

PACIFIC SOUTHWEST Forest and Range Experiment Station

ADAPTABILITY OF 14 TREE SPECIES TO TWO HYDROL HUMIC LATOSOL SOILS IN HAWAII

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Reforestation of marginal and abandoned pasture and cultivated lands in Hawaii could increase their economic value through production of timber, improved watershed conditions and scenery, and better sites for hiking and hunting. In Hawaii, selection of tree species for reforestation may be a serious problem because of wide differences in climate and soils—especially soils in high rainfall areas (more than 100 inches annually). Two such soils are the Akaka and Kaiwiki soil series of the Hydrol Humic Latosol great soil group.¹

The adaptability of two native and 12 introduced tree species to the Akaka and Kaiwiki soil series was studied 1- to 7-years after outplanting. No one species has proved outstanding, but several show desirable characteristics for reforestation. They include nepal alder (*Alnus nepalensis*), blackwood (*Acacia melanoxylon*), Java podocarpus (*Podocarpus imbricatus*), and koa (*Acacia koa*). We suggest larger scale planting trials on Hydrol Humic Latosol soils in which these and other tree species are mixed.

METHODS

Four of the 14 tree species in these trials were planted on both the Akaka and Kaiwiki soils; the other 10 were planted on only one soil or the other. The test site representing the Akaka soil is an abandoned sugarcane field on the northeastern coast of the island of Hawaii. The site representing the Kaiwiki soil is an old pasture, about 9 miles from the Akaka site, on the slopes above Hilo. Soils in this part of Hawaii are subjected to frequent showers, and remain wet throughout the year. Yamamoto² determined that soil moisture for a sample of Akaka soil was nearly 400 percent by dry weight, that is, 1 pound of soil can hold 4 pounds of water.

ABSTRACT: Tree species capable of thriving on soils in high rainfall areas are needed in Hawaii for reforestation. The soils are highly leached and infertile. Two native and 12 introduced tree species were planted at two sites to determine adaptability. Survival, growth, vigor, and form were appraised 1 to 7 years after planting. Performance varied—both within and between species. No one species was outstanding, but several showed qualities that could be used to develop productive forests of mixed species.

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RETRIEVAL TERMS: afforestation; Hawaii; species trials; Laterite soils.

Akaka Soil Site

The Akaka soil site is on the windward slope of Mauna Kea, 3 miles west of Hakalau, at 1,725 feet elevation. Latitude is 19°48'N and longitude is 155°09'W. Aspect is northeast, with a slope of 10 to 20 percent. Mean annual rainfall is 212 inches (minimum 92 inches, maximum 466 inches), but totals for any given month vary greatly from year to year. The mean monthly temperature in January is 52°F.; in July 66°F.³ Under these sub-tropical conditions, tree growth continues throughout the year.

Akaka silty clay loam is moderately well-drained, and developed from volcanic ash. The surface layer is dark reddish brown, subangular blocky, and about 15 inches thick. The subsoil is a reddish brown, subangular blocky and prismatic silty clay loam over 5 feet thick. This soil has thixotropic properties and dehydrates irreversibly into fine gravel-size particles.⁴ It is strongly acid with a pH of 5 in the surface layer (0-12 inches) and a pH of 5.1 in the subsurface layer (12-24 inches). The Akaka soil is extremely low in phosphorus, potassium, calcium, and magnesium; is somewhat low in silicon; but is high in iron and aluminum. Its aluminum content may even be toxic for some plants.⁵

The cover type before the land was cleared was the ohia-koa rain forest type (*Metrosideros collina* [Forst.] Gray-*Acacia koa* Gray). At the time the trials were set up the ground cover consisted of the residual commercial sugarcane (*Saccharum officinarum* L.) and Hilo grass (*Paspalum conjugatum* Berg.). Hilo grass can hinder tree seedlings from becoming established because of its massive root system. To kill the Hilo grass, herbicide was used. Native koa and guava (*Psidium guajava* L.) are scattered invaders among the abandoned cane.

In 1962, five introduced hardwood species were planted:

Alnus nepalensis D. Don. (Nepal alder)
Eucalyptus pilularis Sm. (Blackbutt eucalyptus)
Eucalyptus saligna Sm. (*Saligna* eucalyptus)
Flindersia brayleyana F.V.M. (Queensland-maple)
Terminalia myriocarpa H. & Muell. Arg. (Jhalna)

Eighty seedlings of each species were planted. The experimental design was a Latin square of five replications, with 16 seedlings of a species per plot. Spacing was 10 feet within plots and 15 feet between plots.

