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PROJECT: EUCALYPTUS PLANTATIONS FOR ENERGY PRODUCTION IN HAWAII

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SUMMARY

In 1980 BioEnergy Development Corporation planted 200 acres of eucalyptus trees for a research and development biomass energy plantation bringing the total area under cultivation to 300 acres. Of this total acreage, 90 acres or 30% was planted in experimental plots. The remaining 70% of the cultivated area was closely monitored to determine the economic cost/benefit ratio of large scale biomass energy production.

In the large scale plantings, BioEnergy has set up standard field practices for all phases of production: nursery, clearing, planting, weed control and fertilization. These practices were constantly evaluated for potential improvements in efficiency and reduced cost. Promising experimental treatments were implemented on a large scale to test their effectiveness under field production conditions.

In the experimental areas all scheduled data collection in 1980 has been completed and most measurements have been keypunched and analyzed with the Statistical Analysis Systems (SAS) programs on the University of Hawaii IBM 370 computer. Soil samples and leaf samples have been analyzed for nutrient concentrations. Crop logging procedures have been set up to monitor tree growth through plant tissue analysis.

An intensive computer search on biomass, nursery practices, harvesting equipment and herbicide applications has been completed through the services of the U. S. Forest Service.

INTRODUCTION

There exists in Hawaii an urgent need for additional domestic energy sources to reduce dependence on imported oil. In 1978, more than 12 million barrels of residual fuel were used in the State of Hawaii to produce electricity, process steam, and other forms of energy.

Historically, sugarcane factories have burned bagasse (the plant fibre remaining after sugarcane is processed) to produce electricity and steam for internal energy needs. Any excess power was sold to local utility companies.

Recently, a number of sugarcane factories have formally contracted to supply electricity to public utilities on a regular basis. In 1978, approximately 38% of the electrical power sold on the Island of Hawaii (about 150 million kilowatt-hours) was supplied by sugar companies. Since these companies currently must supplement their bagasse with fuel oil in order to meet their contract quota of kilowatt-hours, they are interested in alternative fuel sources. C. Brewer and Company, Limited is currently spending nearly $2 million annually for this supplemental oil.

One promising source of alternative fuel is wood fibre supplied from fast-growing, commercially-managed forests. The U. S. Forest Service and the State Division of Forestry have classified approximately one million acres in Hawaii as commercial forest lands. The largest block of such lands is located on Hawaii Island, but each major island has significant potential for forest development (Table 1).

Hawaii, with its year-round growing climate, provides an ideal environment for biomass production. In particular Australian eucalyptus, world

Table 1. Commercial forest land in the State of Hawaii.

Island	Commercial Forest Lands (Acres)
Hawaii	710,000
Maui	120,000
Molokai	24,000
Lanai	2,200
Oahu	97,000
Kauai	137,000
	1,090,000

renown for its high fuel value and rapid growth rate, grows well on most sites in the State. As energy plantations, eucalyptus tree farms can help relieve Hawaii of its petroleum dependency.

In 1978 C. Brewer and Company, Limited and the USDA Forest Service prepared a research and development proposal to explore production of biomass energy from eucalyptus trees on Hawaii Island. This proposal was accepted for funding by the U. S. Department of Energy.

Annually renewable federal grants are matched with contributions of land, equipment, roads, generating facilities and managerial resources from C. Brewer. Silvicultural and economic expertise and other technical assistance are provided by the Institute of Pacific Islands Forestry, a research unit of the U. S. Forest Service.

Early in 1979 C. Brewer formed BioEnergy Development Corporation to conduct the research and development project. Together with the Institute of Pacific Islands Forestry, BioEnergy Development Corporation has embarked on one of the largest forestry research and development projects directed at biomass fuel production in the United States.

The objective of BioEnergy's project is to answer eight broad questions:

1. How do different sites, cutting cycles, spacings and intensive cultural practices affect the growth, yield, rotation, length and profitability of short-rotation eucalyptus investments?
2. What are the relative cost/benefits of growing pure stands of eucalyptus with various fertilizers vs. admixtures of eucalyptus with nitrogen fixing species on different sites?
3. Will crop logging (monitoring growth periodically with chemical and physical tests) provide guidelines to produce maximum yields?

4. Can genetically superior eucalyptus planting stock be identified and mass-produced within a short time frame through phenotypic selection in seed orchards?
5. Which species of eucalyptus will prove best adapted on planting sites differing greatly in elevation, rainfall and soil properties?
6. Can existing equipment be modified at minimal cost to plant and cultivate eucalyptus seedlings and to haul wood fibre to generating plants?
7. To what extent do soil and terrain conditions limit acreage in large-scale commercial forest operations on company lands?
8. What is the optimum mixture of eucalyptus wood chips and other biomass fuel sources?

BioEnergy's project will span a 5 year period and 900 acres (700 acres along the Hamakua cost and 200 acres in Ka'u). In 1980,200 acres of eucalyptus trees were planted, bringing the total acreage under cultivation to 300 acres.

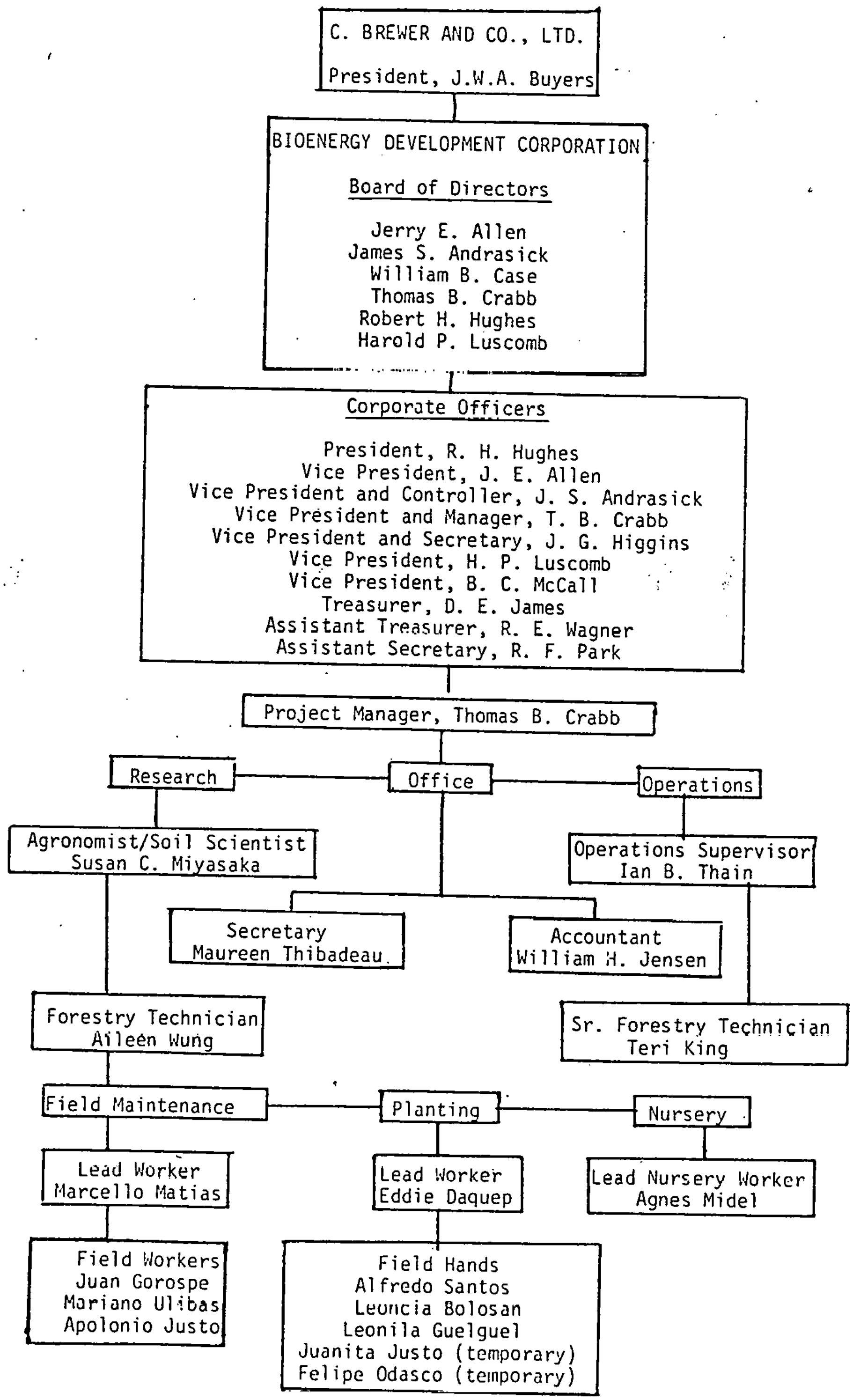
Eucalyptus seedlings are raised at BioEnergy's nursery in Wainaku which has an annual capacity of more than 450,000 seedlings. The seedlings are outplanted at 5 x 5 foot intervals and annual per acre yields of 10 tons dry weight of wood fibre is the production objective.

Once trees reach a harvestable size (50-60 feet in height) after 5 to 7 years, they will be chipped and used as supplemental boiler fuel to produce steam at two nearby sugar plantation power plants. These plants already produce steam-generated electricity from sugarcane bagasse with oil as a supplemental fuel and power is sold to the local public utility company.

Economic impacts are evaluated at every level of the project. Cost accounting is strictly adhered to by BioEnergy and economic data recorded to accurately gauge the cost/benefit ratio of large scale biomass energy production. There must be a net energy gain and a net financial savings relative to the cost of fuel oil for the project to be judged successful.

BioEnergy Development Corporation is staffed with a project manager, an accountant, a secretary, an operations supervisor, an agronomist/soil scientist, 2 forestry technicians, 2 nursery workers, 6 field hands and 4 field workers. See Table 2 for further details.

Table 2. BioEnergy Organization Chart



THE 1980 ACTIVITY SCHEDULE

All project activities in 1980 were on schedule, with one exception in the area of seed orchard establishment (Table 3). The activity blockage here is due to the need to improve vegetative propagation methods in order to clone superior eucalyptus trees. Work on vegetative propagation will continue into 1981.

MAJOR MILESTONES

Research Program	Installation of major experiments in species and herbicide screening, spacing, fertilizer requirements, legume admixtures, other intensive cultural practices and nursery practices completed. Data collection on schedule and results analyzed on IBM 370 computer with SAS programs.
Weed Control	Herbicide screening trials have identified promising treatments that are being applied on a partial field scale. Initial weed control schedules formulated and applied, using aircraft, tractors, and backpack sprayers.
Crop Control	Foliar analysis from fertilizer experiments used as guidelines for monitoring tree growth. Crop logging schedules formulated.
Nursery	Two fully automated propagation houses and outside hardening areas completed and 600,000 seedlings produced. Promising treatments identified in nursery fertilizer experiments were implemented in production practices.

Propagation Methods	Seed propagation used primarily. Vegetative propagation methods being investigated.
Phenotypic Selection	Cooperative effort with Dr. James King, U. S. Forest Service Geneticist. Four major provenance trials installed.
Land Appraisals	Preliminary study completed with updating in progress. Environmental assessment completed on 341-acres Conservation-zoned land parcel in Amauulu mauka.
General Fuel Mix	Cooperative effort with Hilo Coast Processing Company. Preliminary trial run with Capitol Woodchip Company discard material.
Handling and Generators	Ongoing discussions with Hilo Coast Processing Company.

Table 3. Project Tracking Sheet for 1980

ACTIVITY (P = planned, A = actual)		1979	1980	1981	1982	1983
A. SILVICULTURE						
1. Select planting areas	P	├──→				
	A	├────	──→			
2. Intensive cultivation practices and cost analyses	P	├────	────	────	────	──→
	A	├────	──→			
3. Develop and appraise crop-log standards	P	├────	────	────	────	──→
	A		├──→			
4. Vegetative propagation methods	P	├────	────	──→		
	A		├──→			
5. Phenotypic selection in local stands	P	├────	────	──→		
	A	├────	──→			
6. Establish four eucalyptus seed orchards	P	├────	────	──→		
	A					
7. Provenance trials for three species	P		├────	────	────	──→
	A	├────	──→			
8. BTU and wood density variations	P					
	A					├──→
B. ENGINEERING						
1. Equipment modification and evaluation	P	├────	──→			
	A		├──→			
2. Biomass mixes	P			├──→		
	A		├──→			
3. Evaluation of equipment alternatives	P					├──→
	A					
C. ECONOMICS						
1. Market investigations	P			├────	──→	
	A					
2. Economic feasibility studies	P				├──→	
	A					
D. COMBINED AND OTHER						
1. Site preparation and cost analyses (200 ac./yr.)	P	├────	────	────	────	──→
	A	├────	──→			
2. Land use capability appraisals	P	├────	──→			
	A	├────	──→			
3. Establish tree nursery and propagation facility	P	├──→				
	A	├──→				
4. Annual progress report	P	├→	├→	├→	├→	├→
	A	├→	├→			
5. Dissemination of results	P		├──	────	────	──→
	A		├──→			
6. Energy plantation management plan	P				├──→	
	A					
7. Complete field measurements and final reports	P					├──→
	A					

SITE DESCRIPTION

Hamakua Coast

There are four separate planting sites along the Hamakua Coast: Akaka Falls, Onomea, Kamae, and Amauulu. Table 4 presents the summarized data on soil pH and available soil nutrients.

Akaka Falls

The 26-acre (10.5 ha) planting site at Akaka Falls is located at 1600 feet (480 m) in elevation. Annual rainfall is 200 inches (5,080 mm) distributed fairly evenly throughout the year. The soil series is the Akaka silty clay loam, and slopes range from 10 to 20 percent.

The Akaka Falls site is on abandoned cane land that had been prepared for taro production with addition of 2 T/A (4.5 mT/ha) of crushed coral (92% $CaCO_3$). The soil is medium acid (pH 5.7 to 6.0) and the level of calcium is moderately high at 810 ppm at the 18-24" (46-61 cm) depth.

