Using N₂-Fixing Albizia to Increase Growth of Eucalyptus Plantations in Hawaii

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ABSTRACT. Plantations of Eucalyptus saligna Sm. grow rapidly in Hawaii, but supplemental nitrogen (N) is required on many sites. Because of the high cost of synthetic N fertilizer, mixed species plantings in which N is added by Albizia falcataria (L.) Fosb., an N₂-fixing tree, are being tested on the island of Hawaii. Five combinations of Eucalyptus and Albizia were compared with each other, with pure Albizia, and with pure Eucalyptus fertilized periodically with nitrogen. The test is a randomized block design with four replications on the wet, Hamakua coast. At 48 months, Eucalyptus trees in the mixed plantings containing 34% or more Albizia were equal to or larger than those in the pure, fertilized stands. Total dry yields ranged from 109 ton/ha in pure Albizia plantings to 67 ton/ha in mixed species plantings with only 11% Albizia. Yields in the mixed plantings with 34 to 66% Albizia were 103 to 105 ton/ha, whereas yield in the pure, fertilized Eucalyptus stand was 94 ton/ha. Nitrogen concentration of Eucalyptus foliage increased as the amount of Albizia increased in the stand; and in mixed plantings with 34% or more Albizia, foliar N concentration exceeded that of the pure, fertilized, Eucalyptus treatment. Phosphorus levels in Eucalyptus foliage similarly increased as amounts of Albizia increased in the stand. At 48 months, total N was higher in soils of mixed species and pure Albizia plantings than in soils of the pure, fertilized Eucalyptus treatment. Albizia can provide the N needed by Eucalyptus in high-yielding bioenergy plantations along the Hamakua coast. FOR. SCI. 35(1):64-75.

ADDITIONAL KEY WORDS: Biomass, nitrogen, fertilizer, nitrogen fixation, legumes.

Plantations of several Eucalyptus species are being evaluated as a source of energy in Hawaii and other tropical and subtropical areas (Rockwood et al. 1983; Schubert and Whitesell 1985). Their rapid growth results in high yields in short rotations (Walters 1973, Whitesell 1975). On many sites, however, production is limited by low levels of available nitrogen (N). Responses to N fertilizer have been substantial (Miyasaka 1984, Whitesell et al. 1987), and supplemental N will undoubtedly be needed for sustained production from repeated harvests.

The availability and cost of synthetic N fertilizer are closely tied to supplies and price of fossil fuel. Fertilization is, therefore, an expensive practice in Hawaii and would be impractical in many developing countries. Nitrogen can also be added to forest systems through symbiotic N₂-fixation, and N₂-fixing plants are common in many tropical rainforests (Cole and Johnson 1980).

Recently, we began to evaluate cultural systems in which N added to Eucalyptus beyond the establishment stage was supplied by N₂-fixing trees. A
compound fertilizer (NPK) is applied routinely to individual trees at planting and one or two additional times during the first year. A preliminary test showed that 65-month-old *Eucalyptus* trees grown in 50-50 mixtures with either of two N₂-fixing, leguminous trees (*Albizia falcataria* and *Acacia melanoxylon* R. Br.) were significantly taller and larger in diameter than those grown in pure stands, and biomass yields per ha were much greater in the mixed stands (DeBell et al. 1985). Best growth and yield were obtained in the mixtures containing *Albizia*. Given the promising early results of the 50-50 mixtures, we established a study to compare mixed stands composed of various combinations of *E. saligna* Sm. and *Albizia falcataria* with each other, with pure *Albizia*, and with pure *E. saligna* fertilized periodically with synthetic N fertilizer.

This paper reports tree growth, nutrient status, and biomass yields for the various species mixture–fertilizer treatments through stand age of 48 months. Our findings show that applications of synthetic N fertilizer after the first year can be eliminated by planting appropriate combinations of *Albizia* and *Eucalyptus*.

