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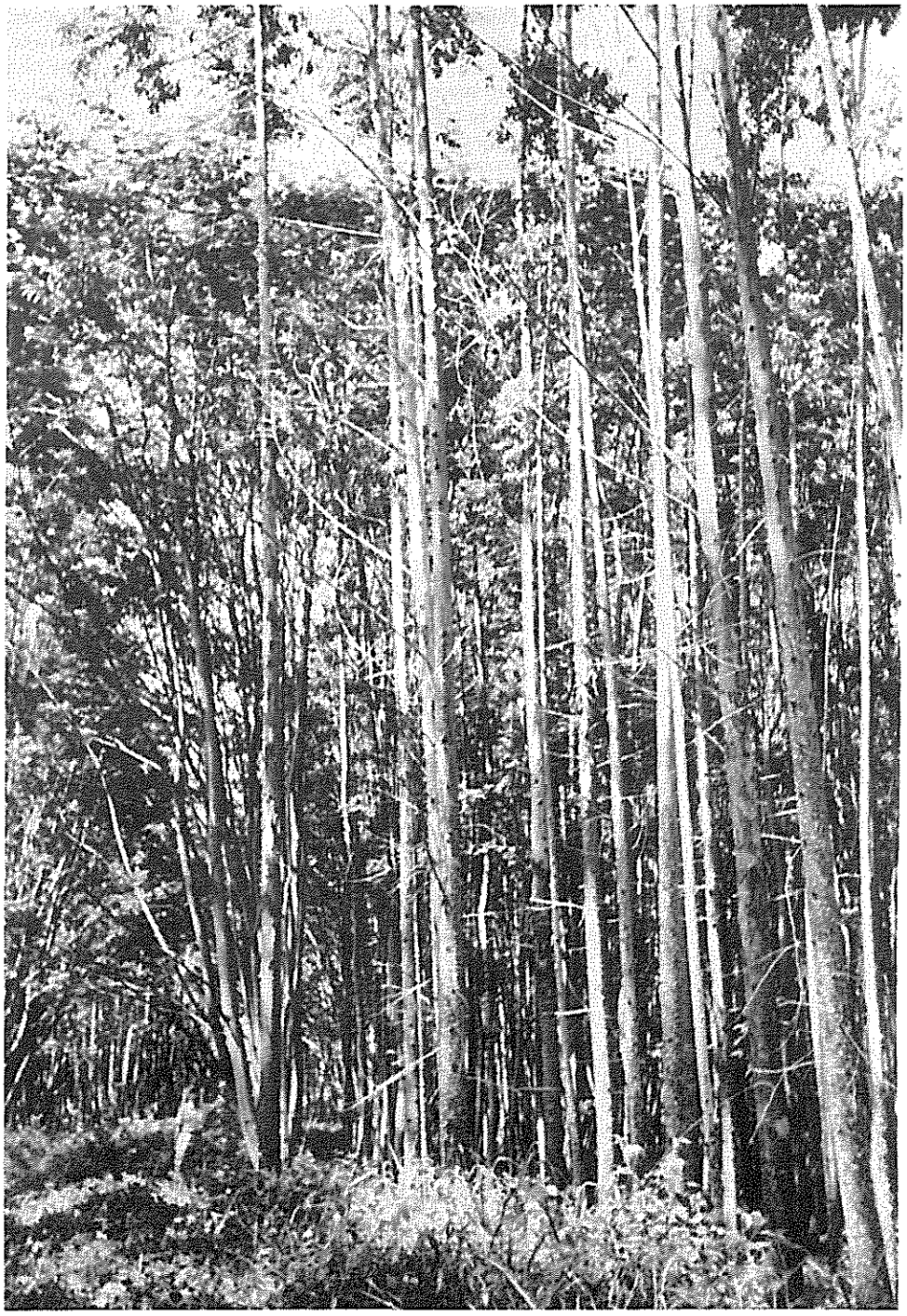
Benefits of *Eucalyptus-Albizia* Mixtures Vary by Site on Hawaii Island

