Influence of Fertilizer on Early Growth of Saligna Eucalyptus in Hawaii

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In two separate studies, fertilizer applied at planting time increased height growth of saligna eucalyptus 127 to 500 percent during the 1st year. Formulations of 10-30-10 and 10-10-10 applied at rates of 28 and 56 grams had about the same beneficial effects on seedling growth.

Most forest soils in Hawaii are strongly acid and are low to very low in nitrogen, phosphorus, and potassium. These soils, although sometimes unable to support thrifty tree growth, often carry a dense growth of adapted competitors. Unless released from overtopping vegetation, tree seedlings may die or their growth rates may be reduced. The principal seedling release method in Hawaii is cutting with sickles and machetes. This method is not only expensive (about 12 cents per tree), but is also dangerous to people and trees alike. Even with release, however, tree seedlings may not grow rapidly because of low soil fertility.

Applying fertilizer at planting time may be a way to decrease establishment costs and increase yields. In South Africa, the number of weedings required in *Eucalyptus grandis* plantings was reduced from four to one by fertilizer, because of rapid canopy closure. Reduction in seedling maintenance cost resulted from faster tree growth and more than offset the cost of fertilization at the time of planting (*3*).

Fertilization probably offers more potential than some methods -such as improved site preparation and establishment techniques, manipulation of silvicultural regimes, crop protection, or use of superior genetic stock -for increasing wood fields (1). The net effect of early fertilization is to reduce rotation length by improving site index (*4*). With fertilization of *Eucalyptus grandis*, a species closely related to *E. saligna*, initial height growth was rapid, but thereafter the rate of height growth of fertilized trees was the same as that of unfertilized trees (*4*). The improvement in site quality decreased gradually over the life of the tree. The mean d.b.h. increases that resulted from fertilizing were maintained until harvesting (*2*). Under average conditions, fertilizing increases total timber yield, and the difference in yield between fertilized and unfertilized trees becomes greater up to at least 9 years, the age of *E. grandis* harvested in South Africa (*2*).

Saligna eucalyptus (Eucalyptus saligna Smith) is one of the most commonly planted tree species in Hawaii. It is grown on rotations of 5 to 7 years for pulp and fuelwood. Trees can potentially grow more than 30 meters tall in only 5 years (*6*). A 5-year-old plantation planted at 2.4 by 2.4 meters produced about 300 cubic meters per hectare (*5*).

A small-scale study was begun in April 1978 to determine the effects of fertilizer on the growth and development of field-planted saligna. This study, called site 1 in this article, indicated the potential benefit of fertilizer for early and rapid seedling growth. Using site 1 results, another study was begun in April 1979 (site 2) to determine the effects of fertilizer formulation and quantity on saligna growth and development. Although results of these preliminary studies do not indicate the optimum fertilizer formulations or application rates, they do indicate the potential benefit of fertilizer for decreasing seedling maintenance costs and rotation length.

Materials and Methods

The physiographic features of the planting sites on the northeast coast of the island of Hawaii are shown in table 1.

Site 1 was an eroded part of a pasture, without vegetation. Site 2 had previously been occupied by eucalyptus trees,

Table 1.—*Physiographic features of planting sites*

Feature	Site 1	Site 2
Elevation (m)	975	460
Aspect	NE	NE
Slope (%)	2	5-30
Rainfall (mm)	2,160	1,900
Soil	Silty clay loam	Silty clay loam
pH		
Topsoil	5.2	5.4
Subsoil	5.4	5.6
Phosphorus		
Topsoil	<30 kg/ha	<30 kglha
Subsoil	60 kgJha	70 kglha
Potassium		
Topsoil	100 kglha	120 kglha
Subsoil	120 kg/ha	150 kglha
Drainage	Good	Good

which were harvested several months before the study began. Weeds, principally popolo (Solanum SP.), joee *(Verbana* rigida), thimbleberry *(Rubus* rosaefolius), and Kikuyu grass (Penniseturn clandestinurn), were bulldozed several days before seedlings were planted. Sprouts on the eucalyptus stumps were broken off to prevent them from competing with the seedlings.

Saligna seedlings for both sites were grown at the Hawaii Division of Forestry Central Tree Nursery. These containerized seedlings were about 5 months old, about 30 centimeters tall, and fairly uniform in leaf area and stem diameter. After a planting hole was made, the container was slipped off and the roots were placed in the hole. At site 1, because much of the topsoil had eroded, the grubbing bar on the dibble had to be used to loosen the compacted soil before the planting hole could be made.

At site 1, 120 seedlings were planted in two rows, which ran across the contours. Spacing was about 1 meter within and 2 meters between rows. One row of seedlings was fertilized with about 56 grams of 10-30-10 granular fertilizer per tree. Fertilizer was poured in a hole made with a dibble about 10 centimeters from the seedling and then covered with soil. Fertilizer was not broadcast because phosphorus is immobile in the soil and most of it would have stayed on the surface or been lost to erosion. Fertilizer was not mixed in the soil to prevent the phosphorus from being chemically "fixed" by the soil.