**STUDY AREA**

Hakalau is an area typical of much marginal and abandoned sugarcane land along the Hamakua coast (19°30'N, 155°15'W) of the island of Hawaii. The test site is at 480-m elevation, and annual rainfall averages about 4600 mm, distributed fairly evenly throughout the year. Slopes are gentle, ranging from 0 to 10%. The soil series is Akaka silty clay loam (thixotropic isomesic Typic Hydrandept) and is moderately acidic (pH 5.8–6.0). Nitrogen concentration is similar to that of most soils of the Hamakua coast, averaging about 0.5% in the 0- to 20-cm surface layer. Sugarcane was produced on the land for more than 50 years, but was abandoned because of low yields after an October 1980 harvest. Immediately before the study was started, the area was occupied by residual sugarcane that was heavily infested with California grass (*Brachiaria mutica* [Forsk.] Stapf.) and smaller amounts of other grasses and broad-leaved weeds. The site was prepared for planting with a Rome cutaway harrow, which flattened and cut up the sugarcane and grass to form a mulch. Reinvading and resprouting vegetation was sprayed with glyphosate\(^1\) prior to planting in January 1982.

**METHODS**

The experimental design was a randomized complete block with seven species mixture–fertilizer treatments replicated in four blocks. The seven treatments, expressed as the percentage of *Eucalyptus* and *Albizia*, respectively, were: 100:0, 89:11, 75:25, 66:34, 50:50, 34:66, and 0:100. Five of the treatments were applied on 0.09-ha plots (30 x 30 m); the other treatments (34% *Eucalyptus*—66% *Albizia* and 100% *Albizia*) were applied on 0.045-ha plots (15 x 30 m). Each plot was planted with 3-month-old container seedlings at 2 x 2-m spacing (2500 trees/ha) in January 1982. The growing media had been inoculated with *Rhizobium* to ensure that *Albizia* seedlings were nodulated prior to planting. The various combinations of *Eucalyptus* and *Albizia* were established systematically with uniform distribution of the two

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\(^1\) This publication does not contain recommendations for herbicide uses reported, nor does it imply that such uses have been registered by the appropriate government agencies.
species throughout the plot (i.e., the species were not planted in pure rows or clumps).

Each seedling was fertilized with 115 g of N-P-K fertilizer at outplanting and at 4 and 8 months later; each application was equivalent to 40 kg N, 18 kg P, and 33 kg K per ha. The pure *Eucalyptus* plots received the same amounts of N-P-K fertilizer at 12, 18, 24, and 36 months; this treatment is the most intensive fertilizer regime we have tested in other ongoing studies, and appears to be near optimum. Trees in the variously mixed *Eucalyptus-Albizia* plots and in the pure *Albizia* plots received P-K fertilizer at the same times. Thus, *Eucalyptus* grown in pure stands received about 160 kg N/ha more than did trees in the other plots. Identical amounts of P and K were applied to all trees in all treatments. No fertilizer was applied after 36 months.

Survival and size of 9 trees in each of 4 subplots (36 trees) in the interior of each plot were recorded at 6-month intervals. Tree heights were measured to the nearest 0.1 m with a telescoping rod until trees were 15 m tall; after that time, they were measured with an Abney level and tape. Diameters at breast height were measured to the nearest 0.1 cm by diameter tape.

Foliage samples were collected from the upper crown of 10 trees per plot at 12 months and at 6-month intervals thereafter until 42 months. By then dominant and codominant trees were too tall for foliage sampling without felling the tree. Dried foliage was analyzed for nutrients at the University of Hawaii as follows: total N by standard Kjeldahl procedure; P, S, Ca, Mg, K, Fe, Cu, Mn, and Zn by x-ray emission spectroscopy.