Dean S. DeBell **Craig D. Whitesell** **Thomas B. Crabb**



The Authors:

did the research reported herein under cooperative agreements among the Pacific Northwest Forest and Range Experiment Station, Pacific Southwest Forest and Range Experiment Station, and BioEnergy Development Corporation. **DEAN S. DeBELL** is in charge of the Pacific Northwest Station's research on the biology and silviculture of forests of the Douglas-fir region, with headquarters in Olympia, Washington. He earned a bachelor of science degree (1963) in biology from Juniata College and master of forestry (1964) and doctoral degrees (1970) in forestry at Duke University. **CRAIG D. WHITESELL** heads up the Pacific Southwest Station's forestry research in the American Pacific Islands, and is stationed in Honolulu, Hawaii. He earned a bachelor of science degree (1951) in forestry at West Virginia University, and a master of forestry degree (1954) at Duke University. **THOMAS B. CRABB** has served in various management and executive positions with C. Brewer Company in the Hawaiian sugar industry; he is currently a vice president and manager with BioEnergy Development Corporation, a subsidiary of C. Brewer Company, Hilo, Hawaii.

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Cover: Plantings of *Eucalyptus saligna* (right, foreground) and *Albizia falcataria* (left, background) on Hamakua Coast of Hawaii Island.

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IN BRIEF

DeBell, Dean S.; Whitesell, Craig D.; Crabb, Thomas B. **Benefits of *Eucalyptus-Albizia* mixtures vary by site on Hawaii Island.** Res. Paper PSW-187. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987. Revised 1988. 6 p.

Retrieval Terms: Eucalyptus saligna, Albizia falcataria, Hawaii, species-mixtures, nitrogen fertilization

Biomass from fast-growing coppice plantations of *Eucalyptus* is a potential alternate source of energy in the Hawaiian Islands and similar tropical locales where conventional sources of energy (such as hydroelectric power and fossil fuels) are limited or must be imported. Because of its rapid growth and high yields, *Eucalyptus saligna* Sm. is being tested on Hawaii Island as a means of providing biomass for conversion to energy. The growth of *E. saligna* is limited on many sites by low levels of available soil nitrogen. Supplemental N needed for sustained yields can be provided by synthetic N fertilizer or through use of N-fixing plants such as legumes. Although responses to N fertilizer have been substantial, repeated N applications are costly in dollars and energy. Therefore, we investigated the possibility of planting leguminous trees with *Eucalyptus*.

Tests of *E. saligna* and *Albizia falcataria* (L.) Fosberg were established on Hawaii Island at Onomea and Chin Chuck on the wet Hamakua Coast and at Ka'u I and Ka'u II in the drier Ninole Valley. Although studies at the four sites varied in their specific treatments, similar treatments were selected at each site for comparison: pure stands of *Eucalyptus* with additional N fertilizer and a 50:50 mixture of *Eucalyptus* and *Albizia*. Treatments were replicated three times at Onomea and Ka'u I and four times at Chin Chuck and Ka'u II. Heights and diameters of all trees were measured annually. Foliar samples were collected and analyzed for nitrogen, phosphorus, and potassium. General trends in growth and nutrient concentrations of the two species at the four sites were examined and compared.

At two sites—Onomea and Chin Chuck—located on the wet, northeast coast, *Eucalyptus* in the mixed stands grew taller, were larger in diameter, and had higher foliar concentrations of N and P than *Eucalyptus* in pure stands. *Albizia* grew very well at these sites, and, in some cases, overtopped the *Eucalyptus*. Growth of *Eucalyptus* in both pure and mixed stands was excellent at the other two sites—Ka'u I and Ka'u II—located near the much drier, southeast coast. In the mixed stands, however, *Albizia* grew very poorly and had no beneficial effect on *Eucalyptus* height growth. Although *Eucalyptus* diameters were larger in the mixed stands, the differences were attributed to decreased competition for growing space because of the smaller size of *Albizia*.

Foliar N concentrations of *Eucalyptus* grown in pure stands and in mixtures with *Albizia* at the four sites varied in patterns similar to those depicted for height growth. Nitrogen concentrations in foliage of *Eucalyptus* grown in mixture with *Albizia* were more than 30 percent higher at Onomea than those of *Eucalyptus* grown in pure stands; about 7 percent higher at Chin Chuck and Ka'u I; and nearly identical in the pure and mixed plantings at Ka'u II.