Onomea

The 22-acre (9 ha) planting site at Onomea is located at 1400 feet (420 m) in elevation. Annual rainfall is 200 inches (5,080 mm) distributed fairly evenly throughout the year. The soil series is the Akaka silty clay loam, and slopes range from 10 to 20 percent.

The Onomea site is on abandoned cane land, and the soil is very strongly acid (pH 4.8 to 5.0) with a low level of calcium at 35 ppm at the 18-24" (46-61 cm) depth.

Kamae

The 170-acre (69 ha) planting site at Kamae is located at 1600 feet (480 m) in elevation. Annual rainfall is 200 inches (5,080 mm) distributed

Table 4. Soil and pH and Soil Nutrient Analysis for BioEnergy's Different Planting Sites.

Field	Depth	N,ppm	P,ppm	K,ppm	Ca,ppm	Mg,ppm	pH
Akaka Falls	0-6"	3,730	7	39	197	39	5.7
	18-24"	4,001	7	50	810	83	6.0
Onomea	0-6"	6,736	6	48	103	112	4.8
	18-24"	3,760	5	50	35	26	5.0
Kamae	0-6"	6,845	18	52	64	37	5.0
	18-24"	4,701	10	43	40	13	5.1
Amauulu (A)	0-6"	4,320	3	83	500	174	6.1
	18-24"	2,936	4	35	89	24	5.4
Amauulu (B)	0-6"	6,736	6	48	103	112	4.8
	18-24"	3,760	5	30	35	26	5.0
Ka'u (Kiloa soil series)	0-6"	4,093	201	110	510	156	5.6
	12-18"	3,582	140	91	696	156	5.7
Ka'u (Alapai soil series)	0-6"	6,507	104	112	792	201	5.7
	12-18"	3,426	77	57	894	208	5.9

fairly evenly throughout the year. The soil series is the Akaka silty clay loam, and slopes range from 10 to 20 percent.

The Kamae site is principally on abandoned cane land with some areas classified as wasteland since they were unsuitable for cane production. The soil is very strongly acid (pH 5.0 to 5.1) and the level of calcium is low at 40 to 64 ppm.

Amauulu

The 28-acre (11 ha) planting site at Amauulu is located at 1600 feet (480 m) in elevation. Annual rainfall is 200 inches (5,080 mm) distributed fairly evenly throughout the year. The soil series is the Kaiwiki silty clay loam, and slopes range from 4 to 20 percent.

The Amauulu site is on an abandoned pasture (wasteland). Location A had been prepared for taro production with the addition of a 4 T/A (9 mT/ha) of crushed coral (92% $CaCO_3$), while location B had never been in agricultural crop production. The soil at location A is slightly acid (pH 6.1), while location B is very strongly acid (pH 4.8 to 5.0). Levels of soil calcium are moderately high at location A (500 ppm) and low at location B (26-112 ppm).

Ka'u

The 65-acre (26 ha) planting site at Ninole Valley in Ka'u is located at 1800 feet (540 m) in elevation. Annual rainfall is 100 inches (2,540 mm) with a dry season from August to September. There are two soil series: the Kiloa extremely stony muck and the Alapai extremely stony silty clay loam. Slopes range from 6 to 20 percent.

Table 4 presents summarized information on soil pH and available soil nutrients. The Ka'u site is on recently abandoned cane land that had been in cane production for only 25 years. Compared to the Hamakua sites, the Ka'u site is on a younger soil with moderately high levels of phosphorus, potassium, calcium, and magnesium.

FIELD OPERATIONS

After two years in operation, BioEnergy Development Corporation has set up standard field practices for all phases of production: nursery, clearing, planting, weed control, and fertilization. These practices are being constantly evaluated for potential reductions in cost and increases in efficiency, yield and employee safety. Mechanization, in particular, is being looked at for future operating improvements.

Nursery

Eucalyptus seedlings are grown in plastic dibble tubes called "Ray Leach Cone-tainers".[1] Raising containerized stock is a convenient, economical way to grow large numbers of seedlings with minimal root damage at time of ourplanting. The "Ray Leach Cone-tainers" are ribbed on the interior, and this prevents circling of the roots with subsequent stangulation or "J" - rooting.

The seedlings are removed from the containers shortly before planting and the containers are recycled after sterilization with a 10% chlorox solution. The potting media used is a 2:1 mix of vermiculite and peat moss. Osmocote[1] (14-14-14), dolomite, and MicroMax[1] (a source of micronutrients) are mixed thoroughly into the media by hand.

The media is settled into the containers manually and a plexiglass compactor plate is used to press down the media to make a seed bed for the eucalyptus seed. Mixed seed and chaff are sown by hand and then covered lightly with fine gravel.

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The racks of tubes are placed in the greenhouse where the eucalytus seedlings germinate in 5 to 7 days. Thinning is done at the stage of two pairs of true leaves, which is about 3 to 4 weeks after sowing. Any required transplanting is also done at this time.

The seedlings are moved from the greenhouse to the hardening area when they are 3 to 4 inches in height, or 4 to 6 weeks after sowing. Depending on the size of the container, the plants are ready for outplanting at 10 weeks to 4 months after sowing, when they are 12-15 inches (30-38 cm) tall.

Fungicides and insecticides are not necessary in Hawaii for the cultivation of eucalyptus seedlings. Occasionally, aphids or Japanese rose beetles become a problem, and diazinon or malathion are used for control. Damping off only becomes a problem when the plants are watered too frequently, and thus timing of irrigation is sufficient control of this fungal problem.

BioEnergy's nursery consists of two greenhouses capable of holding 50,000 seedlings each, and the outdoor hardening area which has the capacity of 64,000 seedlings. With a rotation of 3 to 4 months, the nursery is capable of producing 450,000 seedlings per year, a number more than adequate to plant 200 acres per year at a 5 x 5 foot spacing.

The nursery staff is composed of two hourly paid employees, who carry out all phases of nursery operations. Economic data has been carefully monitored and BioEnergy's current nursery practices will produce eucalyptus seedlings for $36 per thousand in "pine cell" containers (Table 5). One possible area for cost reduction is the potting media used. A less expensive mix or removing the media prior to planting (Meskiman 1973) would reduce seedling costs considerably.

Ongoing research in the nursery is examining the effect of different container sizes as well as the effect of different types of slow release

Table 5. Seedling Costs per Thousand for Three Container Sizes.

	Container Size		
Materials	Super	Stubbie	Pine
1. Media	$ 17.78	$ 12.31	$ 7.28
2. Fertilizer	1.02	0.69	0.33
3. Water	4.88	4.88	4.88
Labor			
4. Seed Collection	$ 1.96	$ 1.96	$ 1.96
5. Sowing	7.94	7.78	5.83
6. Thinning/ Transplanting	5.95	5.83	5.83
Fixed Costs			
7. Grennhouse	$ 4.00	$ 4.00	$ 4.00
8. Containers	7.40	7.20	6.07
TOTAL	$ 50.93	$ 44.65	$36.18

These costs are based on:

1. 2:1 vermiculite to peat mix.
2. Osmocote 14-14-14 at 1040 g/batch, dolomite at 700 g/batch and MicroMax at 200 g/batch. One batch of media fills about 2600 stubbies or 1760 supers or 5400 pine cells.
3. Monthly water bill.
4. Seed collection at Waiakea Forest Reserve. Estimated 40,000 seedlings per kg after germination and thinning.
5. Sixteen man-hours to sow 3 tables (7,056 cells) of supers, or 3 tables (7,200 cells) of stubbies or 4 tables (9,600 cells) of pine cells.
6. Ten minutes per tray for thinning and transplanting (98 cells for supers, 100 cells for pine cells and stubbies).
7. Costs of greenhouse facilities averaged over a 10-year life span - $18,000
8. Costs of containers averaged over a 5 year period, with containers reused 20 times.

fertilizer on seedling growth in the nursery and field. Future research will focus on the effect of different types of media on seedling growth, and the possible use of pelletized seed to reduce the number of seed sown per container. Pelletized seed has the potential to reduce the amount of purchased seed as well as reduce the need for thinning.

Clearing

The planting sites can be classified into 3 main groups: abandoned cane land; wasteland and forest. Along the Hamakua coast, the abandoned cane land is bulldozed clear of vegetation and harrowed. In Ka'u, the abandoned cane land is simply crushed down with a Krajewski roller to form a mat of vegetation. At both locations, Roundup[1] is applied twice prior to planting, with the first shot at 0.75 gal/A and the second shot at 0.50 gal/A.

The wasteland classification consists of areas either in cane or abandoned long ago. The brush is bulldozed and windrowed, then two applications of Roundup[1] are made prior to planting at the same rates as on abandoned cane land.

In forested areas, any commercially harvestable trees will probably be removed prior to bulldozing and windrowing of the vegetation. Two shots of Roundup will be applied before planting.

Clearing abandoned cane land takes about 3 tractor-hours, or 1 hour each for two tractor passes over the area plus 1 hour for Soil Conservation ditch maintenance work. At $80 per hour to rent a D-6 tractor, costs will be about $240 per acre for abandoned cane land.

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Wasteland takes about 6 tractor-hours per acre or $480 per acre. Forested areas are being budgeted at 15 tractor-hours per acre or $1200 per acre.

The cost of two Roundup applications prior to planting is $118 per acre for materials and application. Since Roundup costs $60 a gallon, the first application costs $46 per acre and the second $30 per acre for materials. Rental of the broadcast tractor (D-4) at $42 per hour results in costs per acre of $21 for each application since the tractor covers 2 acres per hour. See Table 6 for an outline of estimated plantation establishment costs, and Table 7 for actual plantation costs.

Clearing costs are being closely monitored with the objective of reducing costs where possible. Ongoing research is examining different herbicide mixes which may be used as less expensive substitutions for Roundup. Future research needs will be to continue to look for different clearing machinery or methods which could lead to reduced costs.

Planting

The 3 to 4 month-old seedlings from the nursery are outplanted manually at 5 x 5 foot spacings (1.5 m x 1.5 m). The 6-person planting crew works in pairs, with one person using a metal or wooden dibble to open a hole, and the other following behind to place a seedling in the hole then covering it.

BioEnergy's 6-person planting crew can plant 600 trees per man-day along the Hamakua coast and 300 trees per man-day in Ka'u where the ground is rocky. At 1742 trees per acre (5 x 5 foot spacing), the 6-person crew can plant 2 acres per day along the Hamakua coast or 1 acre per day in Ka'u. At a wage rate of $4.06 per hour, this amounts to planting costs of $98 per acre in Hamakua and $195 per acre in Ka'u (Tables 6, 7).

Table 6. Estimated Plantation Establishment Costs for a Eucalyptus Biomass Planting Along the Hamakua Coast on Abandoned Cane Land.

Nursery	Costs, $/A
Seedling Stock	$ 70.00
Clearing	
Tractor (D-6)	$ 240.00
Two Roundup applications	$ 118.00
Planting	
Hamakua	$ 98.00
Weed Control	
Sickling	$ 60.00
Paraquat-Simazine application	$ 46.00
Fertilizer	
DC-153 (4oz. applied twice)	$ 136.00
Application	$ 130.00
TOTAL	$ 898.00

Table 7. Per Acre Costs of BioEnergy Fields Under Cultivation as of December 31, 1980.[1]

Field	Classification	Acres	Clearing	Planting	Replanting	Fertilizer	Weed Control	Total
Ka'u 780	Cane land	15	272.09	97.61	69.61	231.87	662.22	1333.41
Ka'u 755	Cane land	41.5	200.55	269.96	10.18	247.89	104.31	832.89
Ka'u 765	Cane land	46	341.97	-	-	-	-	341.97
Amauulu	Waste land	23	658.30	89.85	-	122.77	.67	871.60
Onomea V05A	Cane land	20.3	151.80	70.10	2.44	203.42	310.84	738.60
Onomea V09A	Cane land	2.4	235.03	83.52	-	143.11	141.64	603.30
Akaka 54C	Cane land	24.4	182.81	62.69	20.77	213.16	489.41	968.84
Kamae 25A	Cane land	47.7	219.25	93.70	-	145.30	102.80	561.05
Kamae 25B	Cane land	28.6	347.99	60.17	-	134.00	88.56	630.72
Kamae 26A	Cane land	66.1	207.36	103.32	9.16	238.45	205.53	763.81
Kamae 26B	Cane land	9	280.80	102.06	-	104.38	-	487.24
Kamae 27C	Cane land	17.1	173.62	-	-	-	-	173.62
Kamae 27D	Cane land	20.5	143.78	95.53	2.56	232.39	90.65	564.91

[1]The costs for clearing, planting, fertilizing and weed control vary depending on the number of tractor passes, the number of fertilizer and weed control applications, and the type of equipment used.

Future research will look at increasing the efficiency of planting through improved manual tools or mechanization. BioEnergy is planning to borrow a mechanized transplanter from the Hawaii State Division of Forestry to try along the Hamakua coast.

The advantages and disadvantages of mechanized planting need to be evaluated. Potential problems are the initial cost of investment, the higher costs of tractor rental, and the limitations due to terrain and weather conditions.

Weed Control

Weed control begins with two Roundup applications prior to planting. Roundup has no residual effect, so that 2 to 3 months after outplanting, the fields are again filled with weeds competing with the eucalyptus seedlings for sunlight and nutrients.

In the past, sickling was done to prevent shading of the trees, but the effect was very short-term, sometimes less than a month. Sickling costs depend on the density of weed growth, but it can run up to $60 per acre or 15 man-hours per acre.

BioEnergy is currently experimenting with pre-emergent herbicides that can be applied as a preplanting treatment, either separately or combined with the Roundup application. Pre-emergent herbicides will control the seeding grasses and broad leaf weeds for up to 3 to 4 months. The most promising pre-emergent herbicide tested to date is Simazine.[1]

BioEnergy has also begun testing post-planting herbicide treatments. The rhizomatous grasses are spot-sprayed with Round up, and then after 4 weeks

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a mixture of Paraquat[1]-Simazine is sprayed over the entire area. The cost of applying Paraquat-Simazine is about $46 per acre (Table 6), including labor. Twenty acres along the Hamakua coast have been treated this way and the effectiveness of these post-planting herbicide treatments is being carefully monitored.