In 1964, two native species and six introduced species were planted:

Acacia koa Gray (Koa)
Acacia melanoxylon R. Br. (Blackwood)
Eucalyptus deglupta Bl. (*Deglupta* eucalyptus)
Eucalyptus grandis Hill ex. Maiden (*Rosegum* eucalyptus)
Myoporum sandwicense (D.C.) Gray (Naio)
Pithecellobium saman (Jacq.) (Monkey-pod)
Podocarpus imbricatus Blume (Java podocarpus)
Pterocarpus echinatus Pers. (Prickly narra)

Thirty seedlings of each species were planted. The experimental design was a complete randomized block of six replications, with five seedlings of each species per plot, spaced 8 feet apart.

All seedlings except the Java podocarpus were grown in flats or cans, and then outplanted as balled-root 1-0 stock; the podocarpus were wildlings collected from a forest plantation. Most of the 14 species were measured and appraised at the end of 1 year, 4 years, and then after 7 years for the 1963 planting and at 6 years for the 1964 planting.

The only cultural treatments practiced were annual weedings to release the seedlings from suppression by the Hilo grass. Seedlings that died during the first 9 months were replaced.

Kaiwiki Soil Site

The Kaiwiki soil site is at 1,800 feet elevation. Aspect is east, with a slope of 5 to 20 percent. Mean annual rainfall is 180 inches, and fluctuation may be wide for any given month, and from year to year.

The Kaiwiki silty clay loam is similar to the related Akaka series, but lacks a faint mottling in the B horizon of the Akaka soil.

Ohia-koa forest cover was cleared for sugarcane before 1900, then converted to pasture when the site proved unsatisfactory for cane. At the time trials were set up the vegetation consisted of torpedo grass (*Panicum repens* L.) and a few koa.

In February 1965, we planted three introduced species in six randomized blocks, with 24 seedlings of each species in each replication:

Acacia melanoxylon R. Br. (Blackwood)
Alnus nepalensis D. Don. (Nepal alder)
Pterocarpus echinatus Pers. (Prickly narra)

Three species (alder, blackwood, and narra) in two blocks were planted in alternate rows. In each of the other four blocks we planted three adjacent rows of alder, three of blackwood, and three of narra. Each row had eight seedlings.

In March 1965, 60 *saligna* eucalyptus seedlings were planted nearby. A month later we planted 27

baldcypress (*Taxodium distichum* L. Rich.), from a Mississippi seed source. The saligna and baldcypress were planted in 2 separate blocks.

In these trials, we planted all seedlings 8 feet apart. The sod was removed from each planting spot. Any seedlings that died during the first 9 months were replanted.

Table 1—Survival, height, and vigor of 14 tree species grown on Hydrol Humic Latosols in Hawaii, by soil series and age of plantation

Soil series	Age	Survival ¹	Height		Vigor of live trees	
			Average	Range	Good	Poor
	<i>Years</i>	<i>Percent</i>	<i>—Feet—</i>		<i>—Percent—</i>	
ACACIA KOA (KOA)						
Akaka	1	90	4	1-6	96	4
	4	90	9	4-18	63	37
	6	78	10	3-21	62	38
ACACIA MELANOXYLON (BLACKWOOD)						
Akaka	1	100	5	2-11	100	0
	4	93	10	3-16	82	18
	6	87	13	3-23	100	0
Kaiwiki	1	95	4	1-11	—	—
	4	67	11	1-33	37	63
ALNUS NEPALENSIS (NEPAL ALDER)						
Akaka	1	96	4	1-12	—	—
	4	96	18	5-34	91	9
	7	96	30	13-45	75	25
Kaiwiki	1	100	8	1-20	—	—
	4	100	27	15-41	97	3
EUCALYPTUS DEGLUPTA (DEGLUPTA EUCALYPTUS)						
Akaka	1	97	1	1/2-2	90	10
	4	53	3	1/2-6	69	31
	6	52	5	2-9	80	20
EUCALYPTUS GRANDIS (ROSEGUM EUCALYPTUS)						
Akaka	1	93	2	1/2-2	89	11
	4	63	3	1-5	21	79
	6	57	5	3-7	82	18
EUCALYPTUS PILULARIS (BLACKBUTT EUCALYPTUS)						
Akaka	1	88	2	1-4	—	—
	4	71	4	2-11	26	74
	7	(2)	8	2-36	17	83
EUCALYPTUS SALIGNA (SALIGNA EUCALYPTUS)						
Akaka	1	94	2	1-6	—	—
	4	68	7	2-20	65	35
	7	66	22	1-56	60	40
Kaiwiki	1	100	1	1/2-3	—	—
	5	7	6	4-8	50	50