Both trials at Ka'u (Ka'u I at 24 months and Ka'u II at 48 months) had to be terminated because of severe wind damage.

Clearly, the merits of planting *Eucalyptus-Albizia* mixtures vary with site. Benefits will depend not only on relative growth of the two species but also on the most influential growth-limiting factors—N, moisture, light, and wind—at each site. Excellent results were obtained with mixed *Eucalyptus-Albizia* plantings on the rain-drenched Hamakua Coast. On the other hand, the principal effect of mixed plantings at Ka'u was diminished productivity per hectare. Other leguminous trees may be more useful for mixed plantings in the Ka'u District. Even so, benefits are unlikely to be as dramatic at Ka'u as those on the Hamakua Coast because native supplies of available N at Ka'u appear to be higher.

INTRODUCTION

Eucalyptus saligna Sm. plantations are being tested in Hawaii as a means of providing biomass for conversion to energy. Although growth of the plantations has been acceptable on most sites (Schubert and Whitesell 1985), supplemental nitrogen (N) is needed for sustained growth and high yields. Responses to N fertilizer have been substantial (Qureshi 1978, Whitesell and others, in press) but repeated N applications are costly in both dollars and energy. We are therefore examining the possibilities of planting leguminous trees with eucalypts to provide the needed nitrogen.

Mixtures of *Eucalyptus* with *Acacia melanoxylon* R. Br. or *Albizia falcataria* (L.) Fosberg were remarkably successful in an initial test at Onomea on the wet northeast Hamakua Coast of Hawaii Island (DeBell and others 1985). Another early test of such mixtures in the much drier, southeast Ka'u District of Hawaii Island appeared promising but was damaged at age 24 months by severe winds before effects were fully evident (Bio-Energy Development Corporation 1981). In both tests, however, the growth of *Albizia* and the beneficial effect of *Albizia* on *Eucalyptus* were greater than the growth or effects of *Acacia melanoxylon*. We therefore focused our research efforts on *Albizia-Eucalyptus* mixtures, and established subsequent studies at two additional locations—Chin Chuck on the Hamakua Coast and Ka'u II in the Ka'u District—to determine optimum ratios for planting the two species. Excellent yields were obtained with mixed *Albizia-Eucalyptus* plantings at Chin Chuck, but the growth of *Albizia* was very poor at Ka'u and the mixtures resulted in diminished productivity.

Although we remain optimistic about *Albizia-Eucalyptus* mixtures, considerable site-to-site variation apparently exists in the relative growth of the two species and in the benefits provided by *Albizia* to companion *Eucalyptus*.

This paper examines the growth of *E. saligna* in pure stands fertilized with additional N and the growth of *E. saligna* and *A. falcataria* in mixed stands at four locations on Hawaii Island.

STUDY AREAS

Tests of various combinations of *E. saligna* and *A. falcataria* were established at four sites on Hawaii Island between 1979 and 1982. Two sites (Onomea and Chin Chuck) are located on the Hamakua Coast northwest of Hilo and two (Ka'u I and Ka'u II) are located in the Ninole Valley of the Ka'u District southwest of Pahala. Soils, climate, and elevation vary among these areas with greatest differences occurring between Hamakua Coast sites and those in the Ka'u District (*table 1*). The Ka'u District sites are located at higher elevations, receive much less rainfall, and have more fertile (though rocky) soils than the sites on the Hamakua Coast.

Table 1—*General site and soil characteristics for mixed species plantings of* Eucalyptus saligna *and* Albizia falcataria *on Hawaii Island*

Location	Elevation	Average annual rainfall	Soil type	Total N	Extractable P	pH
	m	*mm*		*Percent*	*ppm*	
Onomea	420	5000	Akaka silty clay loam	0.5	6	4.9
Chin Chuck	480	4600	Akaka silty clay loam	0.6	15	5.0
Ka'u I	550	1700	Kiloa extremely stony muck	0.4	170	5.6
Ka'u II	530	1700	Kiloa extremely stony clay loam	0.5	90	5.8

METHODS

Studies established at the four sites varied somewhat in their specific treatments. We selected the following similar treatments from each study for comparison in this report: pure stands of *Eucalyptus* with additional N fertilizer, and *Eucalyptus* and *Albizia* planted in 50:50 mixture. Specific information regarding planting date, spacing, and fertilizer applications is given in *table 2*. We replicated treatments three times at Onomea and Ka'u I and four times at Chin Chuck and Ka'u II.