At site 2, 480 seedlings were planted. Seedlings were planted in four blocks, each block containing six row-plots of 20 seedlings each. Spacing was about 2 by 2 meters.

The treatments tested at site 2 were fertilizer formulation (10-10-10 and 10-30-10) and quantity (0, 28, and 56 grams per tree) arranged factorially into six treatment combinations, each randomly assigned to a row-plot. As at site 1, fertilizer was poured into at hole made about 10 centimeters from the seedling.

The fertilizer application in these two experiments required 20 to 30 seconds per seedling. In an average day, about 1,000 seedlings can be fertilized. At an average field labor wage of about $40 per day, the labor cost for fertilizing would be about $0.04 per seedling or $67.20 per hectare (1,680 seedlings). The cost of fertilizer would be as shown in table 2.

Table 2.—*Cost of fertilizer*

	Cost per 1,000 seedlings		Cost per hectare at 1,680 seedlings/ha	
Fertilizer formulation	28-gram treatment	56-gram treatment	28-gram treatment	56-gram treatment
		Dollars		
10-10-10	9.00	18.00	15.12	30.24
10-30-10	12.00	24.00	20.16	40.32

Seedlings at both sites were examined at the time of planting and again after 1, 3, 6, and 12 months. Each seedling's stem height and diameter (breast height of trees 2 meters and taller) and vigor were determined. A seedling was rated as having high vigor if its terminal was active and at least 75 percent of its leaves were healthy. Average weed height was determined in areas around each block at the same time seedling examinations were made.

At site 1, stem height comparisons between fertilized and unfertilized seedlings were made using Student's t-distribution for unequal group sizes. At site 2, stem height and diameter data were subjected to factorial analyses of variance. Significant differences were examined by the Student-Newman-Kuels test.

Table 3.—*Survival, stem height, diameter, and vigor of saligna eucalyptus seedlings 1 year after treatment with fertilizers at sites 1 and 2*

Treatment	Survival	Stem height		Stem diameter		High vigor
		Average	Range	Average	Range	
	Percent	*- - - Meters - - -*		*- Centimeters -*		*Percent*
		Site 1				
Unfertilized	87	0.4a[1]	0.2-0.9	—[2]	—	35
10-30-10 56 g	85	2.0b	0.9-3.5	—	—	98
		Site 2				
Unfertilized (site 1)	94	3.4a	0.8-5.8	3.3a[3]	0.5-5.8	95
10-10-10 28 g	94	4.5b	1.5-6.2	4.0b	1.0-5.8	99
10-10-10 56 g	96	4.0b	1.5-6.3	3.7b	1.5-5.6	95
Unfertilized (site 2)	96	3.5a	0.9-5.4	3.2a	1.3-5.8	99
10-30-10 28 g	93	4.5b	2.4-5.8	3.9b	1.5-5.6	99
10-30-10 56 g	94	4.4b	1.7-5.7	4.2b	1.3-5.8	98

[1] Figures under stem height followed by the same letter are not significantly different at the 1-percent probability level.

[2] – = data not available.

[3] Figures under stem diameter followed by the same letter are not significantly different at the 5-percent probability level.

Results

Survival. Survival of seedlings at both sites was good, with or without fertilizer (table *3).* Survival of control (unfertilized) seedlings at site 1 was 2 percent higher than that of the fertilized seedlings. At site 2, survival of the fertilized seedlings varied only 1 or 2 percent from that of the control seedlings.

Placing granular fertilizer in a hole about 10 centimeters from the roots is apparently a safe method of application.

Stem Height. At site 1, after 1 year, the seedlings fertilized with 56 grams of 10-30-10 averaged about 2 meters in height, more than 5 times taller than the unfertilized seedlings (table 3). Weed competition was not a factor on the bare, eroded soil.

At site 2, fertilized seedlings began growing sooner after planting than unfertilized seedlings. After 3 months, the fertilized trees were an average of about 0.8 meter tall. This was several centimeters taller than the weeds and about 0.3 meter taller than the unfertilized trees (fig. 1). Differences between stem heights for fertilized and unfertilized trees were significant (0.01 level). Fertilizer formulation and amount were not factors, as stem height differences between these treatments were not statistically significant at the 5-percent level. Only about 40 percent of the fertilized seedlings were the same height or shorter than surrounding weeds, compared to about 85 percent of unfertilized seedlings.