RESULTS AND DISCUSSION

Observations on survival, growth, and form suggest that several species could prove satisfactory for reforestation (table 1). Nepal alder, with utilization properties similar to that of red alder (*Alnus rubra* Bong)⁶ has—as expected—proved well adapted to

Soil series	Age	Survival ¹	Height		Vigor of live trees	
			Average	Range	Good	Poor
	<i>Years</i>	<i>Percent</i>	<i>—Feet—</i>		<i>Percent</i>	
FLINDERSIA BRAYLEYANA (QUEENSLAND MAPLE)						
Akaka	1	98	1	1/2-1	—	—
	4	89	1	1/2-3	10	90
	7	33	2	1-5	7	93
MYOPORUM SANDWICENSE (NAIO)						
Akaka	1	63	1	1/2-1-1/2	79	21
	4	0	—	—	—	—
PITHECELLOBIUM SAMAN (MONKEY-POD)						
Akaka	1	100	2	1-3	100	0
	4	43	2	1-3	0	100
	6	17	2	1-3	0	100
PODOCARPUS IMBRICATUS (JAVA PODOCARPUS)						
Akaka	1	100	2	1-3	100	0
	4	100	5	2-10	96	4
	6	100	6	2-11	78	22
PTEROCARPUS ECHINATUS (PRICKLY NARRA)						
Akaka	1	100	2	1-4	100	0
	4	90	7	1-13	74	26
	6	83	7	1-15	46	54
Kaiwiki	1	99	2	1-5	—	—
	4	92	4	1-12	13	87
TAXODIUM DISTICHUM (BALDCYPRESS)						
Kaiwiki	1	100	1-1/2	1-3	—	—
	5	100	2	1-3	0	100
TERMINALIA MYRIOCARPA (JHALNA)						
Akaka	1	98	1	1-3	—	—
	4	79	6	1-10	83	17
	7	(2)	4	3-6	6	94

¹Includes replantings during first 9 months.

²Statistics unavailable, trees destroyed by fire.

Hydrol Humic Latosol soils. Its greatest value may be in planting it in admixtures with other, more valuable species. Nepal alder would provide quick watershed cover, serve to break the winds, choke out grasses and other weeds, and act as trainers for the other tree species planted. The Java podocarpus and the native koa should be included in mixed species trials; special efforts should be made to obtain koa seed from trees of good form growing on Hydrol Humic Latosols. The presence of occasional straight, vigorous, tall blackwood and saligna eucalyptus indicates that these introduced species could prove useful in reforestation, and should also be included in larger scale planting trials.

- Koa grows naturally on Hydrol Humic Latosols but has not grown well on the Hakalau site. Survival at age 6 was 78 percent, but the species averaged only 10 feet tall, and only 62 percent were judged vigorous. Tree form varied from good to poor, with 77 percent considered cull. Terminal dieback was noted in 40 percent of the trees, and several were attacked by a rust—probably a member of the genus *Uromyces*. Additional research is needed on establishment problems of koa on these sites.

- Blackwood remains a questionable species on both sites. Its survival was good (67 percent) to excellent (87 percent); and average heights exceeded 10 feet at age 4; but whereas 82 percent of the trees were judged vigorous at that age on the Akaka soil, only 37 percent were so judged on the Kaiwiki soil. Vigor at the Kaiwiki site was affected by the cotton cushion scale (*Icerya purchasi* Maskell) and mites (*Oligonychus* sp.). Most of the blackwood were crooked and limby, and nearly all were judged to be cull trees.

Blackwood planted in three-row groups grew taller and had better form than those planted in single rows between alder and narra. The tallest tree at Kaiwiki at age 4 was 33 feet. The blackwood in single rows were often suppressed by the faster growing alder.

- Nepal alder, a colonizer of landslips and abandoned fields throughout the Himalayas,⁷ thrives on Hawaii's Hydrol Humic Latosols. Survival exceeded 95 percent, and average height was 30 feet at age 7 on the Akaka soil and 27 feet at age 4 on the Kaiwiki soil. Trees on the Akaka soil had an average d.b.h. of 4.2 inches at age 4, and 6.8 inches at age 7. The percentage of vigorous trees decreased from 91 percent at age 4 to 75 percent at age 7 as certain individuals became dominant. Tree form was generally poor, with many trees having sweep, crook, multiple stems, heavy limbs, and broken tops caused by high winds. These cull factors were less pro-

nounced in the younger planting on the Kaiwiki soil.