Height and diameter of the trees were measured annually and plotted to determine growth patterns. Foliage samples were collected at various times in each study and analyzed for N, Phosphorus (P), and potassium (K); mean foliar concentrations were calculated from all samples of each treatment in each study. Growth trends and nutrient concentrations of the two species at the four sites were then examined and compared. More detailed analyses and discussions of the entire experiments at Onomea and Chin Chuck are or will be contained in papers concerned specifically with those studies (e.g. Debell and others 1985, 1987). Basic data and analyses for the Ka'u studies are on file at the Station's Institute of Pacific Forestry in Honolulu, Hawaii.

Table 2—*Information of experimental procedures used in four tests of* Eucalyptus-Albizia *mixtures on Hawaii Island*

Location	Planting date	Spacing	Fertilizer Applications[1]		Trees measured per plot
			Pure Eucalyptus	*Eucalyptus-Albizia* mixture	
Onomea	August 1979	2m x 2m	NPK at 0 and 6 months; urea at 15 months	NPK at 0 and 6 months	50
Chin Chuck	January 1982	2m x 2m	NPK at 0, 4, 8, 12, 18, 24, and 36 months	NPK at 0, 4, and 8 months; PK only at 12, 18, 24, and 36 months	36
Ka'u I	September 1979	1.5m x 1.5m	NPK at 0 and 6 months; urea at 15 months	NPK at 0 and 6 months	50
Ka'u II	March 1981	2m x 2m	NPK at 0, 7, 13, 18, 24, and 39 months	NPK at 0 and 7 months; PK only at 13, 18, 24, and 39 months	36

[1]Fertilizer was placed in holes near individual trees; each application of NPK provided about 16 g N, 7 g P, and 13 g K per tree (or about 40 kg N, 18 kg P, and 33 kg K per ha); PK provided 7 g P and 13 g K per tree; and the urea application at Onomea and Ka'u I provided about 50 g N per tree (about 130 kg N per ha).

RESULTS AND DISCUSSION

Heights of *Eucalyptus* grown in pure stands and *Albizia* grown in mixed stands differed markedly at four sites; in addition, the relative heights of *Eucalyptus* and *Albizia* in mixed stands also varied among the study locations (*fig. 1*). *Eucalyptus* in pure stands grew least at Onomea and most at Chin Chuck and Ka'u II. Heights of *Eucalyptus* trees in mixed stands, however, were more comparable among locations, primarily because height of *Eucalyptus* at Onomea was substantially improved by the presence of *Albizia*.

Albizia heights differed substantially among the four sites; at 48 months, height was greatest at Onomea, followed by Chin Chuck, and Ka'u. The poor growth at Ka'u was especially evident at the second site (Ka'u II) where growth nearly ceased in the third year. Height of *Albizia* two years after planting at Ka'u I was poorer than that at Chin Chuck but somewhat better than growth at Ka'u II. The height growth response of *Eucalyptus* to the admixture of *Albizia* in general paralleled the growth of *Albizia* at each site, being greatest at Onomea, intermediate at Chin Chuck and Ka'u I, and least at Ka'u II.

Another major factor in the relative responses of *Eucalyptus* to *Albizia* at Onomea and Chin Chuck was the greater N fertilizer application in pure *Eucalyptus* stands at Chin Chuck. As a result, N was less limiting, *Eucalyptus* in pure stands grew much more rapidly, and the apparent height growth response observed in the mixtures was reduced.

Diameters of *Eucalyptus* and *Albizia* trees showed relationships among sites that were in general similar to those for heights (*figs. 1 and 2*). Usually at 24 months (and always thereafter), however, diameters of *Eucalyptus* grown with *Albizia* were larger than those grown in pure stands. If *Albizia* were nearly the same size as *Eucalyptus* in pure stands (as at Chin Chuck and Ka'u I) or larger (as at Onomea), we can probably attribute the increased diameter growth of *Eucalyptus* to benefits from *Albizia*—presumably to added supplies of N.