Prior to planting and again at 48 months, soil samples were collected from the 0–20-cm surface layer at 10 or more points in each plot and composited. The composite samples were air-dried at room temperature, rolled, and passed through a 2-mm sieve. Subsamples were analyzed for pH, total N, and mineral nutrients. Soil pH was determined on soil-water pastes by glass electrode. Total N was estimated by the semimicro-Kjeldahl method (Bremner 1965). Mineral nutrients determined and analytical methods used were as follows: extractable P (extracted with Truog solution (Truog 1930)) by the molybdenum blue technique (Chapman and Pratt 1961); exchangeable K, Ca, and Mg (extracted with neutral 1N NH₄OAC) by standard atomic absorption spectrophotometric methods.

Tree survival and size (height and diameter) data were averaged for each plot and species; and differences among treatments at each measurement date were evaluated for each species by standard analyses of variance. We recognize that repeated measurements on the same plots are not independent, and thus statistical tests made for different measurement dates may be somewhat less conservative than probability levels indicate. This matter, however, is unlikely to be of practical importance in the present study. When treatments were significantly different (i.e., \( P < .05 \)), the means were separated by Duncan’s multiple range test. Effects of treatment on tree growth patterns were further examined by plotting average height or diameter as a function of stand composition (percent *Albizia* or percent *Eucalyptus*) at 12, 24, 36, and 48 months. Similar statistical procedures were applied to data on foliar nutrient concentrations from all samplings and to data on soil properties on the plots 48 months after treatments were applied. Effects of treatments on selected nutrients in *Eucalyptus* foliage were graphically displayed by plotting of foliar nutrient concentration as a function of stand composition at 24 and 42 months.

Biomass equations were developed through destructive sampling of trees.
at the study site and similar locations. Trees were selected to include the range of sizes encountered in our study.

Total aboveground, dry biomass at 48 months was estimated for each *Eucalyptus* and *Albizia* tree in each plot of each treatment with the equations:

**Eucalyptus:**
\[
\ln \text{dry weight} = -3.8604 + 0.9644 \ln (\text{dbh}^2 \times \text{height})
\]
\((n = 93, R^2 = 0.99, \text{RMSE} = 0.11)\)

**Albizia:**
\[
\ln \text{dry weight} = -6.1393 + 0.8180 \ln \text{dbh} + 2.9295 \ln \text{height}
\]
\((n = 20, R^2 = 0.92, \text{RMSE} = 0.35)\)

with dry weight expressed in kg, dbh in cm, and height in m.

The estimated weights of all surviving trees in each treatment of each block were summed and expanded to ton/ha based on area occupied by the measurement plots. Differences among treatments were evaluated by analysis of variance, and means were separated by Duncan's multiple range test.

**RESULTS AND DISCUSSION**

**TREE SURVIVAL AND GROWTH**

Survival was excellent for both species and was unaffected by treatment. Percent survival at 48 months ranged from 94 to 98 for *Eucalyptus* and 99 to 100 for *Albizia*.

Average height and diameter of *Eucalyptus* did not vary significantly among treatments during the first 18 months. But at 24 months, *Eucalyptus* trees in the 50% *Eucalyptus*-50% *Albizia* mixture were significantly taller and larger in diameter than trees in one or more of the treatments having a smaller proportion of *Albizia* in the stand (Figure 1). And at 36 months and thereafter, size differences between trees in the pure, fertilized *Eucalyptus* stand and *Eucalyptus* trees in the mixtures containing 11 and 25% *Albizia* became progressively greater. During the 24-48-month period, trends of increasing height and diameter of *Eucalyptus* grown with increasing amounts of *Albizia* became firmly established. At 48 months, *Eucalyptus* trees in the treatments with 50 and 66% *Albizia* were significantly larger than *Eucalyptus* trees in most treatments containing lesser amounts of *Albizia*; moreover, such trees were substantially larger than those in the pure, fertilized *Eucalyptus* stand. *Eucalyptus* trees in the treatment containing 34% *Albizia* were similar in size to those in the pure, fertilized treatment. The size of *Albizia* trees was not significantly affected by treatment until the 36-month measurement when diameters in the 75% *Eucalyptus*-25% *Albizia* treatment were significantly larger than those in the 34% *Eucalyptus*-66% *Albizia* treatment (Figure 2). Such differences in diameter increased through 48 months. Effects of stand composition on *Albizia* heights also became apparent with trees in mixtures containing 25 and 34% *Albizia* being taller than those in other treatments (Figure 2). In general, *Albizia* trees in treatments containing 25 and 34% *Albizia* tended to be larger than those in treatments containing 50 and 66% *Albizia*. The diminished *Albizia* growth in the latter two treatments can be attributed at least in part to greater competition associated with enhanced growth of *Eucalyptus* trees in these mixtures. Average 48-month height of *Eucalyptus* and *Albizia* differed by less
than 2 m in mixtures containing 34% Albizia or less, but Eucalyptus trees averaged 5 to 6 m taller than Albizia trees in mixtures containing 50 and 66% Albizia (Table 1).

