included jute netting for soil moisture conservation and erosion control. The effect of windbreak fencing was evaluated across all treatments. Drill seeding plus broadcast application of at least 560 kg ha⁻¹ fertilizer was the most cost-effective treatment. Jute netting and windbreak fencing significantly enhanced plant production, but the high cost of materials and maintenance limits their use to critical areas. The planted species with greatest promise for the windy, semiarid conditions on Kaho‘olawe were buffelgrass, bermudagrass, and weeping lovegrass. Although not included in the seed mixture, Australian saltbush, a naturalized species, responded favorably to fertilization. A subsequent, larger-scale revegetation project using a specially modified chisel plow seeder to scarify, plant, and apply in-furrow fertilization in a single-pass operation reduced the cost and improved the results of the revegetation process.

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Foreword

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LTC David J. Rehbein is Commander, USACERL, and Dr. L.R. Shaffer is Director.
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STEVEN D. WARREN AND STEFANIE G. ASCHMANN

Abstract

Over the past 2 centuries, the island of Kaho'olawe has suffered the ravages of war, slash-and-burn agriculture, and overgrazing. Today, much of the island is barren and severely eroded. A research project initiated in 1988 has sought to identify effective, economical techniques to revegetate portions of the island. Treatments included drill seeding plus several rates of fertilization with monoammonium phosphate (11-52-0). Some treatments also include jute netting for soil moisture conservation and erosion control. The effect of windbreak fencing was evaluated across all treatments. Drill seeding plus broadcast application of at least 62 kg ha⁻¹ N plus 291 kg ha⁻¹ P₂O₅ was the most cost-effective treatment. Jute netting and windbreak fencing significantly enhanced plant production, but the high cost of materials and maintenance limits their use to critical areas. The planted species with greatest promise for the windy, semiarid conditions on Kaho'olawe were buffelgrass (Cenchrus ciliaris L.), bermudagrass (Cynodon dactylon (L.) Pers.) and weeping love grass (Eragrostis curvula (Schrad.) Nees). Although not included in the seed mixture, Australian saltbush (Atriplex semibaccata R. Br.), a naturalized species, responded favorably to fertilization. A subsequent, larger-scale revegetation project using a specially modified chisel plow seeder to scarify, plant, and apply in-furrow fertilization in a single-pass operation reduced the cost and improved the results of the revegetation process.

Key Words: fertilization, jute netting, windbreak fence, drill seeding

Kaho'olawe, smallest of the 8 major islands of the Hawaiian Archipelago, suffers from a long history of natural and man-induced exposure to the forces of erosion. The island measures about 17.7-km long by 10.5-km wide, comprising some 11,340 ha. The highest point is the rim of an extinct volcano at 449 m above sea level. Kaho'olawe lies in the rain shadow of Haleakala on Maui. Climatic records for the island are scant. but estimated annual precipitation is approximately 500 mm (Department of the Navy 1979), with most of it falling from November through March. In addition to the low precipitation, Kaho'olawe is the windiest of the Hawaiian Islands (Stearns 1940). Deflected by Haleakala, the persistent northeasterly tradewinds accelerate across the intervening channel, reaching an average speed of about 9 m s⁻¹ at Kaho'olawe (Department of Geography, University of Hawaii 1973).

Much of Kaho'olawe may have been covered with a scrub forest at one time (Cuddihy and Stone 1990). Today, however, approximately a third of the island is barren, while the remainder is dominated by the introduced shrub kiawe [Prosopis pallida (Humb. & Bonpl. ex Willd.) Kunth] and a variety of introduced grasses and forbs. The only native species contributing significant
bimessary are *pili* grass or tanglehead (*Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult.), *ma'o* or Hawaiian cotton (*Gossypium tomentosum* Nutt. ex Seen.), *'ilima* (*Sida fallax* Walp.), *'ahaloa* (*Waltheria indica* L.), and *ma'io* or hoary abutation (*Abutilon incanum* (Link) Sweet).