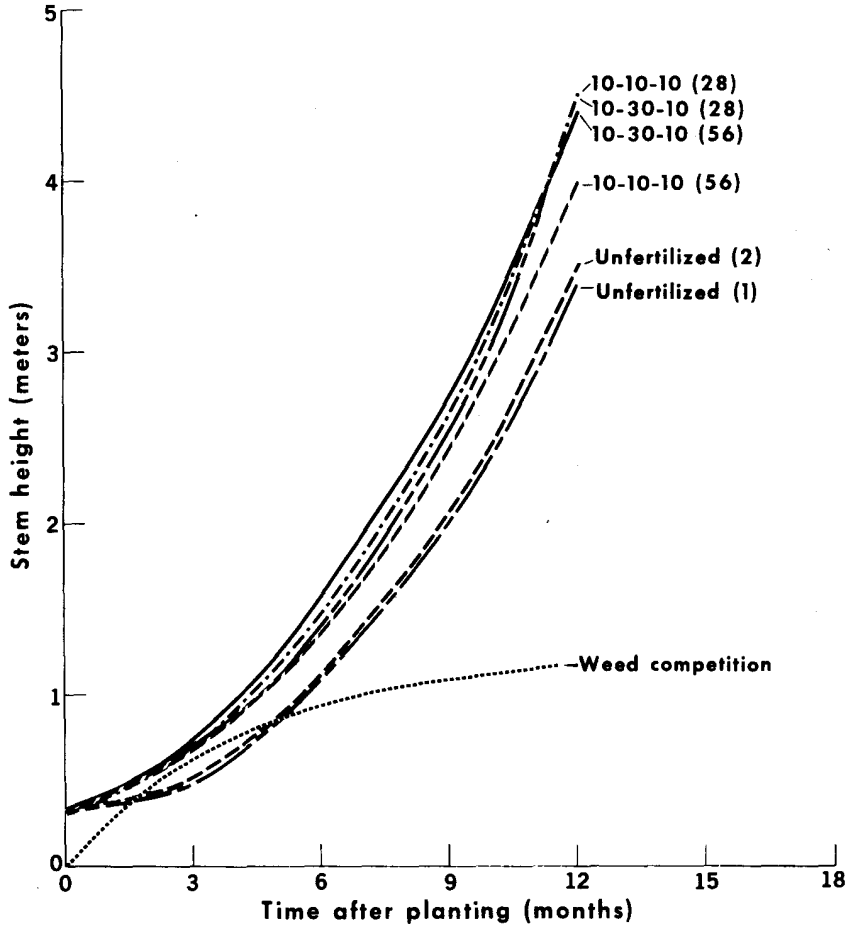

Figure 1.—*Cumulative height growth of saligna eucalyptus for treatment with fertilizer in two formulations and at three levels and comparative height of weed competition.*

After 6 months, the fertilized trees averaged about 1.5 meters tall, compared to 1.1 meters for the unfertilized trees. Again, fertilizer application made a significant difference in stem height, but neither the amount nor the formulation of fertilizer applied made any difference. All the fertilized trees and about 85 percent of the unfertilized trees were taller than the weeds.

After 12 months, fertilized trees averaged about 4.3 meters tall and unfertilized trees about 3.4 meters (table 3). All the trees were taller than the weeds.

Stem diameter. After 1 year at site 1, about 20 percent of the fertilized and none of the unfertilized trees were tall enough to determine d.b.h. After 1 year at site 2, an average of about 97.5 percent of the fertilized trees were tall enough to determine d.b.h. and an average of 91 percent of the control seedlings were tall enough. The d.b.h. of fertilized trees averaged about 4.0 centimeters, significantly greater (0.05 level) than the 3.3 centimeter average of the control trees. As for stem height, d.b.h. differences between fertilizer treatments were not statistically significant (0.05 level).

Vigor. Vigor is an indication of the plant's present condition and its growth potential. At site 1, the beneficial effects of fertilizer were still apparent after 1 year; only 35 percent of the unfertilized trees had high vigor, compared to 98 percent of the fertilized trees. In the future, because of the low percentage of vigorous trees, the growth rate of unfertilized trees will probably continue to be slow while the growth rate of fertilized trees, because of the

high percentage of vigorous trees, will continue to be rapid.

At site 2, because 95 percent or more of the fertilized and unfertilized trees had high vigor, the present growth rates will probably continue.

Management Implications

In these studies, as in South Africa (3) the seedling maintenance cost reduction resulting from faster tree growth more than offset the cost of fertilization at the time of planting (table 4).

Table 4.—*Establishment costs for fertilized and unfertilized saligna eucalyptus seedlings at site 2*

Cost item	Cost per hectare, unfertilized trees	Cost per hectare, fertilized trees
	Dollars	
Maintenance Fertilization	162.79[1]	76.56[2]
Labor	0	67.20[3]
Fertilizer	0	15.12
Total	162.79	158.88

[1] Basis: 1,680 seedlings per hectare x 95 percent survival = 1,596 per hectare x 85 percent seedlings requiring maintenance 3 months after planting = 1,357 x $0.12 maintenance cost per seedling.

[2] Basis: 1,598 seedlings surviving x 40 percent seedlings requiring maintenance 3 months after planting = 638 x $0.12 maintenance cost per seedling.

[3] Basis: 1,880 seedlings x $0.04 labor cost per seedling and $0.009 fertilizer cost (10-10-10 applied at 28 g per seedling).

The long-term effect of fertilizer on saligna timber yields on these and similar sites remains to be determined. The work done in New Zealand (1, 4) and South Africa (3) suggests, however, that the application of fertilizer at the time of planting will result in an increased timber yield.

Because of the reduction in seedling maintenance costs and the potential for increased timber yields, saligna seedlings should be fertilized at time of planting. Further research is needed to determine yield curves resulting from different fertilizer formulations and application rates on the principal sites where saligna is grown.

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