At Ka'u II, however, additional growing space was associated with increased diameter growth. *Albizia* trees at that site were markedly smaller than *Eucalyptus* trees; thus, *Eucalyptus* trees in mixed stands faced less competition for growing space compared to those in the pure *Eucalyptus* treatment. Results from a spacing trial at Ka'u II showed that trees having a growing space of 4 m^2 had diameters at 48 months of 10.3 cm, whereas trees having a growing space of 6 m^2 had diameters of 12.5 cm—an increase of about 21 percent.[1] In the *Eucalyptus-Albizia* trial, each *Eucalyptus* growing in the pure stands had 4 m^2 per tree; in the mixed stands, if competition from *Albizia* is discounted entirely, each *Eucalyptus* tree had 8 m^2 per tree. The gain in diameter was only about 17 percent. Thus, the increased diameter growth of *Eucalyptus* in the mixed planting at Ka'u II is probably attributable to the additional "effective" growing space resulting from the poor growth of *Albizia*.

[1] Unpublished data on file at the Station's Institute of Pacific Islands Forestry, Honolulu, Hawaii.

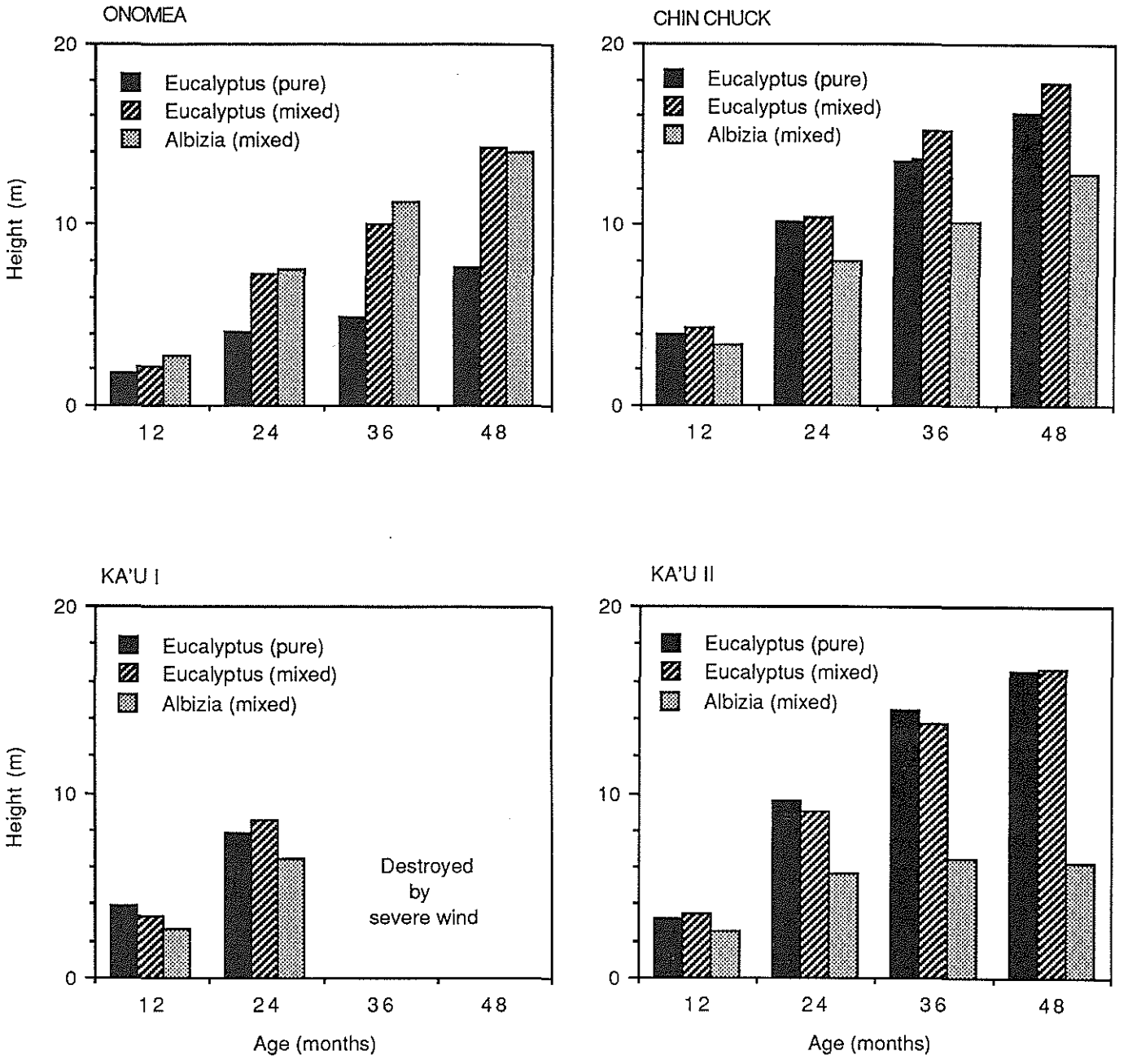

Figure 1—Height of *Eucalyptus* and *Albizia* at different ages at four sites on Hawaii Island.