**ESTIMATED DRY BIOMASS YIELDS**

Effects of treatment on height and diameter combined to amplify differences among treatments in dry biomass per tree at 48 months (Table 1). Mean dry
weight of *Eucalyptus* trees in the various mixtures increased from 27 and 28 kg in the treatments with 11 and 25% *Albizia* to 66 kg in the treatment containing 66% *Albizia*. Dry weight of *Albizia* trees varied in the same manner described earlier for height and diameter. The heaviest *Albizia* trees (34 kg) grew in the mixture containing 34% *Albizia*; the lightest (31 to 32 kg) were in the treatments with 11, 50, and 66% *Albizia*; and trees from the pure *Albizia* stand and from the mixed treatment with 25% *Albizia* had intermediate weights.

Pure stands of *Eucalyptus* fertilized periodically with synthetic nitrogen...
TABLE 1. Mean tree characteristics, stocking, and estimated yields of dry biomass at 48 months, for various combinations of Eucalyptus and Albizia. a

<table>
<thead>
<tr>
<th>Species combinationb</th>
<th>dbh (cm)</th>
<th>Height (m)</th>
<th>Dry weight (kg)</th>
<th>Stems/ha (no.)</th>
<th>Dry biomass/ha (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% E Eucalyptus</td>
<td>11.3b</td>
<td>16.2bc</td>
<td>39.1bc</td>
<td>2396</td>
<td>93.7bc</td>
</tr>
<tr>
<td>89% E:11% A Eucalyptus</td>
<td>9.6b</td>
<td>14.1a</td>
<td>27.6c</td>
<td>2101</td>
<td>58.1</td>
</tr>
<tr>
<td>Albizia</td>
<td>13.1ab</td>
<td>12.5a</td>
<td>31.9b</td>
<td>278</td>
<td>8.9</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2379</td>
<td>67.0c</td>
</tr>
<tr>
<td>75% E:25% A Eucalyptus</td>
<td>9.7b</td>
<td>14.3ad</td>
<td>26.6bc</td>
<td>1806</td>
<td>48.1</td>
</tr>
<tr>
<td>Albizia</td>
<td>13.9a</td>
<td>13.0a</td>
<td>46.2c</td>
<td>625</td>
<td>28.9</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2431</td>
<td>77.0bc</td>
</tr>
<tr>
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<td>16.1bcd</td>
<td>37.0bc</td>
<td>1562</td>
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<td>Albizia</td>
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<td>14.6a</td>
<td>53.8c</td>
<td>833</td>
<td>44.8</td>
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<tr>
<td>Total</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2395</td>
<td>102.5bc</td>
</tr>
<tr>
<td>50% E:50% A Eucalyptus</td>
<td>13.2a</td>
<td>17.9b</td>
<td>55.7bc</td>
<td>1181</td>
<td>65.8</td>
</tr>
<tr>
<td>Albizia</td>
<td>10.7a</td>
<td>12.8a</td>
<td>30.8b</td>
<td>1267</td>
<td>39.0</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2448</td>
<td>104.8a</td>
</tr>
<tr>
<td>34% E:66% A Eucalyptus</td>
<td>14.3a</td>
<td>18.4a</td>
<td>65.5bc</td>
<td>815</td>
<td>53.4</td>
</tr>
<tr>
<td>Albizia</td>
<td>10.0a</td>
<td>12.1a</td>
<td>31.1bc</td>
<td>1632</td>
<td>50.8</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2447</td>
<td>104.2a</td>
</tr>
<tr>
<td>100% A Albizia</td>
<td>11.2bc</td>
<td>13.3b</td>
<td>44.6c</td>
<td>2465</td>
<td>109.8c</td>
</tr>
</tbody>
</table>