- Deglupta and rose gum eucalyptus both were unsatisfactory at the end of 6 years, with only fair (52 to 57 percent) survival, and averaging less than 1 foot of height growth per year. In the last 2 years, the seedlings have shown improved vigor; their growth rate may increase. However, stem form varied from good to poor, with 40 percent of the deglupta eucalyptus and 12 percent of the rose gum eucalyptus rated as cull trees.

- Blackbutt eucalyptus appears not adapted to the Akaka soil. Survival was 71 percent at age 4. Losses from fire prevented a survival count at age 7. The trees remaining at age 7 averaged an annual growth of only 1.2 foot, and had low vigor. The three tallest trees after 7 years averaged 28 feet, which is far better than the over-all average of 8 feet, but still not an impressive growth rate for blackbutt in Hawaii. Many seedlings have spindly, crooked stems, and exhibit symptoms of a nutrient deficiency.

- Saligna eucalyptus is one of the more promising species tried at the Akaka soil site. Survival was 66 percent at age 7, with heights ranging from 1 to 56 feet, and averaging 22 feet. Sixty percent of the trees were considered vigorous. A few trees had excellent form, but many had such defects as crook, sweep, or terminal dieback, were spindly, or were suppressed by the faster growing saligna or grass. At Kaiwiki, the test trees showed signs of nutrient deficiencies—soon after planting. Once the weeding of the torpedo grass ceased, this grass quickly overtopped and smothered most of the saligna.

- Queensland-maple is a failure on the Akaka soil. Although it was constantly suppressed by the Hilo grass despite periodic weeding, survival was good (89 percent) at age 4. Yet the seedlings have failed to grow, and survival had declined to 33 percent by age 7.

- Naio, a native species occurring at all elevations up to 8,000 feet on somewhat drier sites, was a complete failure. The seedlings rapidly became sickly, and by the fourth year all were dead.

- Monkey-pod, the raintree of the Caribbean, failed on the Akaka soil. After the first year, decreased vigor, dieback, and mortality occurred.

- Java podocarpus had excellent survival (100 percent) after 6 years, but its height growth, averaging only 1 foot a year, must be considered disappointing. Seventy-eight percent of the seedlings appeared vigorous. All have good form.

- Narra had good survival (83 percent) on the Akaka soil, but appears less promising as time passes. Average height failed to increase during the last two

years of measurements. The trees are not vigorous, and dieback is occurring in the branches. The situation is the same at the Kaiwiki site.

- The Mississippi provenance of baldcypress had high survival, but poor growth and low vigor after 5 years on the Kaiwiki soil.

- Jhalna began to look vigorous by the fourth year, then declined quickly, accompanied by terminal dieback and mortality. The species is a failure.

Further silvicultural studies recommended for the Hydrol Humic Latosol soils include; (a) larger plantings of mixed species; (b) fertilizer trials to correct the serious nutrient deficiencies common to these soils; and (c) methods for controlling grasses before crown closure.

NOTES

¹Classified as the Order Inceptisols, Great Soil group 3.25 Hydrandepts, in the 7th Approximation by the U.S. Soil Conservation Service.

²Yamamoto, T. *Soil moisture and soil strength characteristics of five Hawaiian soils*. U.S. Forest Serv. Res. Note 184, 8 p. 1961.

³Taliaferro, W. J. *Rainfall of the Hawaiian Islands*. Hawaii Water Authority, Honolulu. 394 p. 1959.

⁴U.S. Department of Agriculture. *Descriptive legend*. Soil Conservation Serv., Honolulu, Hawaii. 1971. (In press)

⁵Hawaiian Sugar Planters' Association, Honolulu. Agronomy Department Special Study GSG: K. Pepeekeo Sugar Company, 1968.

⁶Peters, C. C. and J. F. Lutz. *Some machining properties of two wood species grown in Hawaii—Molucca albizzia and Nepal alder*. U.S. Forest Serv. Res. Note FPL- 0117, 17 p. 1966.

⁷Streets, R. J. *Exotic forest trees in the British Commonwealth*. Oxford: Clarendon Press. 765 p. 1962.

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