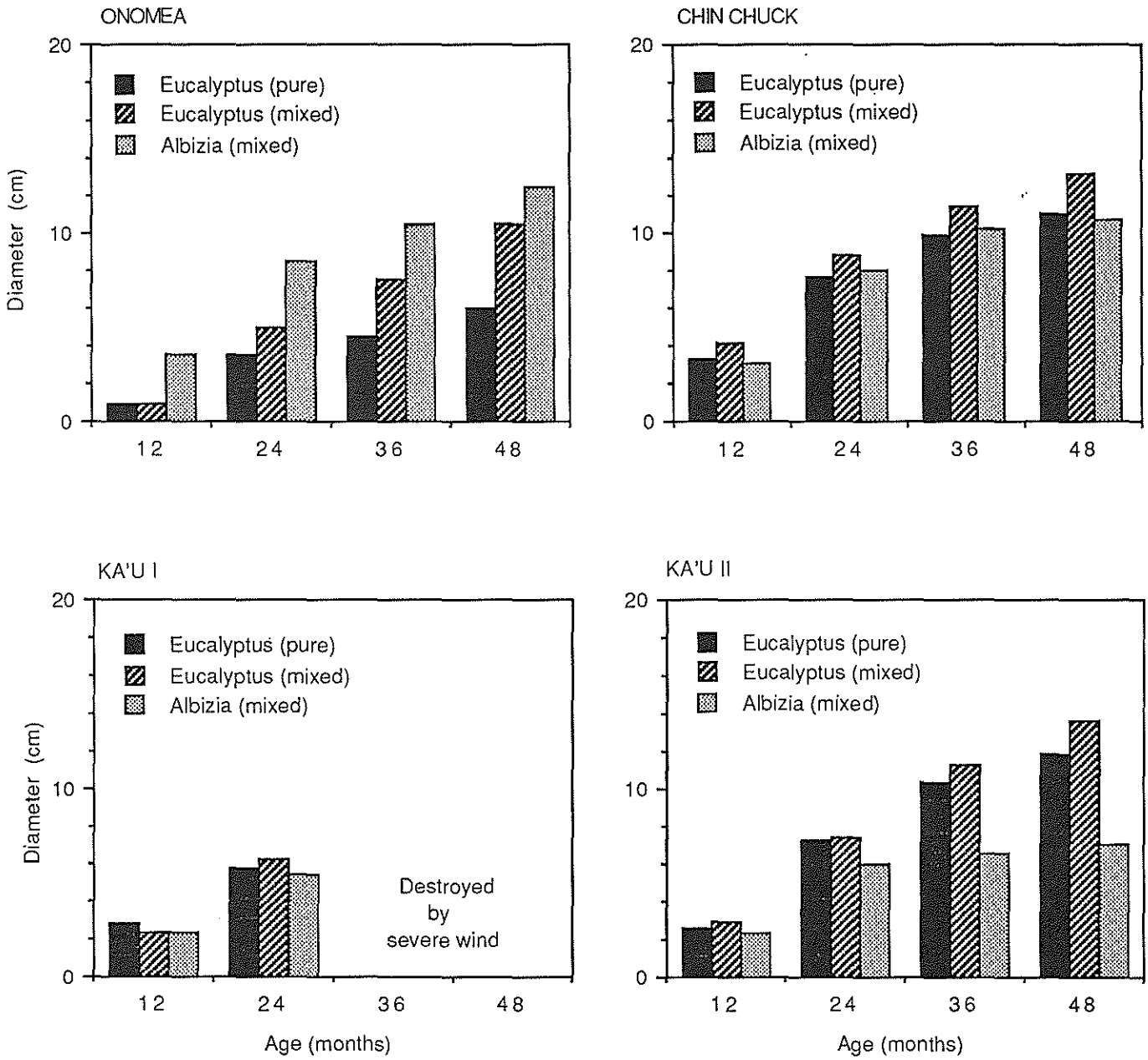

Figure 2—Diameter of *Eucalyptus* and *Albizia* at different ages at four sites on Hawaii Island.

Table 3—*Mean foliar nutrient concentrations of* Eucalyptus saligna *grown in pure stands and in mixture with* Albizia falcataria *on Hawaii Island*[1]

Location	Stand treatment	Foliar nutrient			Number of samples
		N	P	K	
Onomea	Pure	0.88	0.11	0.67	3
	Mixed	1.16	.13	.87	3
Chin Chuck	Pure	1.84	.18	1.21	28
	Mixed	1.96	.19	1.17	28
Ka'u I	Pure	2.38	.24	.94	3
	Mixed	2.54	.22	.92	3
Ka'u II	Pure	2.19	.21	1.30	24
	Mixed	2.18	.22	1.24	24

[1]Mean concentrations were calculated from all samples collected in the respective treatments at each location. Onomea and Ka'u I samples were collected only at 12 or 13 months; Chin Chuck and Ka'u II samples were obtained at 6-month intervals from 12 to 42 months.

Foliar N concentrations of *Eucalyptus* grown in pure stands and in mixture with *Albizia* at the four sites varied in patterns similar to those depicted for height growth (*table 3, fig. 1*). Nitrogen concentrations in foliage of *Eucalyptus* grown in mixture with *Albizia* were more than 30 percent higher at Onomea than those of *Eucalyptus* grown in pure stands; about 7 percent higher at Chin Chuck and Ka'u I; and nearly identical in the pure and mixed plantings at Ka'u II. The latter finding thus provides additional support for our presumption that the larger diameter for *Eucalyptus* grown in the mixed planting at Ka'u II was due primarily to increased growing space and not to enhanced N status.