In Ka'u, the mat of crushed cane serves as an effective mulch that reduces weed problems considerably. Currently, the major weed problem is controlling cane regrowth, but this is a minor problem after two Roundup applications.

Ongoing weed control research at BioEnergy is a continuous screening of herbicides for pre-emergent and post-emergent activity combined with minor phytoxicity towards eucalyptus. Future research will include additional herbicide evaluation as well as determining the most effective methods of application. The dangers of Paraquat are recognized, and less dangerous contact poisons will be tested in 1981.

Fertilizer and Crop Logging

The trees are fertilized immediately after planting and 6 months later. Metal or wooden dibbles are used to bury 4 ounces (113 g) of DC-153[1] (12-24-12) fertilizer about 6 inches away from the tree. Each fertilizer application takes about 2 man-days per acre, or at $4.06 per hour, $65 per acre.

During the first year of establishment, eucalyptus trees receive 104 lbs/A of nitrogen, 208 lbs/A of phosphorus, and 104 lbs/A of potassium. The cost of fertilizer in the first year is $136 per acre plus $130 per acre for application (Tables 6, 7).

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Crop logging, or monitoring tree growth through plant tissue analysis will be carried out through the entire cropping cycle. Data from the ongoing fertilizer experiments will be used as a guideline for establishing critical plant nutrient levels.

After the first year of plantation establishment, foliar analysis will be used to determine fertilizing schedules. BioEnergy is testing aerial application of A-4[1] fertilizer (25-0-27) at a rate of 50 lbs/A of nitrogen and 54 lbs/A of potassium. The cost of fertilizer is $28 per acre while the cost of application ranges from $2.44 - $6.07 per acre depending on area size and amounts applied.

Experiments along the Hamakua coast have shown that nitrogen is the primary limiting nutrient. The rate of nitrogen fertilization has been increased in a trial 15-acre planting. Two ounces of DC-141[1] (14-14-14) per tree were applied at planting, then four months later, 4 ounces of A-4 were applied. This method of fertilization results in 138 lbs/A of nitrogen, 30 lbs/A of phosphorus, and 148 lbs/A of potassium. Costs are $94 per acre for materials and $130 per acre for two hand applications.

In Ka'u, the level of available nitrogen, phosphorus, and potassium in the soil is much greater than along the Hamakua coast, perhaps due to the lower rainfall and less leaching. The trees appear very healthy and lower rates of fertilizer over the entire rotation will be required. The reduced cost of fertilization may more than compensate for the higher costs of planting.

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Ongoing research is being conducted to examine the effects of varying levels of nitrogen, phosphorus, and potassium on the growth of eucalyptus seedlings. Future research will focus attention on the possible merits of rock phosphate and liming. Further work also needs to be done on crop logging procedures, since the problems of leaf sampling increase proportionately with the height of the trees. Finally, more economical methods of fertilizer application need to be looked at to reduce man-hours required.

Harvesting

A computer search on harvesting equipment has been carried out by the Institute of Pacific Islands Forestry, and literature on this subject is being compiled. Also, all major harvesting equipment companies in the United States have been contacted for equipment specifications and recommendations. BioEnergy Development Corporation is looking to the U. S. Forest Service for technical expertise in this area. A visit by an equipment specialist is being examined for 1981 or 1982.

Economic Analysis

BioEnergy's accountant, W. H. Jensen, is recording all the economic data necessary to gauge the cost/benefit ratio of this biomass project. BioEnergy is working with the U. S. Forest Service to use Dr. George Dutrow's expertise on economic analysis. Dr. Dutrow (1971) has worked on the economics of the silage sycamore concept and he plans to visit BioEnergy's project in 1981 to help set up a computer program for economic analysis.

BUDGET

The budget for 1980 was $546,315 made up of $505,070 of new authorization plus a carry-over of $41,245 from 1979. Expenditures totaled $533,875 for an underexpenditure of $12,440.

This budget provided funds for the clearing and planting of 200 acres of trees plus maintenance on 100 acres planted in 1979. An access road into one new area was completed. Expenditures for administration, field supervision, research and nursery operations were generally on target. Expenditures on weed control exceeded budget by a considerable amount, but were offset by reduced expenditures for clearing new areas.

The budget and actual expenditures for 1980 are summarized below:

	Budget	Actual
Salaries and Wages	$ 179,760	$ 194,395
Payroll Benefits	38,940	45,893
Materials	68,970	114,149
Travel	11,600	6,843
Other - Contract Services Rentals, taxes, etc.	205,800	172,595
Carry Over from 1979	41,245	
Totals	$ 546,315	$ 533,875

EXPERIMENTS IN PROGRESS OR COMPLETED
Hamakua District Studies

Spacing Study at Akaka Falls

The objective of this spacing study is to determine the optimum spacing of *Eucalyptus saligna* for an intensive, short-rotation (5 to 7 years) biomass energy plantation along the Hamakua coast.

Materials and Methods

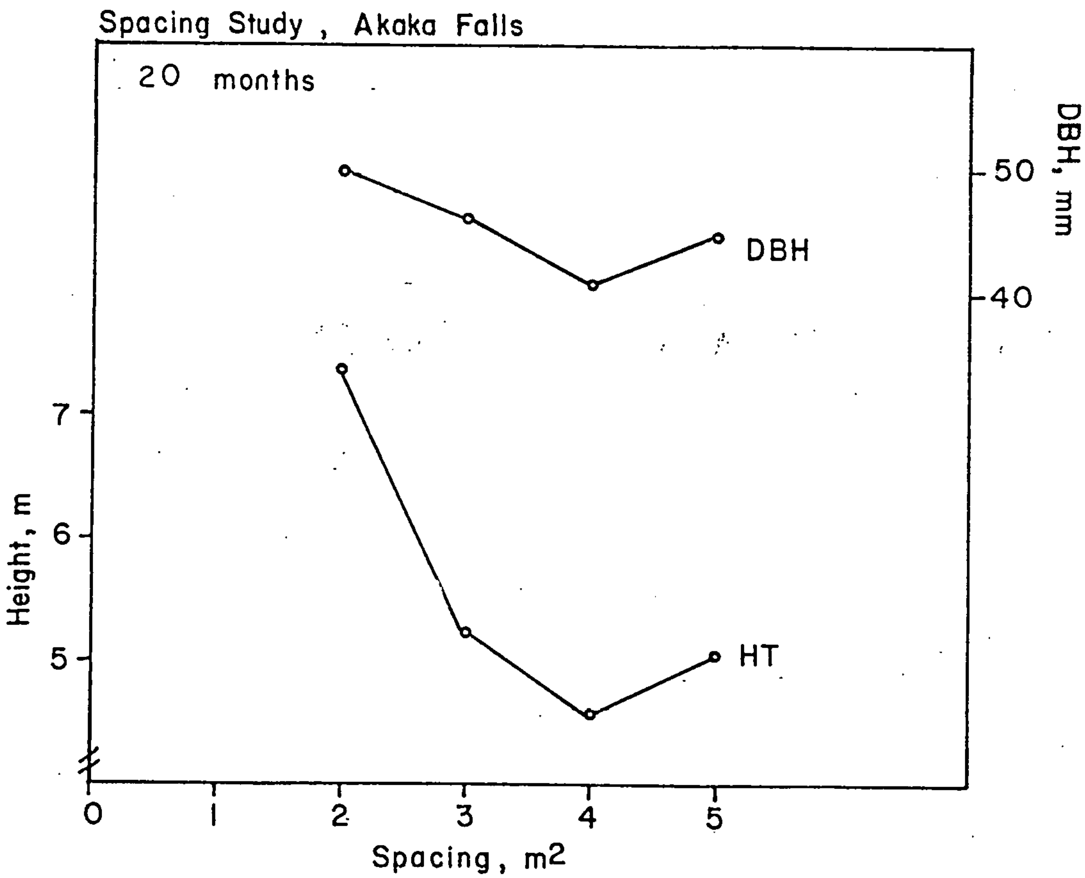
Eucalyptus saligna trees were outplanted at four different spacings in April, 1979. The spacings are: 1m x 2m, 2m x 2m, 2m x 2.5m, and 1.2m x 2.5m. This experiment follows a randomized complete block design with 4 treatments and 5 replicates.

Each plot is approximately 30m x 30m, with 496 trees at the closest spacing and 338, 256, and 208 trees at progressively wider spacings. The inner 49 trees were measured for height and diameter breast high (dbh), with border rows of 6 meters. Biomass equations will be generated in 1981 after 2 years of growth, and dry weight yields will be estimated per acre.

Results and Discussion

Increased tree density tended to result in increased tree height and diameter breast high at 6, 12, and 20 months after outplanting (Graph 1). Trees at the 1m x 2m spacing were significantly taller than trees at the two widest spacings (95% probability level), however their diameter breast high was not significantly different from the other treatments.

The greater heights at the closer spacings could be expected, due to competition for light. The diameters also tended to be greater at the closer spacings. This effect may be due to the early canopy closure at the closer spacings and subsequent decreased weed competition in these plots.



Graph 1. Tree height and diameter breast high of Eucalyptus saligna 20 months after outplanting at four different spacings along the Hamakua coast.

Fertilizer NP Trial at Akaka Falls

The objective of this experiment is to determine the optimum levels of nitrogen and phosphorus fertilizers for the establishment and growth of *E. saligna* along the Hamakua coast.

Materials and Methods

The *E. saligna* trees were outplanted in August, 1979 at a 1.5m x 1.5m spacing. This experiment has randomized complete block design with 16 treatments and 4 replicates. The 16 fertilizer treatments are a 4 x 4 factorial with 4 levels of nitrogen and 4 levels of phosphorus (Table 8).

The treatments were applied three times: at outplanting, 6 months, and 15 months later. During the first year, the four rates of nitrogen applied were 0, 98, 198, and 296 kg/ha. The four rates of phosphorus applied were 9, 116, 234, and 350 kg/ha in the first year (Table 8).

Each plot is 13.5m x 13.5m with 81 trees per plot. The inner 25 trees were measured with 2 border rows remaining.

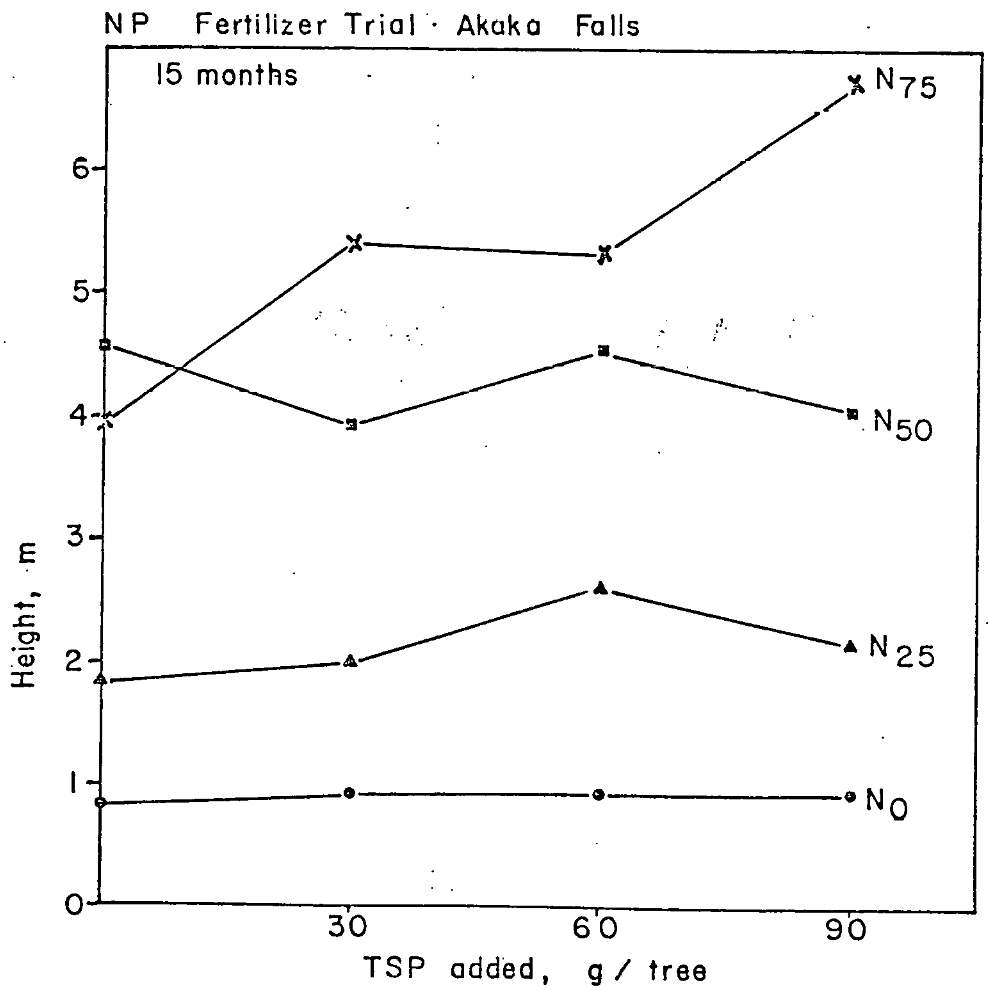
Results and Discussion

Nitrogen appears to be the primary limiting nutrient along the Hamakua coast. *Eucalyptus saligna* showed a tremendous positive growth response to the addition of urea (Graphs 2, 3). Height and diameter breast high at 3, 6, 9, 12, and 15 months after outplanting increased significantly (95% level) with increasing amounts of applied phosphorus, particularly at the highest level of nitrogen (Graphs 2, 3). The effect of phosphorus on tree height and diameter was significant (95% level) at 3, 6, and 9 months, however the effect was not significant at 12 and 15 months after outplanting.