* Eucalyptus and Albizia sizes were compared statistically within species only; biomass yields were compared for the total plot (both species combined). Values followed by the same letter do not differ significantly at the 5% level of probability.
b E = Eucalyptus; A = Albizia.
c Based on four subplots of nine trees (planting spots) each in each treatment in each of four blocks.

produced about 94 ton/ha at 48 months (Table 1). Dry yields from stands with only 11 or 25% Albizia were much reduced (67 and 77 ton/ha respectively), presumably because N provided by such mixtures was less adequate for growth during most of the 48-month period. Total production in mixed stands containing 34, 50, and 66% Albizia, however, was 103 to 105 ton/ha—equal to or better than production in the pure, fertilized Eucalyptus treatment. Yields of the pure Albizia stand were slightly greater, about 110 ton/ha.

FOLIAR NUTRIENT CONTENT

The various species mixture–fertilizer treatments did not significantly affect concentration of any foliar nutrient at 12 or 18 months, presumably because of the uniform applications of fertilizer to all trees at 0, 4, and 8 months. Foliar concentrations of N, P, and Mn began to vary with stand composition at 24 months (Figure 3), and differences among some treatments became statistically significant. Such differences persisted through 42 months when the last sample was collected. In general, foliar N concentrations of Eucalyptus grown with only 11 or 25% Albizia were less than (24 months) or
FIGURE 3. Foliar nutrient concentration of Eucalyptus trees grown in pure stands with nitrogen fertilizer and those grown with various ratios of Albizia without nitrogen fertilizer.
equal to (42 months) concentrations of N in the foliage of Eucalyptus grown in pure stands that received periodic applications of synthetic N fertilizer. Eucalyptus grown with more than 34% Albizia usually had higher foliar concentrations of N and P than did Eucalyptus grown in pure, fertilized stands. Such effects of treatment on N concentrations were anticipated and may be attributed to N added to the ecosystem via symbiotic N$_2$-fixation by Albizia. This addition of N is probably the primary factor responsible for the parallel trends in growth of Eucalyptus trees.

We did not expect the higher foliar P concentrations of Eucalyptus grown in mixture with Albizia. Phosphorus concentrations of other species have been lowered when N status is enhanced by synthetic N fertilizer (Radwan et al. 1984) or N$_2$-fixing companion species (Binkley et al. 1984). These results do confirm, however, the observation in our earlier study of somewhat higher concentrations of P in foliage of Eucalyptus grown with Albizia (DeBell et al. 1985). Such increases in foliar P concentrations may be related to enhanced root growth (hence, increased exploitation of soil) or to increased rates of nutrient cycling (hence, greater availability) associated with the presence of Albizia and additions of enriched Albizia litter to the soil in mixed plantings, or to both conditions.