Foliar concentrations of P appeared to be enhanced by the presence of *Albizia* at Onomea, Chin Chuck, and Ka'u II (*table 3*). Foliar potassium concentration was increased by *Albizia* at Onomea, but was somewhat lower in the mixed stands at the other three sites. Enhancement in the concentration of non-nitrogenous nutrients in foliage of *Eucalyptus* grown in the mixed stands may be related to more rapid nutrient cycling associated with additions of N-rich litter or to enhanced root growth, or to both conditions.

Why were height growth and foliar N concentration of *Eucalyptus* enhanced at Onomea and Chin Chuck and not at Ka'u II? At least two factors may be responsible for such differences: (1) nitrogen may have been non-limiting (or less limiting) at Ka'u and very limiting to growth at Onomea and Chin Chuck, and (2) vigor of *Albizia* was so poor at Ka'u that little additional N was provided by its presence. Results from fertilizer trials on the Hamakua Coast and in the Ka'u District support the first possibility (Whitesell and others MS); 18-month-old *E. saligna* seedlings receiving 50 g urea were five times as tall as unfertilized seedlings on the Hamakua Coast (5.2 m vs. 1.0 m) whereas similarly fertilized seedlings were only about 50 percent taller than unfertilized seedlings in the Ka'u District at the same age (7.1 m vs. 4.6 m). Although total N contents of soils in both areas were similar, amounts of N available for tree growth apparently differed substantially. That *Albizia* grew very poorly at Ka'u II, especially after the second year, is obvious; moreover, a number of studies have demonstrated a strong, positive correlation between growth and nitrogen fixation in other tree species (Gordon and Wheeler 1978, Bormann and Gordon 1984). Thus, it seems equally plausible that little additional N was provided by *Albizia* to *Eucalyptus* in the mixed plantings at Ka'u.