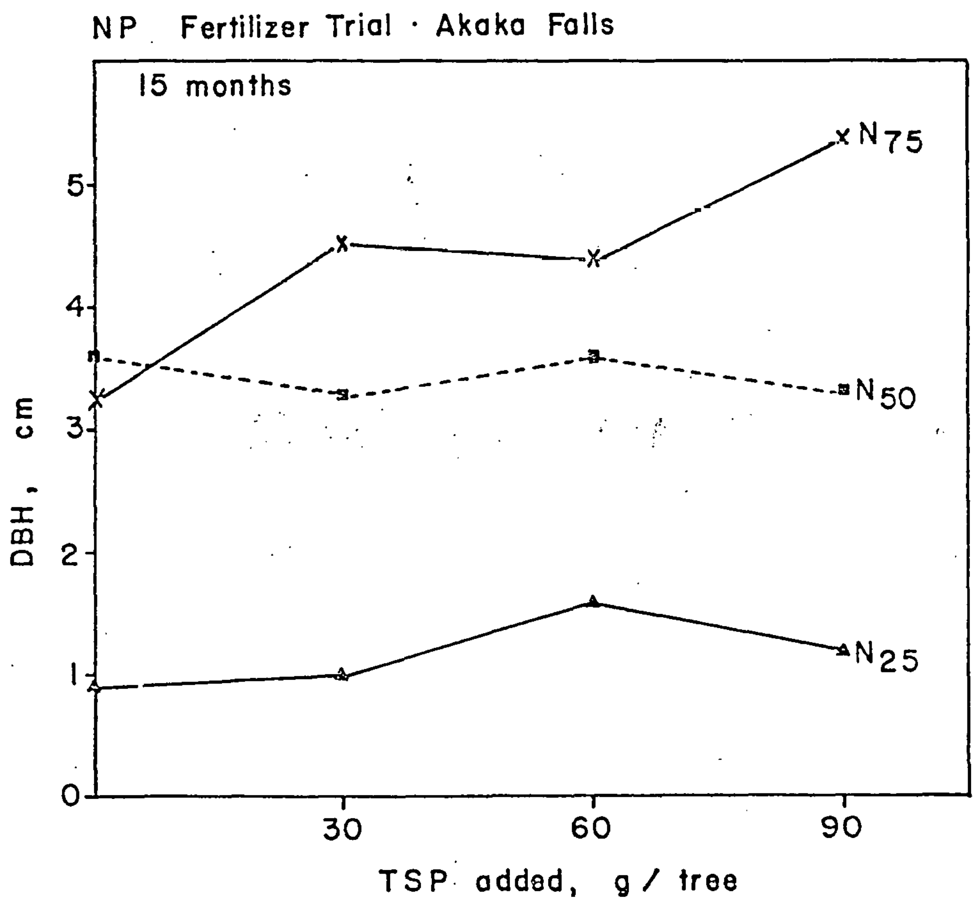
Interaction between nitrogen and phosphorus was also significant (95% level) at 3, 6, 9, 12, and 15 months. This interaction effect seemed to be due to a nitrogen threshold necessary for a phosphorus response.

Table 8. Rates and Costs per Hectare for One Application of the Fertilizer Treatments in the Fertilizer NP Trial at Akaka Falls

Treatment	Urea, g/tree	Tsp, g/tree	KCl, g/tree	N, kg/ha	P_2O_5 kg/ha	K_2O kg/ha	Cost, \$/ha	Cost, \$/A
1	0	0	30	0	0	129	29.26	11,84
2	0	30	30	0	58	129	71.46	28.92
3	0	60	30	0	117	129	113.64	45.99
4	0	90	30	0	175	129	155.82	63.06
5	25	0	30	49	0	129	56.39	22.82
6	25	30	30	49	58	129	98.57	39.89
7	25	60	30	49	117	129	140.75	56.96
8	25	90	30	49	175	129	182.95	74.04
9	50	0	30	99	0	129	83.50	33.74
10	50	30	30	99	58	129	125.70	50.87
11	50	60	30	99	117	129	167.88	67.94
12	50	90	30	99	175	129	210.04	85.00
13	75	0	30	148	0	129	110.63	44.77
14	75	30	30	148	58	129	152.81	61.84
15	75	60	30	148	117	129	194.99	78.91
16	75	90	30	148	178	129	237.09	95.98



Graph 2. Height of Eucalyptus saligna trees, 15 months after outplanting at 4 levels of urea (0, 25, 50, and 75 g/tree) and 4 levels of treble superphospate (0, 30, 60, and 90 g/tree).



Graph 3. Diameter breast high of Eucalyptus saligna trees 15 months after outplanting, at 4 levels of urea (0, 25, 50, and 75 g/tree) and 4 levels of treble superphosphate (0, 30, 60, and 90 g/tree).

The level of total nitrogen in the Hamakua soils doesn't indicate a nitrogen-poor site (Table 4), however the high annual rainfall (5,080mm) probably leaches away a large proportion of the available nitrogen. The results of this experiment show that 300 kg/ha of nitrogen combined with 300 kg/ha of phosphorus is optimum for E. salgina growth in the first year along the Hamakua coast.

Economic considerations in fertilization will be examined more closely in 1981. Biomass equations will be generated, fibre yields will be estimated, and fertilizer costs will be evaluated in terms of economic returns.

Future fertilizer research along the Hamakua coast will also look at the possibility of applying rock phosphate before planting, so that only urea and murite of potash will need to be applied after planting. This method of fertilization will eliminate problems of incompatibility between urea and treble superphosphate, which make commercial NPK mixes of high nitrogen analysis impractical.

Species Trial at Onomea

The objective of this experiment is to determine the best tree species for a biomass plantation along the Hamakua coast.

Materials and Methods

Ten species of eucalypts and leguminous trees were outplanted at a 1.5m x 1.5m spacing in August, 1979. The species are: E. saligna, E. grandis, E. urophylla, E. dunii, E. camaldulensis, E. citriodora, E. robusta, E. globulus, Acacia melanoxylon, and Albizia falcataria.

Each plot is 9m x 9m and contains 36 trees, except for E. globulus which has 12 trees and E. camaldulensis which has 24 trees. The inner 16 trees in a plot were measured with 1 border row remaining, except for E. globulus plots where 8 trees were measured and E. camaldulensis where 12 trees were measured. The experimental design is a randomized complete block design with 10 treatments and 4 replicates.

Results and Discussion

E. citriodora seedlings had a very low survival rate (less than 10 percent) and thus no further measurements were taken.

Twelve months after outplanting, Albizia falcataria had a significantly greater diameter breast high (95% level) than all the other species, and a significantly greater height than all the other species except E. saligna (Graph 4). In this area of high annual rainfall (5,080mm) and excessive leaching of nitrogen, a leguminious tree such as Albizia seems to have a greater growth advantage over the eucalypts.

However, Albizia falcataria has two disadvantages: 1) low specific gravity and 2) a tendency for branching. Harvesting an excessively branched tree trunk may be too time consuming a task to be economical.

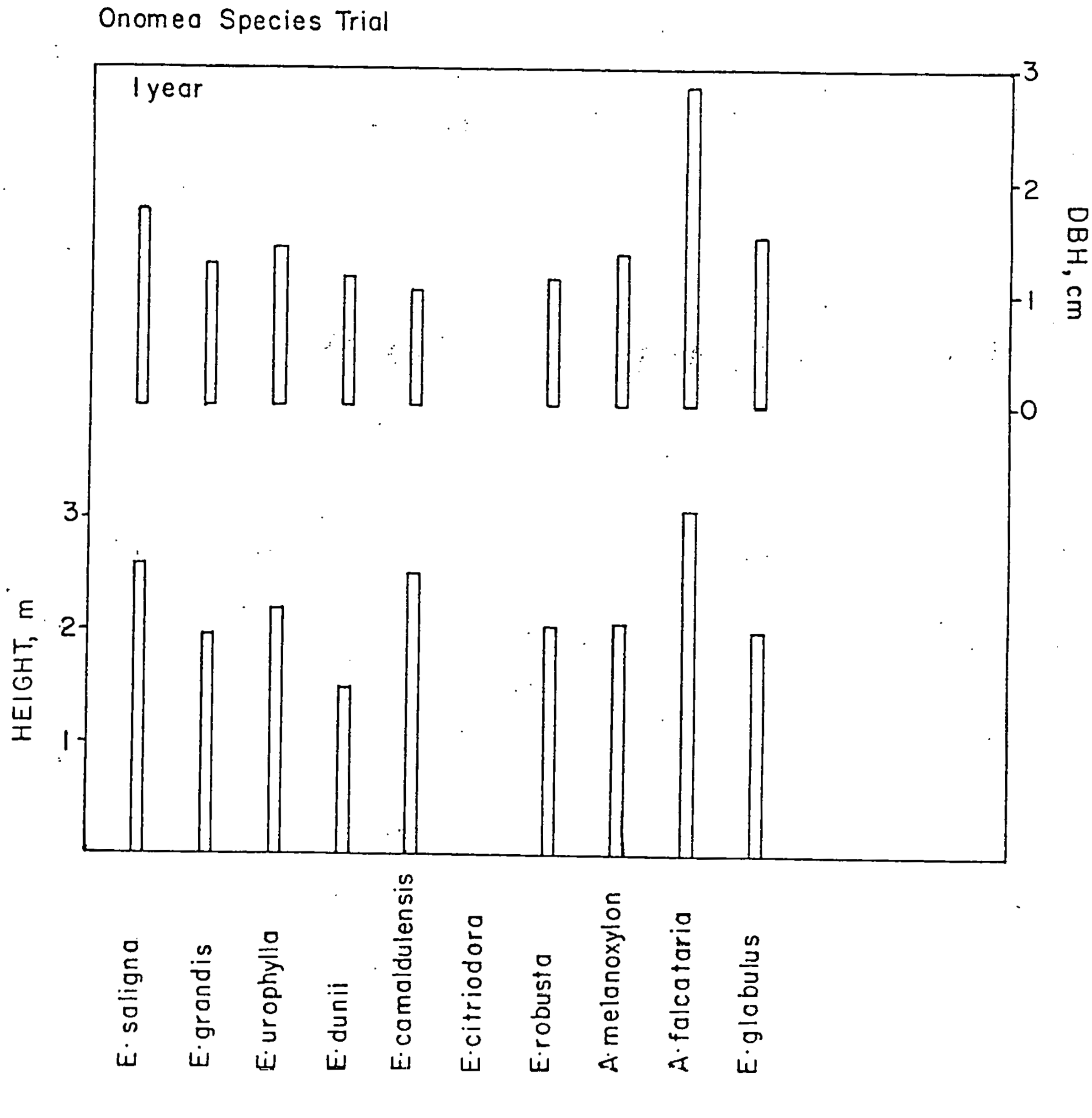
Species Mix Trial at Onomea

The objective of this experiment is to determine the advantages and disadvantages of interplanting leguminous trees with eucalypts. It is hypothesized that the leguminous trees will share their "fixed" nitrogen with the eucalypts through leaf litter and root decay, and help increase soil fertility.

Materials and Methods

The eucalypts and leguminous trees were outplanted at a 2m x 2m spacing in August, 1979. The eucalypt species are E. saligna and E. grandis, while the leguminous tree species are Acacia melanoxylon and Albizia falcataria.

This experiment has a randomized complete block design with 3 treatments and 3 replicates. The three treatments are pure Eucalyptus, Eucalyptus



Graph 4. Height and diameter breast high 12 months after outplanting of 10 different species of eucalyptus and leguminous trees.

interplanted with Acacia, and Eucalyptus with Albizia. Each plot is at least 0.4 hectares, and 49 trees were sampled from each plot.

Results and Discussion

No significant differences in height or diameter of eucalypts were found 12 months after outplanting. However, one year is too early to expect a significant transfer of nitrogen from the legumes through leaf litter or root decay. Foliar analysis does suggest that some nitrogen is being transferred from the leguminious trees to the eucalypts.

One major problem in the management of interplanted trees is that one species may outcompete the other. The Albizia trees have grown so rapidly that they are shading out the light-demanding eucalypts and causing them to die back. One solution to this problem is to reduce the number of interplanted Albizia so that shading of eucalypts is no longer a problem, and an experiment in 1981 will look at different ratios of legumes to eucalypts.

Herbicide Screen Trial I at Kamae

The objective of this experiment was to identify the most promising pre-emergent herbicides to use as a preplant treatment for weed control in a eucalyptus biomass plantation.

Materials and Methods

This experiment tested 8 different herbicides at varying rates for a total of 18 treatments. The herbicides applied were TOK[1], Atrazine[1], Treflan[1], Simazine[1], Sencor[1], Ronstar[1], Dacthal[1], and a Paraquat[1] + Simazine mixture (Table 9).

The herbicides were applied manually with a pressurized sprayer in December, 1979. Three increments of E. grandis seedlings were outplanted

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Table 9. Rates and Effects of Herbicide Treatments

Treatment	Effect	Rates (a.i.)[1] kg/ha	Rates (a.i.)[1] lbs/A
1. TOK WP50	Pre-emergent	5.6	5.0
2. TOK WP50	Pre-emergent	8.4	7.5
3. Atrazine 80W	Pre-and post-emergent	3.6	3.2
4. Atrazine 80W	Pre-and post-emergent	7.2	6.4
5. Atrazine 80W	Pre-and post-emergent	10.8	9.6
6. Treflan	Pre-emergent	0.6	0.5
7. Treflan	Pre-emergent	1.1	1.0
8. Treflan	Pre-emergent	4.5	4.0
9. Simzaine 50WP	Pre-emergent	2.2	2.0
10. Simazine 50WP	Pre-emergent	4.5	4.0
11. Sencor	Pre-and post-emergent	2.8	2.5
12. Sencor	Pre-and post-emergent	5.6	5.0
13. Ronstar	Pre-emergent	4.5	4.0
14. Ronstar	Pre-emergent	11.2	10.0
15. Dacthal	Pre-emergent	16.8	15.0
16. Paraquat CL + Simazine 50WP	Post-and Pre-emergent	0.1 + 2.2	0.1 + 2.0
17. Check			
18. Check			

[1]Active ingredient is abbreviated as a.i.

one week apart at a 1.5m x 1.5m spacing, beginning a week after the herbicide application.