Concentrations of K (Figure 3), Ca, Mg, S, Fe, Cu, and Zn in foliage of Eucalyptus trees were unaffected by treatment. Manganese concentrations, however, were negatively related to amounts of Albizia in the stands (Figure 3). At 24 months, Eucalyptus foliage from treatments with only 11 or 25% Albizia had nearly twice as much Mn as foliage from the pure, fertilized Eucalyptus stands; foliar Mn in mixed stands containing 50 to 66% Albizia was similar to that in the pure, fertilized stands. At 42 months, Mn in Eucalyptus foliage from the mixture containing only 11% Albizia was similar to that of the pure, fertilized stands, and Mn concentrations decreased progressively as amounts of Albizia in the mixed species treatments increased. This finding also parallels other studies with other species which indicated that Mn and N levels are inversely correlated (Radwan and DeBell 1980, Binkley et al. 1984).

Species mixture treatments had no significant effect on nutrient concentrations in the foliage of Albizia.

**SOIL PROPERTIES**

Analyses of macronutrients and pH in soils collected at 48 months revealed that only one property differed significantly among treatments. Total N was significantly higher in soils of treatments including Albizia (0.55 to 0.64%) than in soils occupied by pure, fertilized Eucalyptus (0.51%).

There were marked differences, however, in soil characteristics of the plots prior to planting and soils data from the same plots 48 months later. Such influences at 48 months of stand growth on soil properties are reflected in the grand averages for initial characteristics and after 48 months of selected treatments (Table 2). Both total N and extractable P were higher in most (86 to 89%) of the plots when the plantation was 48 months old. Conversely, extractable amounts of the other nutrients (K, Ca, and Mg) decreased markedly on most (82 to 100%) of the plots. Such increases in total N can be attributed to nitrogen fertilization and to additions of N-enriched litter associated with the fertilized Eucalyptus, mixed Eucalyptus-Albizia, and pure Albizia stands.

The increased amounts of P extractable with Truog solution may also be attributed in part to P fertilizer applied during the study. In addition, other
research has indicated that *Eucalyptus* trees can utilize soil phosphorus complexes generally regarded as insoluble or unavailable (Mullette et al. 1974). Furthermore, phosphorus concentrations in *Eucalyptus* foliage in this present study suggest that such utilization is enhanced by the presence of *Albizia*. Much phosphorus had been applied to the site when it was cropped for sugarcane. Perhaps the trees in our study could absorb and utilize fixed or complexed P remaining from such operations and thus reintroduce it into the nutrient cycle in a form more readily extracted by the Truog solution.

Some reduction in exchangeable bases (K, Ca, Mg) is not surprising and is probably associated with both leaching and tree uptake. The large decrease of exchangeable Ca from 300 ppm to less than one-tenth that amount, however, is probably attributable mostly to gradual leaching of a 2000 kg per ha application of CaCO₃ in 1978 for the last sugarcane crop. Native amounts of Ca in soils of the Akaka series and similar soils of the Hamakua coast are extremely low; thus, large amounts of crushed coral are applied for sugarcane production (critical level is assumed to be 800 ppm). Similarly, the decrease in soil pH is probably related primarily to the gradual loss of CaCO₃ in this high rainfall zone. The higher nitrification rates and nitrate leaching likely to be associated with the increased soil N levels may also increase soil acidity.

**IMPLICATIONS**

The results confirm our earlier report that *Eucalyptus saligna* growth can be enhanced by planting the species in mixture with *Albizia falcataria* (DeBell et al. 1985). The need for applications of synthetic N fertilizer after the first year can be eliminated on the test site—and on similar sites along the Hamakua coast—by establishing mixed *Eucalyptus-Albizia* plantations. Growth of *Eucalyptus* trees and estimated per ha yields of total dry biomass for mixed stands containing 34, 50, and 66% Albizia were equal to or greater than growth and yield of pure, fertilized *Eucalyptus* stands. The fertilizer regime for the pure *Eucalyptus* treatment represents the most intensive fertilization schedule we have tested to date and was assumed to be near optimum. If less N had been applied to the pure *Eucalyptus* treatment, the beneficial effects of *Albizia* on growth of *Eucalyptus* and total yield in the mixed species plantings would have appeared even greater. For example, trees measured in pure *E. saligna* plantings having standard fertilizer applications adjacent to our trial indicate that mean diameter and height were 20 to 25% smaller than those of trees in the pure *Eucalyptus* study plots. Dry yield for the standard plantings (fertilizer applied at planting and 6 months