Why was growth of *Albizia* so poor at Ka'u? Initial growth (up through 24 months) appeared acceptable. At that age, Ka'u I was destroyed by severe winds. The *Albizia* at Ka'u II, however, made essentially no growth during the third and fourth year; there was little diameter increase and much dieback of terminals, especially in the last year. Apparently, *Albizia* is much less suited to the soils and climate of the Ka'u area than it is to the Hamakua Coast. The species is native to the Indonesian archipelago and New Guinea, and planted trees seem to grow well only in the wet tropics where rainfall is at least 2,000 mm per year (National Academy of Sciences 1979). Average annual rainfall at the Ka'u site (1700 mm) is less than this "minimum," and problems with drought are likely to be exacerbated by the very high stone content of the Ninole and Alapai soils. Perhaps such limitations do not appear until the stand fully occupies the site—beyond 24 months.

Another factor, possibly even more important, in the acceptable performance of *Albizia* through 24 months and failure thereafter (at Ka'u II) is a drastic change in rainfall. During the first 24 months after planting, rainfall for both Ka'u studies was equal to or greater than the 10-year average. A drought occurred during the third and fourth year of the Ka'u II study, however, and rainfall was 15 to 20 percent below normal.

Even if *Albizia* had grown well at Ka'u, frequent windstorms could be a problem, especially in the Ninole Valley, Wind damage is a common problem in *Albizia* plantations throughout the tropics because the tree's root system is commonly shallow and its rapid growth results in weak limbs (National Academy of Sciences 1979). Both of the mixed *Eucalyptus-Albizia* trials at Ka'u (Ka'u I at 24 months and Ka'u II at 48 months) had to be terminated because of severe wind damage.

CONCLUSIONS

Clearly, the merits of planting *Eucalyptus-Albizia* mixtures vary with site. Benefits will depend not only on relative growth performance of the two species but also on the most influential growth-limiting factors—N, moisture, light, and wind—at each site. Excellent results were obtained with mixed *Eucalyptus-Albizia* plantings on the rain-drenched Hamakua Coast where soils are deficient in available nitrogen. On the other hand, the principal effect of mixed plantings at Ka'u was diminished productivity per hectare; the *Albizia* produced far less biomass than the *Eucalyptus* they replaced and there was no compensating stimulation of growth of *Eucalyptus* in the mixed stand. Other leguminous trees may be more useful for mixed plantings

in the Ka'u District. *Acacia mangium* performed fairly well through 54 months in species trials on both Kiloa and Alapai soils (Schubert and Whitesell 1985). Even so, benefits are unlikely to be as dramatic at Ka'u as those obtained on the Hamakua Coast because native supplies of available N at Ka'u appear to be higher.

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Eucalyptus saligna Sm. plantations are being tested in Hawaii as a means of providing biomass for conversion to energy. Initial growth rates have been excellent, but supplemental nitrogen (N) is needed for sustained productivity on most sites. Although responses to N fertilizer have been substantial, costs of N applications are costly in dollars and energy. The possibility of planting leguminous trees with *Eucalyptus* to provide the needed N was therefore investigated. In this paper, we compare the growth of *E. saligna* in pure, N-fertilized stands with that of *E. saligna* and *Albizia falcataria* (L.) Fosberg, a leguminous tree, in mixed (50:50) stands at four sites on the island of Hawaii. At two sites located on the wet, northeast coast, *Eucalyptus* in the mixed stands grew taller, were larger in diameter, and had higher foliar concentrations of N and P than *Eucalyptus* in pure stands. *Albizia* grew very well at these sites, and, in some cases, overtopped the *Eucalyptus*. Growth of *Eucalyptus* in both the pure and mixed stands was excellent at the other two sites located near the much drier, southeast coast. In the mixed stands, however, *Albizia*, grew very poorly and had no beneficial effect on *Eucalyptus* growth. Thus, *Eucalyptus-Albizia* mixtures can replace the need for repeated N applications in bioenergy plantations along the wet, northeast coast. In the drier, southeast district, however, productivity of such mixtures will be lower than that of pure *Eucalyptus* stands.

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