The experiment design is a randomized complete block design, with 18 treatments and 4 replicates. Plot size was 4.5m x 7.5m with a 0.75m boarder.

The plots were observed monthly and ratings were given for weed control, based on the percentage of area covered by broad leaf weeds and grasses. Phytotoxicity ratings were also determined for the E. grandis seedlings.

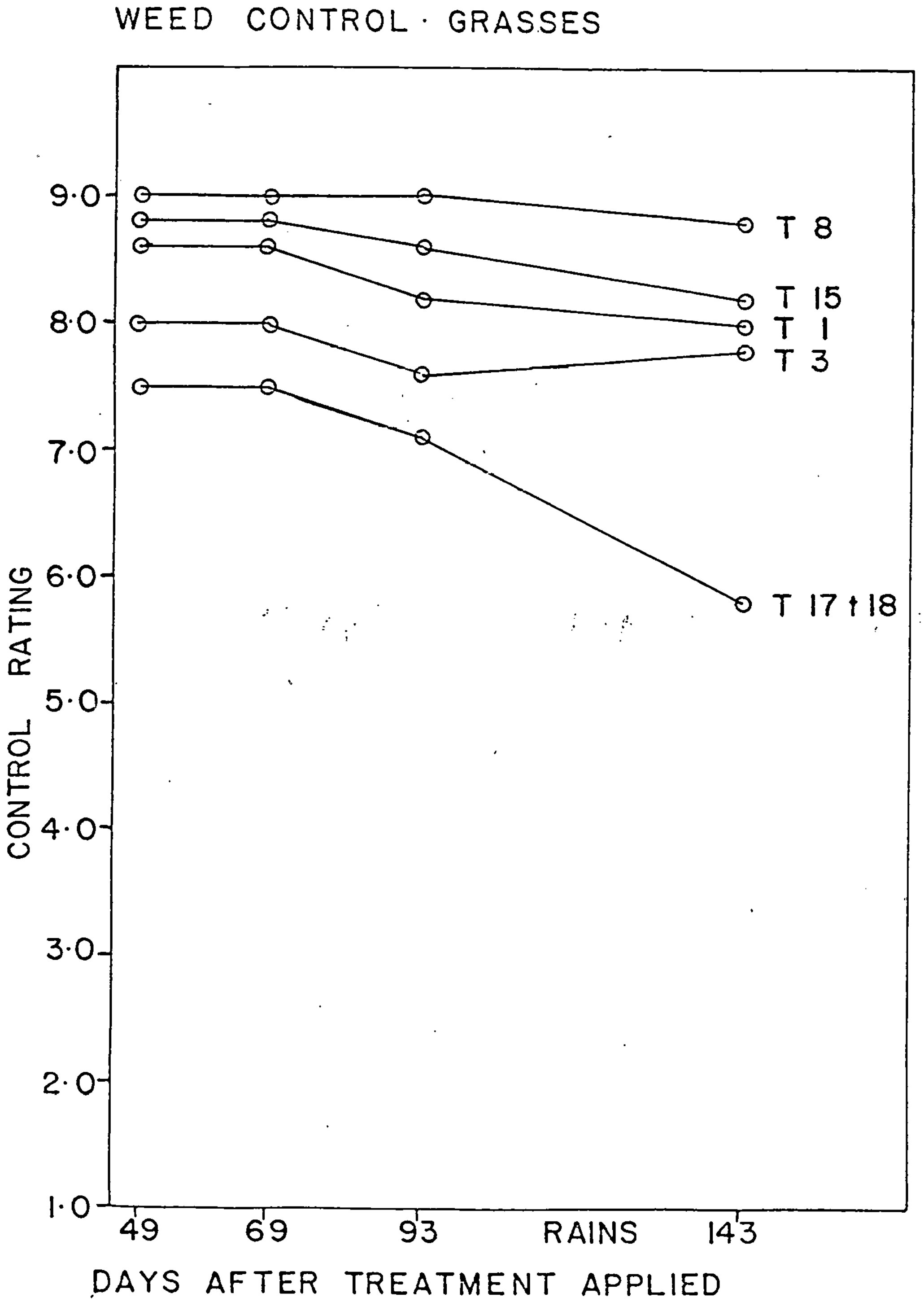
Results and Discussion

The problem weeds in the experimental area were primarily broad leaf annuals such as ageratum (Ageratum conyzoides) and fire weed (Erechtites hieracifolia). Treatments of Atrazine at 7.2 and 10.8 kg/ha (a.i.)[1] as well as Simazine at 4.5 kg/ha (a.i.)[1] and Sencor at 5.6 kg/ha (a.i.)[1] showed good control of weeds but also a high degree of phytotoxicity in Eucalyptus grandis 3 months after outplanting. Thus, these treatments are not considered further as clean fields are not desired at the expense of the trees.

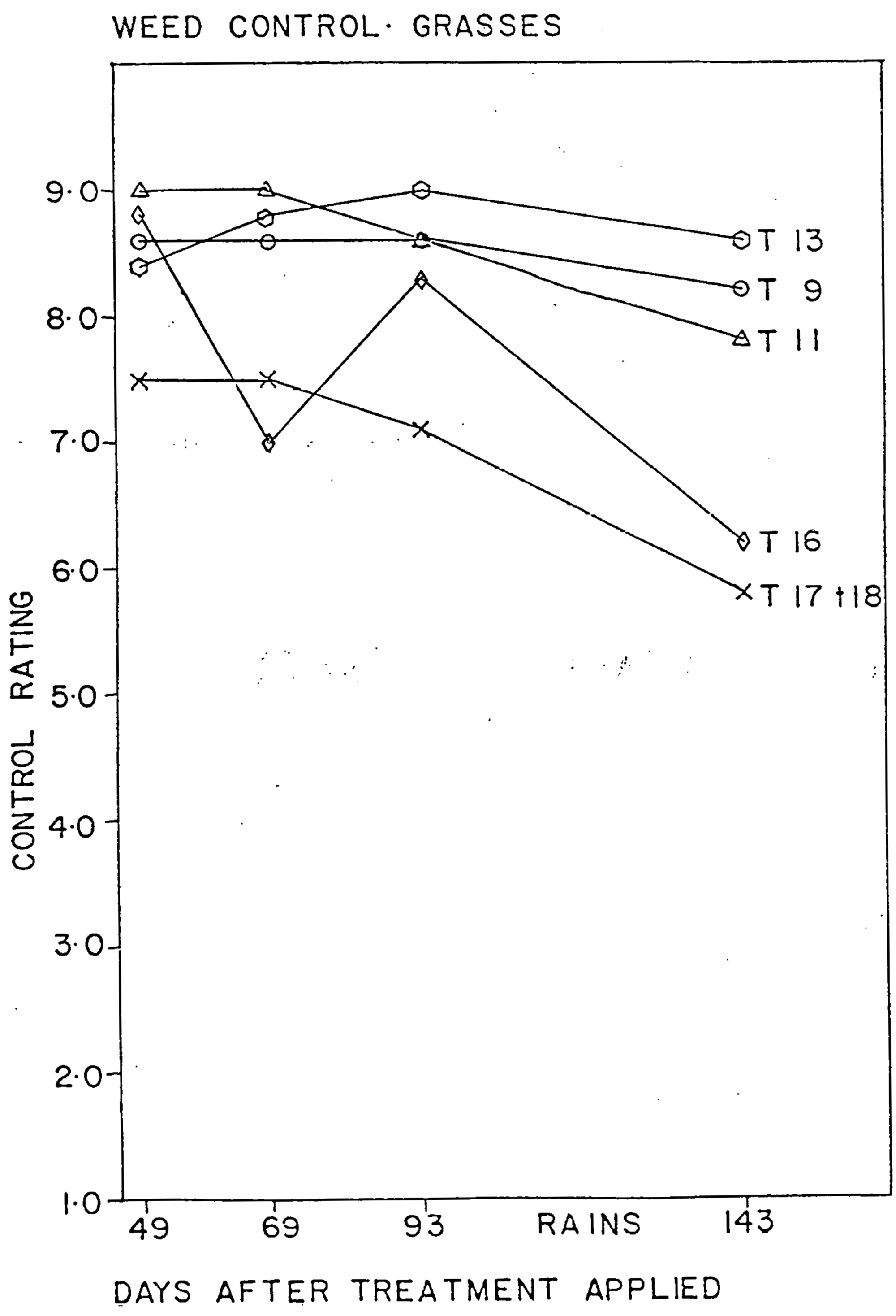
Atrazine at 3.6 kg/ha (a.i.)[1], Sencor at 2.8 kg/ha (a.i.)[1], Simazine at 2.2 kg/ha (a.i.)[1], and a Paraquat + Simazine mixture at 0.1 + 2.2 kg/ha (a.i.)[1] showed good control of broad leaf annuals as well as good control of annual grasses at 3 months (Graphs 5, 6, 7, 8). Of the above four treatments, Paraquat + Simazine had the lowest phytotoxic effect (Graph 9). TOK, Treflan, Ronstar and Dacthal showed poor control of broad leaf weeds after 3 months but acceptable control of grasses present (Graphs 5, 6, 7, 8).

Table 10 shows a breakdown in cost per hectare for each type of herbicide applied. Of the four promising treatments (Atrazine, Simazine, Sencor, and Paraquat + Simazine), Sencor was the most expensive, while Simazine was the least expensive.

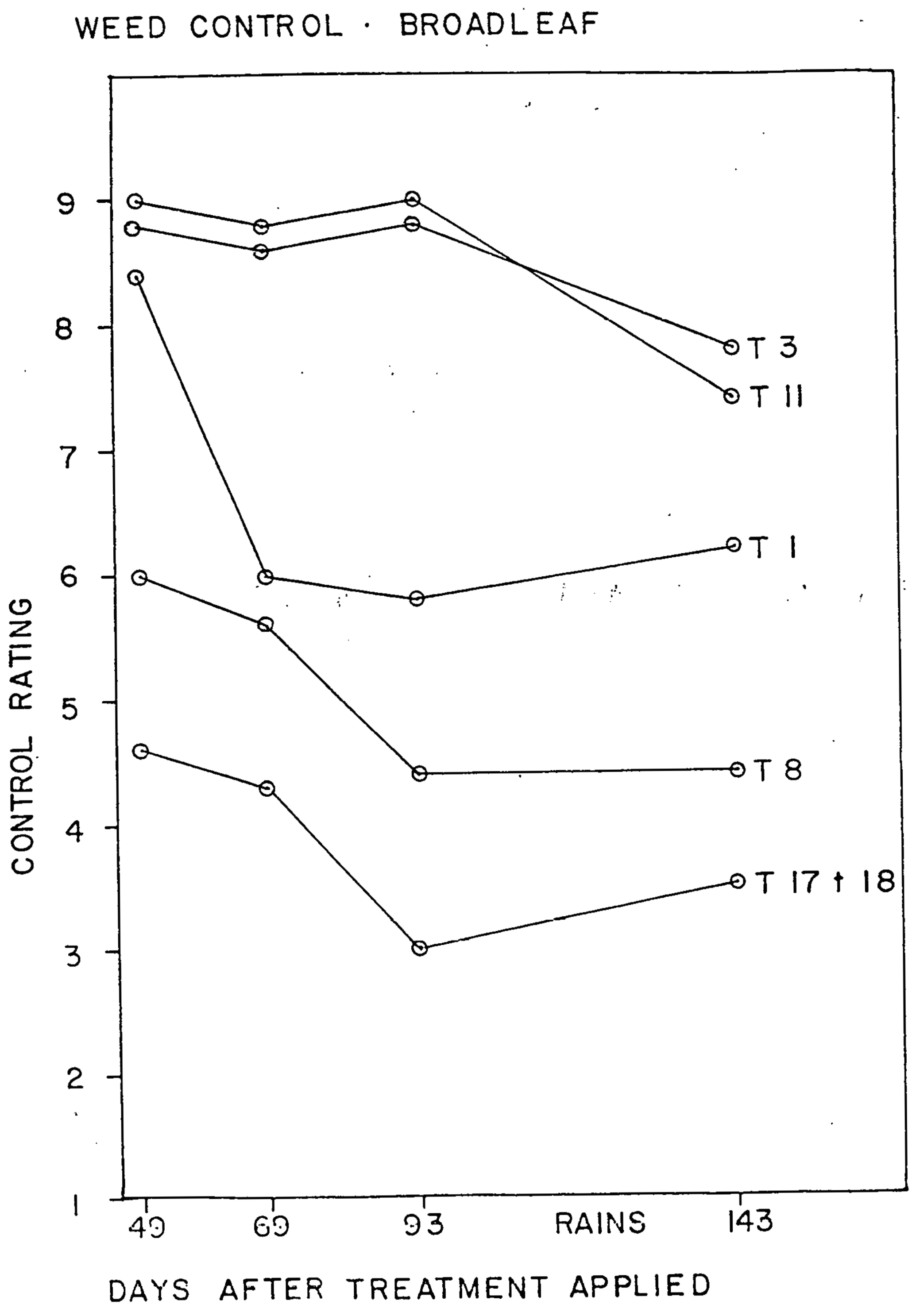
[1]Active ingredient is abbreviated as a.i.