The disturbance of native vegetation on Kaho'olawe probably began with slash-and-burn agriculture practiced by early Hawaiians (Kirch 1982). Intense interisland warfare before the arrival of European explorers left the island "nearly overrun with weeds, and exhausted...of inhabitants" (VanCouver 1798). The population had declined from an estimated peak of 800 around 1500 A.D. to approximately 60 at the time of European discovery (Hommon 1980), presumably in response to a depleted natural resource base. In 1779 the crew of Captain Cook described the island as "barren," "desolate," and an "altogether poor island" (Beaglehole 1967). The same explorers that lamented the poor condition of the island unwittingly contributed to its further deterioration by introducing goats as gifts to native monarchy, thus accelerating soil erosion. Beginning in 1859, ill-fated sheep and cattle ranchers exacerbated the declining condition of Kaho'olawe. Reports over the next half-century place livestock populations as high as 20,000 sheep, 9,000 goats, and 200 head of cattle (Anonymous 1875, Bagot 1884). By 1916 approximately a third of the island was completely denuded, and from 1 to 3 m of topsoil had been blown or washed into the Pacific Ocean, leaving behind a wind-swepthardpan (Judd 1916).

With the entrance of the United States into World War II, Kaho'olawe was acquired by the U.S. military and became a target for offshore gunnery and aerial bombing practice. While military use of the island accounts for much hardpan production, the introduction of livestock has undoubtedly had a significant effect on the island's natural vegetation. By 1916 approximately a third of the island was completely denuded, and from 1 to 3 m of topsoil had been blown or washed into the Pacific Ocean, leaving behind a wind-swepthardpan (Judd 1916).

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**Materials and Methods**

The study site was a broad, relatively flat swale near the center of the island. The area supported less than 2% plant cover, according to aerial photography and a ground survey conducted in May 1974. The site was selected after a 10-week study of the island's vegetation and soils (Warren et al. 1988). Soil analyses indicate that the soil of the central hardpan is predominantly clay loam texture (Warren et al. 1988). Iron and aluminum hydrous oxides, well known for phosphorus fixation (Sanchez 1976), dominate the clay component. Nitrogen, extractable phosphorus, and organic carbon levels are very low, and potassium content is very high. Soil pH tends to be slightly acidic. The soil surface is very hard and often polished and/or stratified by blowing soil particles.

To create soil surface conditions suitable for planting, the entire study site was chiseled to a depth of approximately 10 cm during November 1988. The surface soil was very dry at the time of planting in December of that year. However, subsoil surface soil moisture conditions were surprisingly good; moisture was evident to a depth of at least 45 cm, due to previous rains.

Five experimental blocks were established adjacent and parallel to each other. Within each block, 7 adjacent strips 60 m long and 1.8 m wide were laid out to accommodate 6 revegetation treatments and an unplanted control. All strips were oriented parallel to each other and parallel to the prevailing wind direction. Each strip except the control was planted with a single longitudinal pass of a randall drill. The drill planted 5 rows in a total swath of 1.5 m. A mixture of 6 grasses and 1 legume (Table 1) was planted at a depth of 2.5 cm. Species selection was limited to