<table>
<thead>
<tr>
<th>Nutrient or pH</th>
<th>Initial¹</th>
<th>100% <em>Eucalyptus</em></th>
<th>50% <em>Eucalyptus</em></th>
<th>50% <em>Albizia</em></th>
<th>100% <em>Albizia</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>0.50</td>
<td>0.51</td>
<td>0.64</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>P (ppm)</td>
<td>9</td>
<td>13</td>
<td>11</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>K (ppm)</td>
<td>43</td>
<td>27</td>
<td>31</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Ca (ppm)</td>
<td>301</td>
<td>16</td>
<td>18</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Mg (ppm)</td>
<td>34</td>
<td>18</td>
<td>22</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>5.9</td>
<td>5.4</td>
<td>5.5</td>
<td>5.2</td>
<td></td>
</tr>
</tbody>
</table>

¹ Averaged for all plots in study.
later) was estimated at 44 ton/ha, or less than half of that in the pure Eucalyptus study plots. Thus, compared with performance of the standard plantings, even the mixed species treatment with 11% Albizia enhanced Eucalyptus growth and substantially increased total yield.

The highest dry yields were produced in the pure Albizia plantings (110 ton/ha); the best mixtures produced 103–105 ton/ha. But the density of Albizia falcataria wood is only about one-half that of Eucalyptus saligna (Skolmen 1974). Therefore, nearly twice as much wood volume of Albizia as Eucalyptus must be produced and processed (felled, bunched, yared, chipped, and dried) to provide similar amounts of dry biomass. Moreover, Albizia tends to be multistemmed with wide crowns, and its branches are easily broken during felling and skidding operations. Because of these limitations, the most effective treatment as to costs and returns is probably the mixture containing 34% Albizia. Additional information that may influence selection of an optimum mixture includes comparative drying traits and energy content per unit weight of the two species.

Applications of P and K fertilizer beyond the establishment stage may be unnecessary and, if so, can also be eliminated in both pure Eucalyptus and mixed Eucalyptus-Albizia stands. Recent data from fertilizer trials at other research sites on the Hamakua coast indicate that P and K fertilizers may affect growth of Eucalyptus trees during the first year but have little or no effect thereafter.2 The enhancement of foliar P concentration of Eucalyptus grown with Albizia is particularly intriguing, and occurred despite the periodic applications of P fertilizer to all trees in all treatments. This finding may have important implications in other tropical and subtropical areas where “available” P is low because of high P-fixation capacity of the soil, yet substantial amounts of insoluble or “unavailable” P are naturally present in the soil or remain from applications of fertilizer to prior crops. Perhaps both N and P fertilization can be minimized by use of certain N2-fixing trees in other managed forest and agroforest ecosystems. Additional research on the factors and processes associated with P enhancement is clearly warranted.

Total N and extractable P appear to be conserved in the surface soil layer beneath Eucalyptus and Eucalyptus-Albizia plantations, a positive finding since these nutrients are those mostly likely to limit plant growth on many sites. Moreover, total N was significantly higher in soil in treatments involving Albizia than under pure, fertilized Eucalyptus stands.

Finally, any application of our findings should recognize that great diversity exists among climates and soils of tropical regions. Albizia grew very poorly, and provided no advantage in a companion test in the much drier Ka‘u District, some 80 km distant on Hawaii Island (DeBell et al. 1987). On the wet Hamakua coast of the same island, however, the benefits of establishing mixed Eucalyptus-Albizia plantations are impressive and perhaps can be obtained in similar environments elsewhere.

LITERATURE CITED


2 Unpublished report on file at Institute of Pacific Islands Forestry, Pacific Southwest Forest and Range Experiment Station, Honolulu, Hawaii.

74/ Forest Science