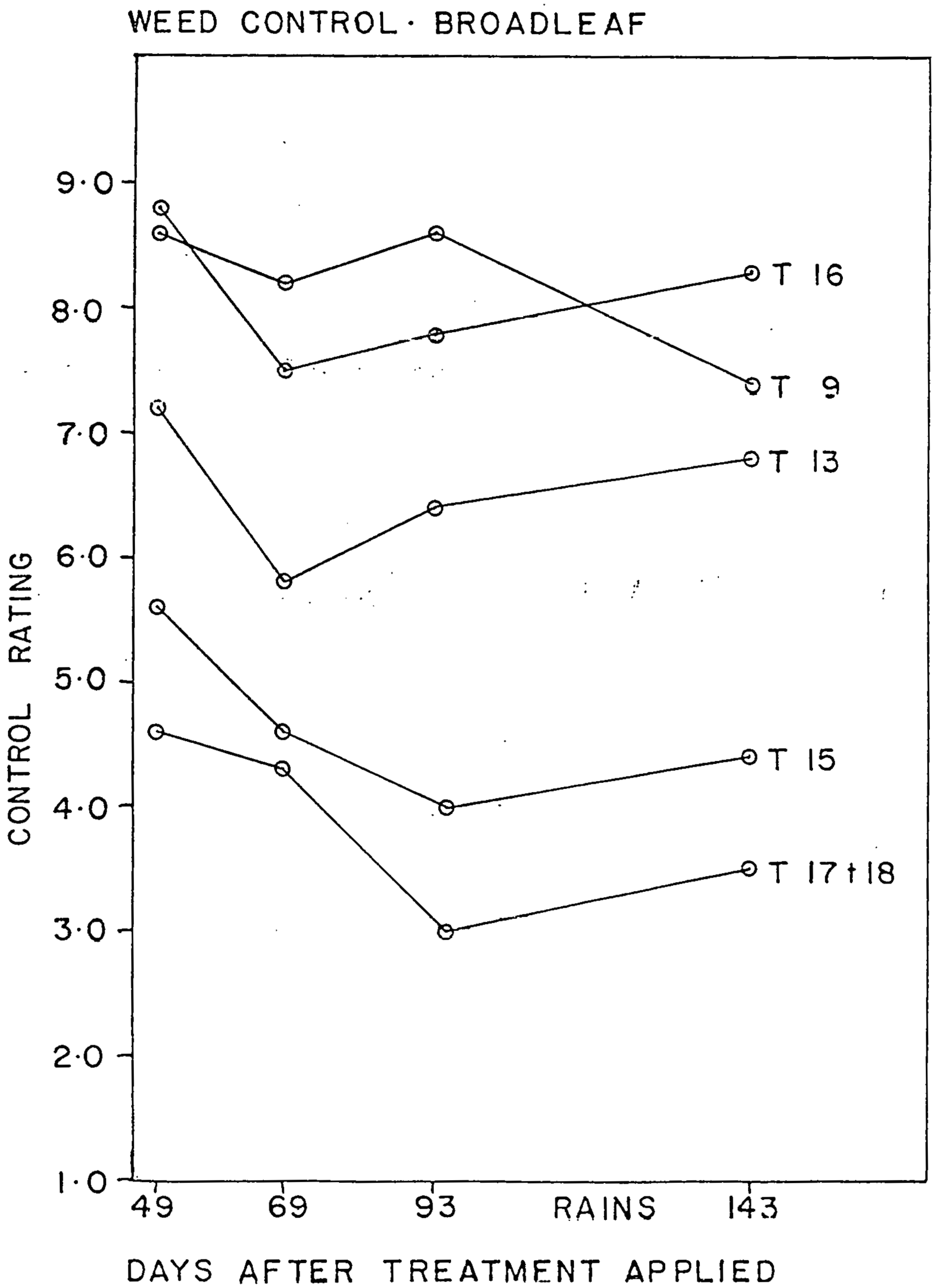
Graph 5. Ratings for control of seeding grasses with 1 as 100% weed cover and 9 as 1% weed cover. Ratings of 7 or greater are considered satisfactory weed control.



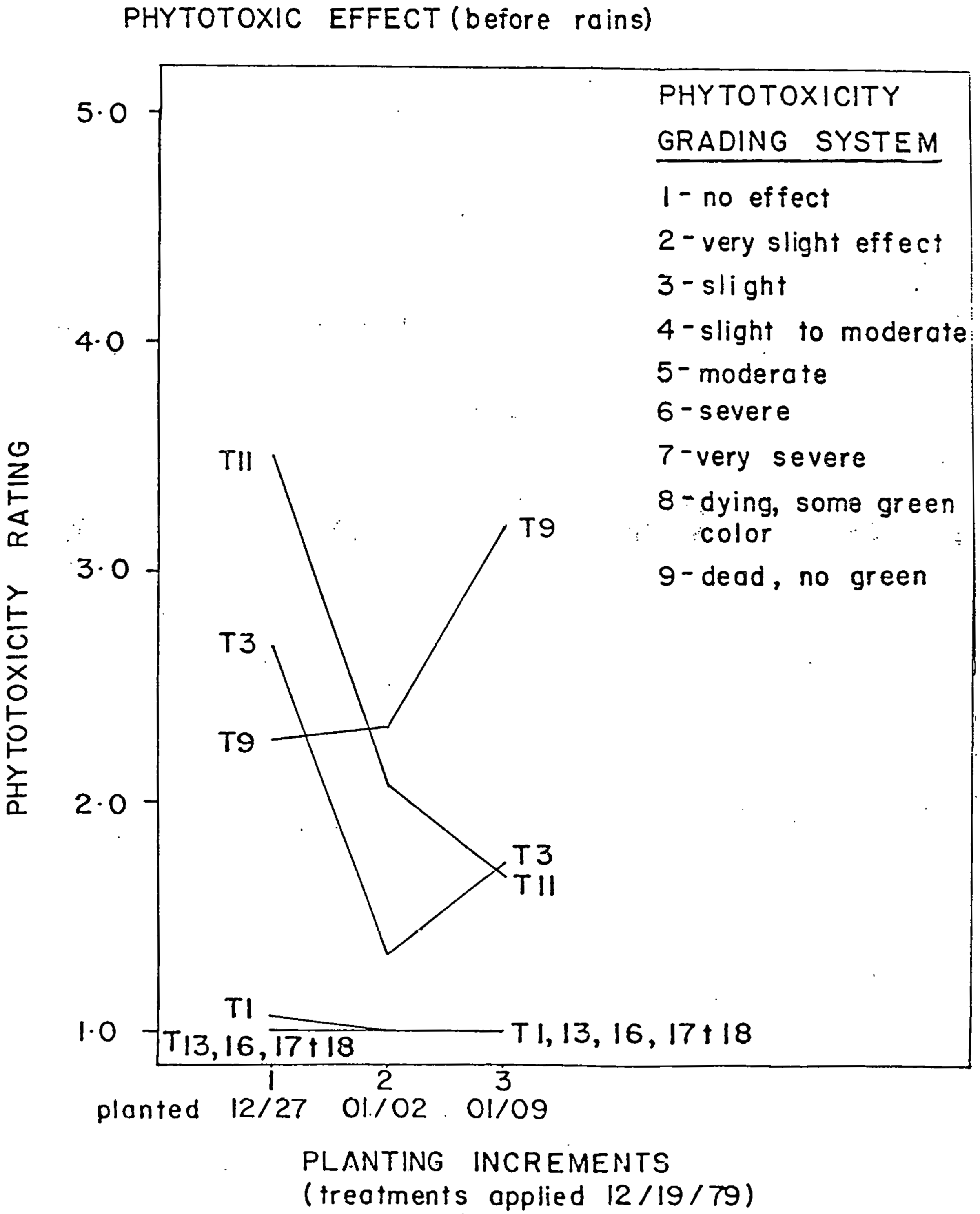
Graph 6. Ratings for control of seeding grasses with 1 as 100% weed cover and 9 as 1% weed cover. Ratings of 7 or greater are considered satisfactory weed control.



Graph 7. Ratings for control of broadleaf weeds with 1 as 100% weed cover and 9 as 1% weed cover. Ratings of 7 or greate- are considered satisfactory weed control.



Graph 8. Ratings for control of broadleaf weeds with 1 as 100% weed cover and 9 as 1% weed cover. Ratings of 7 or greater are considered satisfactory weed control.



Graph 9. Ratings for Phytotoxicity of E. Grandis

Table 10. Costs of Herbicide Treatments.

Treatment	Chemical	Rate (a.i.) kg/ha	Cost $/Acre	Cost $/ha
3	Atrazine 80 WP	3.6	$ 7.52	$ 18.58
9	Simzaine 50 WP	2.2	7.25	17.91
11	Sencor	2.8	55.25	136.52
16	Paraquat CL & Simazine 80 WP	0.1 + 2.2	11.79	29.13
1	TOK	5.6	34.50	85.25
8	Treflan	4.5	40.49	100.05
13	Ronstar	4.5	180.00	444.78

Paraquat + Simazine was selected as the most promising treatment due to its low phytotoxic effect on E. grandis (Graph 9). The plots which received Paraquat + Simazine showed no phytotoxic effect on the trees, and the tree growth comparable to those on the check plots.

Simazine is the active ingredient in Princep[1], and a new 90-calibre Princep[1] has been cleared for use in eucalyptus plantations in all states, thereby making it more accessible. It was found that even 5 months after outplanting and following heavy rains, the Paraquat + Simazine plots were still acceptably weed-free and the trees were growing satisfactorily.

Herbicide Screening Trial II at Kamae

The objective of this small trial was to compare the effectiveness and residual action of Roundup alone and Roundup mixed with the pre-emergent herbicides, Princep and Dual.

Material and Methods

In July, 1980, six herbicide treatments (Table 11) were applied by back-pack sprayers in plots measuring 15m x 4.5m. The herbicides were applied between the rows of 7 month-old Eucalyptus grandis trees spaced at 1.5m x 1.5m. Since this was simply a "skirmish" test, there was only one replicate of each treatment.

Observations were taken by visual assessment 1 and 2 months after application. Effectiveness of weed control as well as phytotoxic effect on the trees were evaluated.

Results and Conclusions

It was noted that initial weed control was good for all treatments except those which had 0.8 kg/ha (a.i.) of Roundup mixed with Princep and Dual.

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Table 11. Rates per Hectare of Herbicide Treatments.

Treatment	Roundup, kg/ha (a.i.)	Princep, kg/ha (a.i.)	Dual, kg/ha (a.i.)
A	1.7	2.2	2
B	1.7	4.5	2
C	0.8	0	0
D	1.7	0	0
E	0.8	2.2	2
F	0.8	4.5	2

Control of grasses was poor probably because of the adverse interaction between Roundup and the clay particles in Princep.

The plots with 1.7 kg/ha (a.i.) of Roundup alone showed good initial weed control, but had an abundance of weed seedlings after one month. The plots which received Roundup plus pre-emergents were still free of annual weed seedlings after 2 months.

Trees in plots which received Roundup plus pre-emergents did show some interveinal chlorosis, but symptoms disappeared after 2 months. There was no significant difference in growth between the affected trees and the controls.

The use of Roundup mixed with pre-emergent herbicides should be considered as a post-plant treatment, since it controlled both pernnial grasses and broad leaf annual weeds at the higher rate of 1.7 kg/ha (a.i.) of Roundup. This mixture can be applied as needed until the crowns close and weeds are no longer a problem.

Comparison of Fertilizer Type Study at Kamae

This study includes two experiments, one on *E. saligna* and one on *E. grandis*. The objective of this study is to identify the best fertilizer for the cost (soluble versus slow release) for eucalyptus growth along the Hamakua coast of the Island of Hawaii.

Materials and Methods

The *E. saligna* and *E. grandis* trees were outplanted in January 1980 at a 3m x 0.75m spacing. This study follows a randomized complete block design with five treatments and four replicates on each of the two *Eucalyptus* species.

The five fertilizer treatments are: DC-153[1] (12-24-12) applied once: DC-153[1] applied twice; Osmocote[1] (14-14-14) applied once; Agriform[1] (20-10-5)

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applied once; and Nitrogano[1] (3-4-25) applied once. Fertilizer costs are outlined in Table 12. Two applications of DC-153 were applied in one treatment, because the cost of DC-153 is half that of any other fertilizer. The fertilizer rates are calculated to give 54 kg/ha of nitrogen (48 lbs/A) for each application.

Each plot is approximately 27m x 7.5m, with two border rows on the narrow rows and a one border row on the side rows. Forty trees were measured for height and diameter breast high.

Results and Discussion

No significant difference in heights among the five treatments (95% level) was found at 3 months; however, by 6 months, the Osmocote treatment resulted in significantly greater heights (95% level) compared to all the other treatments (Graphs 10, 11). This effect was probably due to the slow-release nature of Osmocote fertilizer.

At six months, one of the DC-153 treatments received another dose of fertilizer and by 9 months, this treatment had significantly greater heights and root collar diameters (95% level) compared to all the other treatments (Graphs 10, 11).

Osmocote fertilizer was almost three times the cost of the soluble DC-153 fertilizer (Table 12); however, it did not produce three times the tree growth (Graphs 10, 11). A second application of DC-153 cost less than one application of Osmocote and resulted in significantly greater heights and diameters (95% level) compared to Osmocote. Based on economic considerations, Osmocote is not the optimum fertilizer for a eucalyptus tree plantation along the Hamakua coast.