<p>| Table 1. Seeding rates (pure live seed) for grass and legume species included in a mixture evaluated for revegetation on Kaho'olawe. |
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<table>
<thead>
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<th>Grasses</th>
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<tr>
<td>&quot;T-4644&quot; buffelgrass (<em>Cenchrus ciliaris</em> L.)</td>
<td>1.1 kg ha⁻¹</td>
<td>Plains bristlegrass (<em>Setaria leucopila</em> (Scribn. &amp; Merr.) K. Schum.)</td>
<td>1.1 kg ha⁻¹</td>
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<tr>
<td>&quot;W&quot; ironmaster yellow bluestem (<em>Bothriochloa ischaemum</em> (L.) Keng)</td>
<td>0.6 kg ha⁻¹</td>
<td>Buffalo grass (<em>Buchloë dactyloides</em> [Nutt.] Engelm.)</td>
<td>1.7 kg ha⁻¹</td>
</tr>
<tr>
<td>&quot;NK&quot;-37&quot; Bermuda grass (<em>Cynodon dactylon</em> (L.) Pers.)</td>
<td>0.7 kg ha⁻¹</td>
<td>Green panicgrass (<em>Panicum maximum</em> Jacq. var. trichoglume)</td>
<td>1.1 kg ha⁻¹</td>
</tr>
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| "De-awned" introduced species because seeds of native species were not commercially available. Cracked corn was mixed with the seed prior to planting to improve uniformity of distribution. Seeds were covered by dragging 6-cm diameter steel pipes behind the drill. Four strips in each block were selected for fertilizer treatments. One strip was fertilized with 3.6 kg ha⁻¹ nitrogen (N) plus 17.1 kg ha⁻¹ phosphorus (P₂O₅) applied in-furrow by the drill. Two strips were fertilized by broadcast application of 62 kg ha⁻¹ N plus 291 kg ha⁻¹ P₂O₅, and 1 strip was broadcast at 123 kg ha⁻¹ N plus 582 kg ha⁻¹ P₂O₅. All fertilizer was applied as a granular form of monomomium phosphate (11-52-0). The use of a high ratio of phosphorus to nitrogen is common in subtropical and tropical regions where phosphorus-fixation by iron and aluminum hydrous oxides is a problem (Sanchez 1976). Within each block, 1 unfertilized strip and 1 strip fertilized at 62 kg ha⁻¹ N plus 291 kg ha⁻¹ P₂O₅ were covered with woven jute netting. The fabric, supplied in rolls 1.2 m wide, provided approximately 35-40% coverage of the soil surface. It was secured to the soil surface with 15 cm long staples immediately following seeding and fertilization. To evaluate the potential benefits of wind abatement on plant establishment, a single 1.2-m tall, high-density polyethylene plastic windbreak fence was erected across the entire study site. The fence was attached to galvanized steel posts and situated perpendicular to the prevailing wind direction, approximately 12 m downwind of the windward edge of the experimental blocks. This configuration allowed an evaluation of the effects of wind abatement in each treatment strip on both the windward and leeward sides of the fence. Elliptical apertures in the windbreak fence provided approximately 37% porosity, which is ideal for a wind barrier (Van Eimern et al. 1964). To avoid disturbance associated with wind turbulence at the ends of windbreaks, the fence was extended 4.5 m beyond the edge of the study site on both sides. Data were collected at the study site during January 1991, approximately 25 months after planting. A 0.25-m² quadrat was placed on the ground at 2-m intervals along the central axis of each treatment strip, beginning at the windbreak fence and proceeding to the end of the strip in both the windward and leeward directions. Percent foliar cover in each quadrat was visually estimated by percent foliar cover in each quadrat was visually estimated by
results and discussion
Twenty-five months after planting, treatments that included fertilization with at least 62 kg ha$^{-1}$ N plus 291 kg ha$^{-1}$ P$_{2}O_{5}$ produced significantly more foliar cover than other treatments (Fig. 1). Treatment strips fertilized at 3.6 kg ha$^{-1}$ N plus 17.1 kg ha$^{-1}$ P$_{2}O_{5}$ had no more vegetation than the unplanted strips. Foliar cover increased as fertilization increased. The rate of increase, greatly enhanced vegetation response. When applied at the maximum rate, the cost of fertilizer was approximately $560 ha$^{-1}$, but with 25 to 30% greater foliar cover compared to 60% foliar cover on the next best treatment. Unfortunately, at a cost of $14,000 ha$^{-1}$ for materials shipped to Hawaii, use of jute netting must be reserved for critical areas where less costly methods are ineffective.
Fig. 2. Percent foliar cover by distance upwind or downwind from the windbreak fence, averaged across all treatments and blocks, 25 months after planting on Kaho'olawe. Means with the same letter are not significantly different at \( P = 0.05 \), according to Duncan's multiple range test.

Fig. 3. Percent foliar cover of various plant species, averaged across all treatments, block, and distances from the windbreak fence, 25 months after planting on Kaho'olawe, Means followed by the same letter are not significantly different at \( P = 0.05 \), according to paired comparison t-tests for all possible combinations of species.

Species

- Australian saltbush
- Buffelgrass
- Bermudagrass
- Glycine
- Weeping lovegrass
- Green panicgrass
- Plains bristlegrass
- Buffalograss
- Yellow bluestem
- Other

Adequate fertilization is the apparent key to revegetation success on Kaho'olawe. In-furrow fertilization at approximately 70 kg ha\(^{-1}\) N plus 179 kg ha\(^{-1}\) P\(_{2}O_{5}\) provided excellent results when compared to past attempts to revegetate the island. Jute netting and windbreak fencing significantly enhanced plant production, but the high cost of materials and maintenance limits their use to critical areas where other methods are ineffective. Buffelgrass, bermudagrass, and weeping lovegrass showed the greatest potential for revegetation. Glycine, a legume, also produced significant biomass, but its aggressive climbing characteristic may threaten...
woody species. Yellow bluestem, plains bristlegrass, buffalograss, and green panicgrass showed little promise for Kaho'olawe.

Literature Cited