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[1]Trade names are used solely to provide specific information
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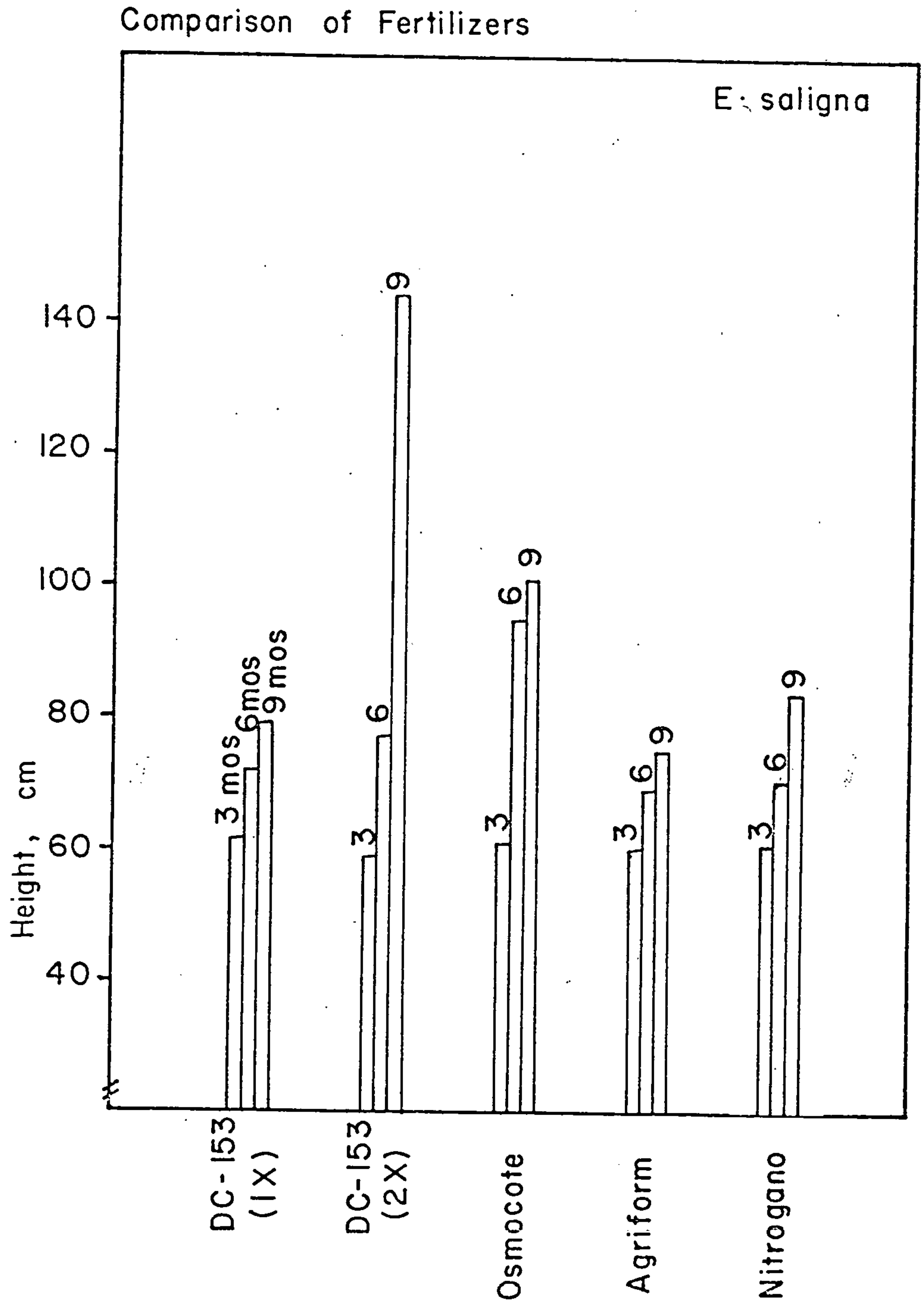
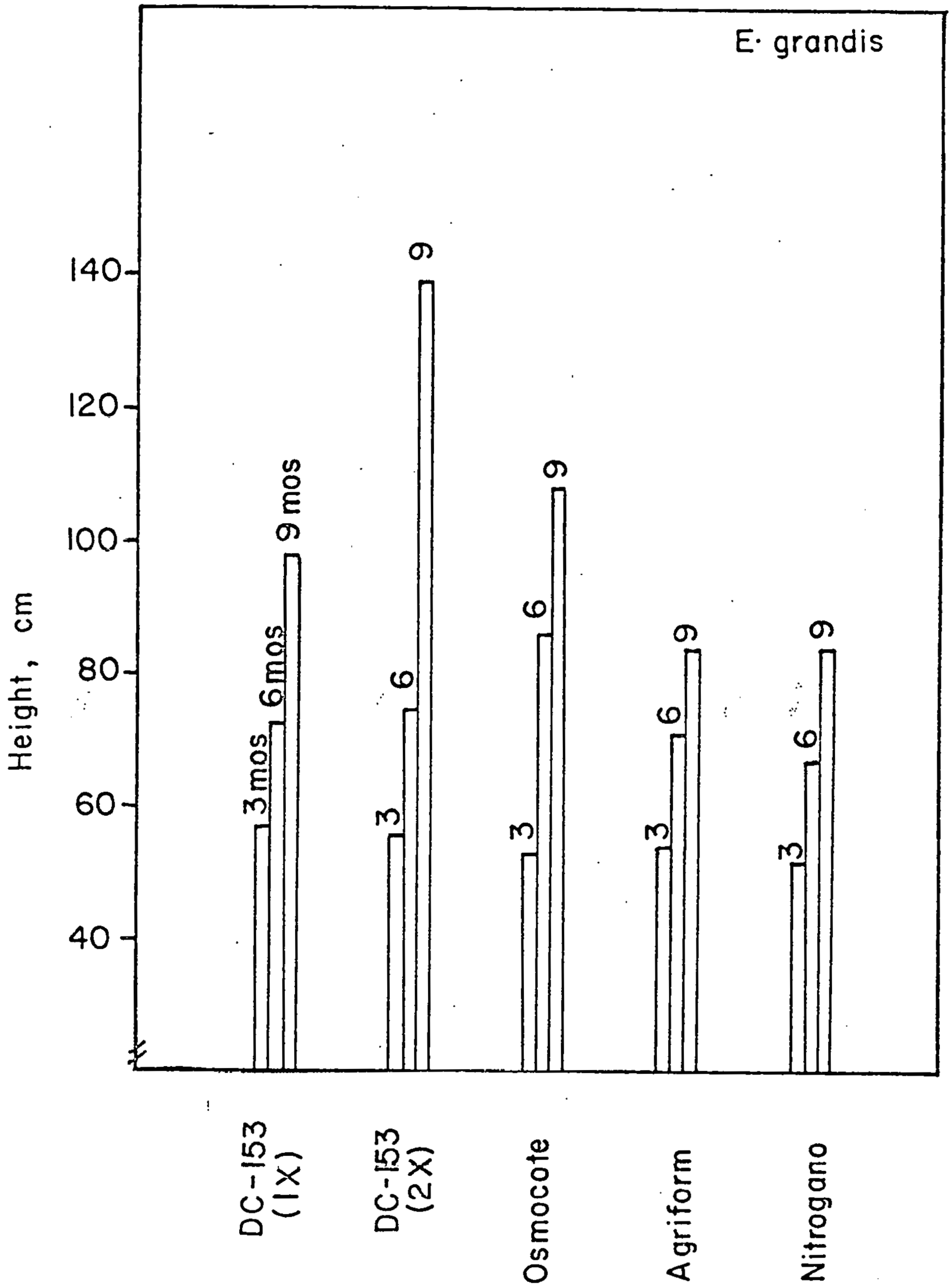


Graph 10. Comparison of heights of E. saligna given 5 different fertilizer types at 3, 6, and 9 months after outplanting.

Comparison of Fertilizers



Graph 11. Comparison of heights of E. grandis given 5 different fertilizer types at 3, 6, and 9 months after outplanting.

Table 12 Rates and costs of fertilizers used in the Comparison of Fertilizer Type Study at Kamae

Treatment	Fertilizer	Type	Effective Duration	Cost $/ha[1]	Cost $/A[1]
1	DC-153	Soluble	2 mos.	192	78
2	DC-153	Soluble	2 mos.	383	155
3	Osmocote	Slow-release	3-4 mos.	528	214
4	Agriform	Slow-release	1 year	762	309
5	Nitrogano	Slow-release	1 year	428	173

[1]Cost figures include materials and labor.

Agriform and Nitrogano both performed very poorly compared to DC-153 and Osmocote. These fertilizers were 2 to 3 times the cost of DC-153 (Table 12) and did not produce even as much tree height or diameter as one application of DC-153 (Graphs 10, 11).

Species Trial II at Kamae

The objective of this experiment is to determine the fastest growing biomass species for an energy plantation along the Hamakua coast of the Island of Hawaii.

Materials and Methods

Ten *Eucalyptus* species and one *Acacia* species were outplanted in April, 1980. The species are: *E. microcorys*, *E. maidenii*, *E. nitens*, *E. saligna*, *E. dunii*, *A. mangium*, *E. viminalis*, *E. robusta*, *E. urophylla*, *E. grandis* and *E. botryoides*.

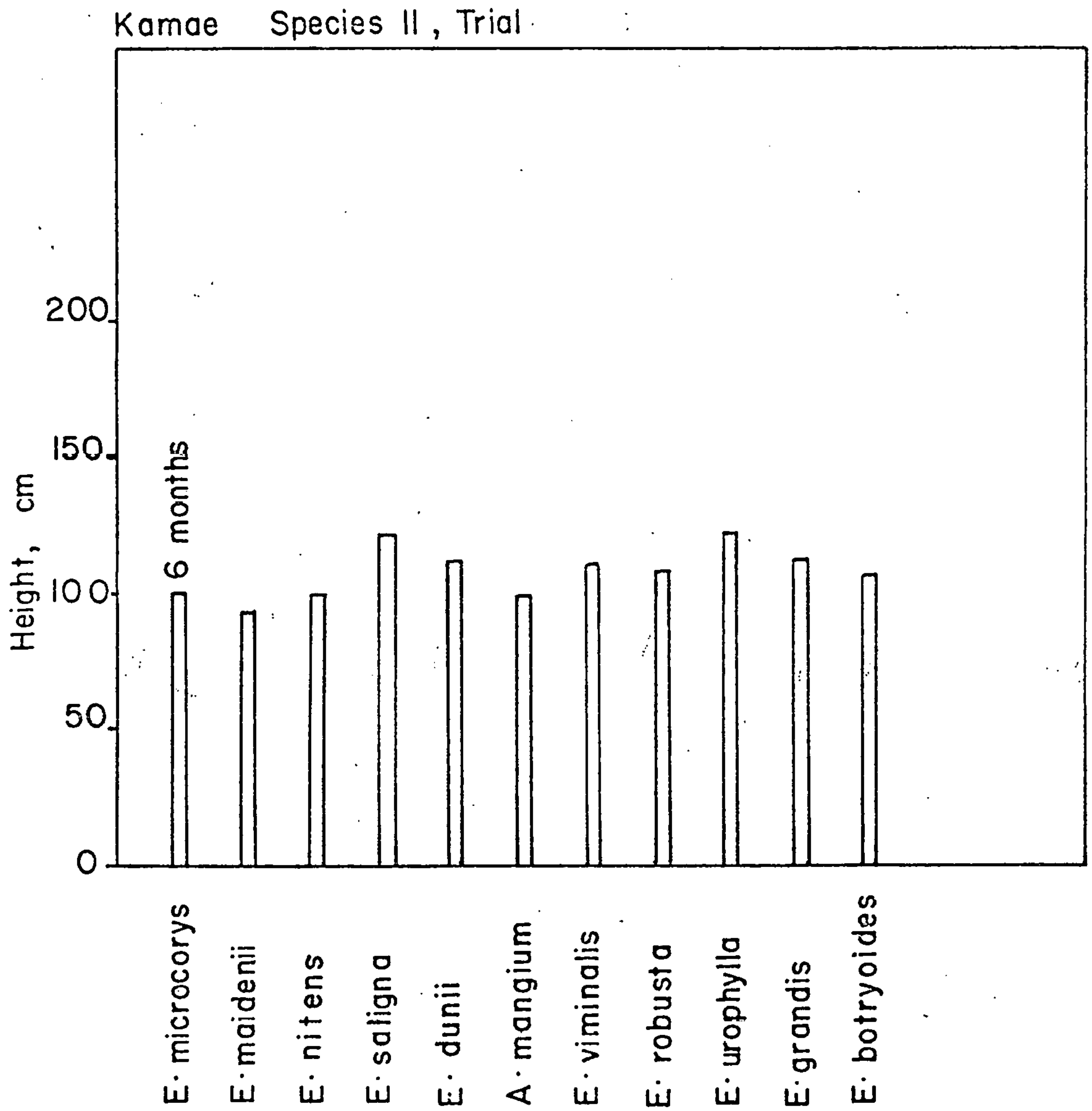
The experiment follows a randomized complete block design with eleven treatments and four replicates. Plot size is 13.5m x 13.5m with 81 trees per plot. The inner 5x5 trees (25) were measured for height and diameter with two border rows.

Results and Discussion

E. saligna and *E. urophylla* had the greatest heights at 6 months (Graph 12); however, this difference was not significant (95% level). No significant difference in height of the eleven species was found.

The block effect, however, was significant (95% level) due to the varied terrain with the experimental area. Two blocks were laid out on a wet site, one block was on a ridge top and the fourth was on a 10% slope.

All the species tested grew best on the sloping, well-drained site. Most species did the poorest on the wet sites except for *E. dunii* and *E. viminalis* which were shortest on the expose ridge top site.



Graph 12. The growth of ten species of _Eucalyptus_ and one of _Acacia_ 6 months after outplanting at Kamae.

Six months is too early to draw any conclusions about the fastest growing species along the Hamakua coast. However, with the great variations in terrain the optimum species may vary from field to field and even within a field.

Legume Ground Cover Screening Trial I at Kamae

The objective of this experiment was to determine the legume ground cover species best suited for interplanting in a eucalyptus tree farm along the Hamakua coast.

Materials and Methods

Eucalyptus grandis was outplanted in April 1980 at a 1.5m x 1.5m spacing. Treble superphosphate was broadcast at 118 kg/ha to aid in the establishment of the legumes. Then legume seeds were coated with the appropriate inocculum and broadcast by hand.

Three different legumes were tested, based on the recommendations of the Soil Conservation Service and a Plant Introduction Specialist, Mr. DeReath Palmer. Haifa white clover (Trifolium repens) New Zealand white clover (Trifolium repens) and Seca Stylo (Stylosanthes guianensis) were each sowed at 3.4 kg/ha.

The experimental design was a randomized complete block with 4 treatments and 4 replicates. Plot sizes were 18m x 18m with 144 trees per plot. Percent cover of the ground was measured with the point-intersection method (Mueller-Dombois and Ellenberg, 1974).

Results and Discussion

None of the legumes tested were successful in outcompeting the weeds (Table 13). Percent cover ranged from 4 to 13 and the experiment was terminated due to the poor legume establishment.

Table 13. Percent cover of the ground by three different legumes and various weed species.

Treatment	Legume[1] %	Weed Species Ageratum,%	Weed Species Grass,%	Other,%	Bare Ground,%
New Zealand white clover	10.5	52.0	22.0	6.0	9.5
Seca stylo	4.0	49.5	19.0	12.5	15.0
Haifa white clover	13.0	53.0	22.5	5.5	6.0
Control	0.0	51.0	26.0	11.5	11.5

[1]Percent ground cover was determined by the point-intersection method (Mueller-Dombois and Ellenberg, 1974).

Legume Ground Cover Screening Trial II at Kamae

The objective of this experiment was to determine the legume ground cover species best suited for interplanting in the eucalyptus tree farm along the Hamakua coast.

Materials and Methods

Eucalyptus saligna was outplanted in October 1980 at a 3m x 0.75m spacing. Treble superphosphate was broadcast at 118 kg/ha to aid in the establishment of the legumes. Legume seeds were coated with the appropriate inocculum and broadcast by hand.

Three different legumes were tested, one a repeat from the first screening trial. New Zealand white clover (*Trifolium repens*)and Birdsfoot trefoil (*Lotus corniculatus*) were sowed at 6.7 kg/ha. Lana vetch (*Vicia desycarpa*) was sowed at 27 kg/ha and 54 kg/ha.

The experimental design was a randomized complete block with 5 treatments and 4 replicates. The plot size was 9m x 9m with 52 trees per plot. Percent cover of the ground was measured with the point-intersection method.

Results and Discussion

Lana vetch at the higher seeding rate of 54/kg/ha grew vigorously and covered 41% of the area (Table 14). However, the remaining percentage of ground was covered with seeding grasses and broad leaf weeds.

Birdsfoot trefoil did poorly, covering only 9% of the area, while New Zealand white clover covered only 13% of the area (Table 14).

Part of the problem in legume establishment is the method of hand broadcasting the seed. A mechanical means of broadcasting the seed might result in a more even distribution and a higher percent cover of the total area.

Table 14. Percent cover of the ground by three different legumes.

	Percentage Cover				
Legume	I	II	III	IV	Ave.
Control-none(27 kg/ha)	0	0	0	0	0
Lana vetch	48	30	8	40	31
Lana vetch (54 kg/ha)	36	56	24	50	41
Birdsfoot Trefoil	10	10	2	16	9
N. Z. white clover	30	4	14	6	13

Osmocote Fertilizer Trial at Kamae

The object of this experiment was to compare slow release (1 year) Osmocote (17-7-12) with soluble DC-141 (14-14-14) fertilizer.

Materials and Methods

Eucalyptus saligna trees were outplanted in September 1980 at a 1.5m x 1.5m spacing. The fertilizer treatments were placed in a hole 4-6" from the seedlings and covered. The 3 treatments were 93 g/tree of DC-141, 186 g/tree of DC-141 and 153 g/tree of Osmocote (Table 15). The DC-141 treatments will be repeated 6 months after outplanting.

The experimental design follows a randomized complete block design with 3 treatments and 4 replicates. Plot size is 16.5m x 16.5m with 121 trees per plot. There were 3 border rows and the inner 5x5 trees were measured for height and diameter.

Results and Discussion

No significant difference (95% level) was found in tree heights for the three treatments at 3 months. This is too early to evaluate the effectiveness of these fertilizer treatments.

Fertilizer NPK Trial at Amauulu

The objective of this experiment is to determine the growth effect on *Eucalyptus saligna* of nitrogen, phosphorus, potassium, lime and micronutrients.

Materials and Methods

Eucalyptus saligna was outplanted in October, 1980 at a 1.5m x 1.5m spacing. The experimental design was a randomized complete block design with 12 treatments and 4 replicates.

The twelve fertilizer treatments are outlined in Table 16. These treatments are based on results from the NP Trial at Akaka Falls where nitrogen was found to be the primary limiting nutrient.

Table 15. Comparison of fertilizer rates and cost of DC-141 and Osmocote.

	Fertilizer Rates, lbs/A-yr.	N, lbs/A-yr.	P_2O_5, lbs/A-yr.	K_2O, lbs/A-yr.	Fertilizer Costs, $/A	Application Costs, $/A	Total Costs, $/A
DC-141 (14-14-14)	714	100	100	100	101.74	97.00	198.74
DC-141 (14-14-14)	1,428	200	200	200	203.49	97.00	300.49
Osmocote (17-7-12)	588	100	41	71	431.00	48.50	479.50

Table 16. Rates of fertilizer used in the NPK experiment at Amauulu.

Treatment	Fertilizer	Urea, g/tree	TSP g/tree	KCL g/tree	Dolomite g/tree	Micro Max, g/tree
1	0	0	0	0	0	0
2	N_1	25	0	0	0	0
3	N_2	50	0	0	0	0
4	N_3	75	0	0	0	0
5	N_1P_1	25	30	0	0	0
6	N_2P_2	50	60	0	0	0
7	N_3P_3	75	90	0	0	0
8	$N_1P_1K_1$	25	30	20	0	0
9	$N_2P_2K_2$	50	60	40	0	0
10	$N_3P_3K_3$	75	90	60	0	0
11	$N_1P_1K_1$+lime	25	30	20	70	0
12	$N_1P_1K_1$+lime+ micronutrients	25	30	20	70	10

Plot size is 13.5m x 13.5m with 81 trees per plot. The inner 25 trees will be measured with 2 border rows remaining.

Results and Discussion

No measurements were taken in 1980.

Seedling Container Size Trial at Amauulu

The objective of this experiment is to compare the survival and initial field growth of *Eucalyptus saligna* raised in 3 different sizes of plastic dibbles.

Materials and Methods

The *E. saligna* trees were outplanted in October, 1980 at a 1.5m x 1.5m spacing. Three sizes of plastic dibble tubes were used to raise the seedlings in the nursery. "Pine" cells are 66 cubic centimeters, "Super" cells are 164 cubic centimeters and "Stubbies" are 131 cubic centimeters.

The experimental design is a randomized complete block with 3 treatments and 4 replicates. Plot size is 16.5m x 16.5m with 121 trees per plot. The inner 5x5 trees will be measured with 3 border rows remaining.

Results and Discussion

No measurements were taken in 1980.

KA'U DISTRICT STUDIES

Spacing Study at Ka'u

The objective of this experiment is to determine the optimum spacing of *Euclyptus saligna* for an intensive, short-rotation (5-7 years) biomass energy plantation in Ka'u.

Materials and Methods

The *E. saligna* trees were outplanted in September, 1979 at 4 different spacings. The spacings are: 1m x 2m, 2m x 2m, 2m x 2.5m, and 1.2m x 2.5m.

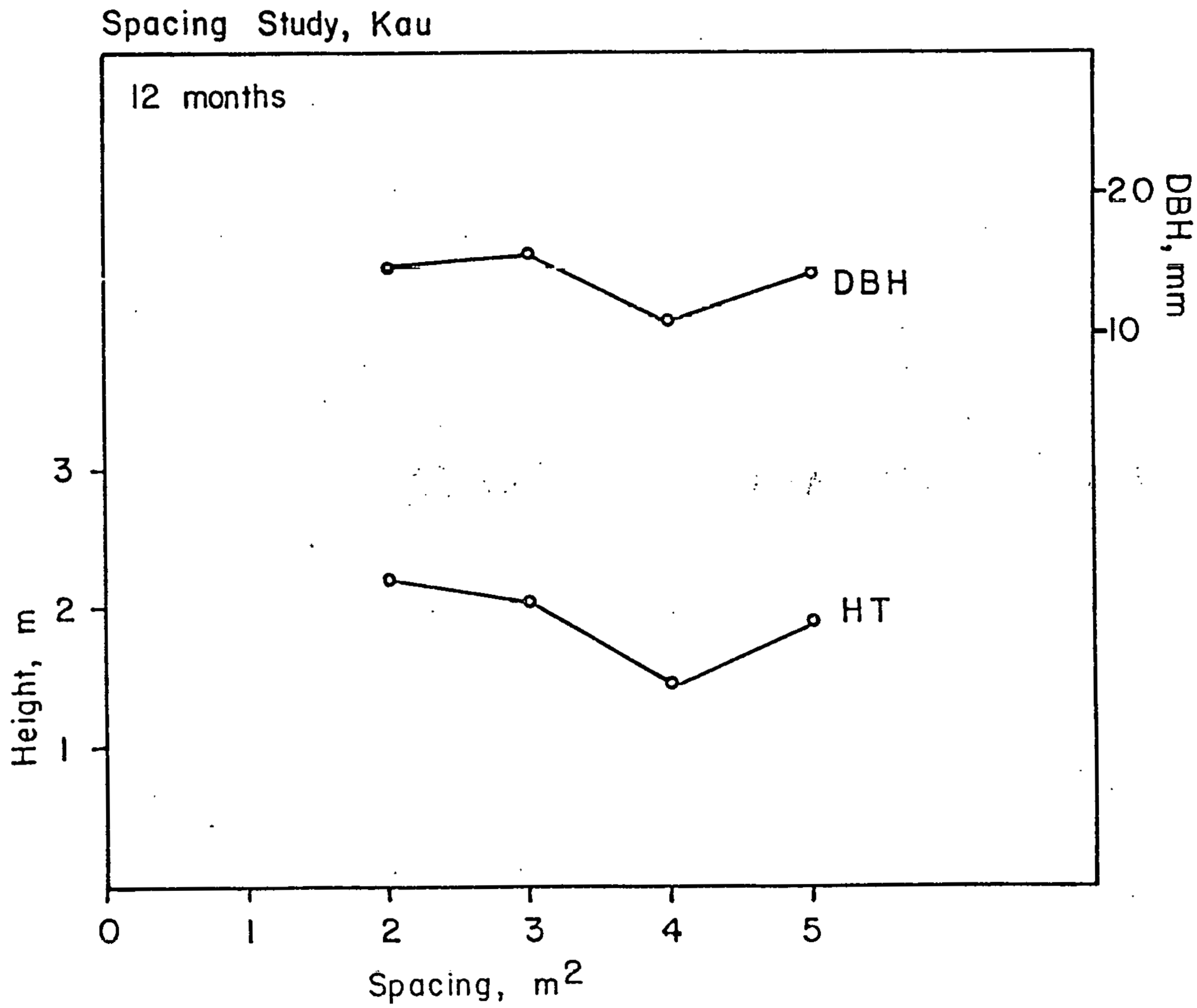
The experiment follows a randomized complete block design with 4 treatments and 4 replicates. The plot size is approximately 26m x 30m with 390 trees at the closest spacing and 260, 195, and 156 trees at progressively wider spacings. The inner 50 trees were measured, leaving a buffer zone 4 meters wide.

Results and Discussion

No significant difference (95% level) in height or diameter breast high was found among the treatments 12 months after outplanting. There was no consistent trend with increasing tree density, although the two closest spacings had the greatest heights and diameters breast high 12 months after outplanting (Graph 13).

This lack of treatment effect may be due to the large percentage of replants. Seedling diebacks were caused by dry weather conditions at the time of outplanting and later weed problems. Survival in the plots ranged from 38% to 96%.

A second spacing study has recently been installed in 1981 and hopefully the wetter winter months will increase seedling survival.



Graph 13. Height and diameter breast high of <u>E. saligna</u> 12 months after outplanting at 4 different spacings.

Eucalyptus-Legume Admixture Trial at Ka'u

The purpose of this experiment is to determine the costs and benefits of interplanting Eucalyptus with leguminous trees. It is hypothesized that the transfer of "fixed" nitrogen from the legumes through leaf litter or root decay will benefit the eucalyptus and increase soil fertility.

Materials and Methods

The eucalypts and leguminous trees were outplanted at a 1.5m x 1.5m spacing in September, 1979. The experimental design was originally intended to be a randomized complete block design with 6 treatments and 4 replicates. Unfortunately, due to poor germination of *Albizia* seed, the number of seedlings was inadequate for the entire experiment. Only 2 replicates were planted, and it was understood that this trial would be a preliminary test only.

The 6 treatments are: pure *E. grandis*, pure *E. saligna*, *E. grandis* + *Albizia* (alternate rows), *E. grandis* + *Albizia* (alternate trees), *E. saligna* + *Albizia* (alternate rows), and *E. saligna* + *Albizia* (alternate trees). The plot size is 24m x 24m with 256 trees per plot. The inner 49 trees were measured with 4 border rows remaining.

Results and Discussion

Twelve months after outplanting, there were no real growth differences among the 6 treatments. No increase in foliar nitrogen of eucalypts was observed in interplantings with leguminous trees. However, one year is too soon to expect significant transfer of nitrogen from the legumes to the eucalypts.

It is interesting to note that at the Ka'u site, the eucalypts were outcompeting the *Albizia* trees in contrast to the situation at the Onomea site. Although total nitrogen levels in the soil are lower at the Ka'u site compared to the Onomea site (Table 4), the lower rainfall and less leaching at the Ka'u site results in greater available nitorgen. Thus, the leguminous trees do not have a growth advantage over the eucalypts on the Ka'u site.

Fertilizer NP Trial at Ka'u

The objective of this experiment is to determine optimum levels of nitrogen and phosphorus for the growth of *E. saligna* on the Alapai and Kiloa soil series in Ka'u.

Materials and Methods

The *E. saligna* trees were outplanted in June 1980 at a 1.5m x 1.5m spacing. The experimental design is a randomized complete block design with 16 treatments and 4 replicates on the Alapai soil series and 4 replicates on the Kiloa soil series.

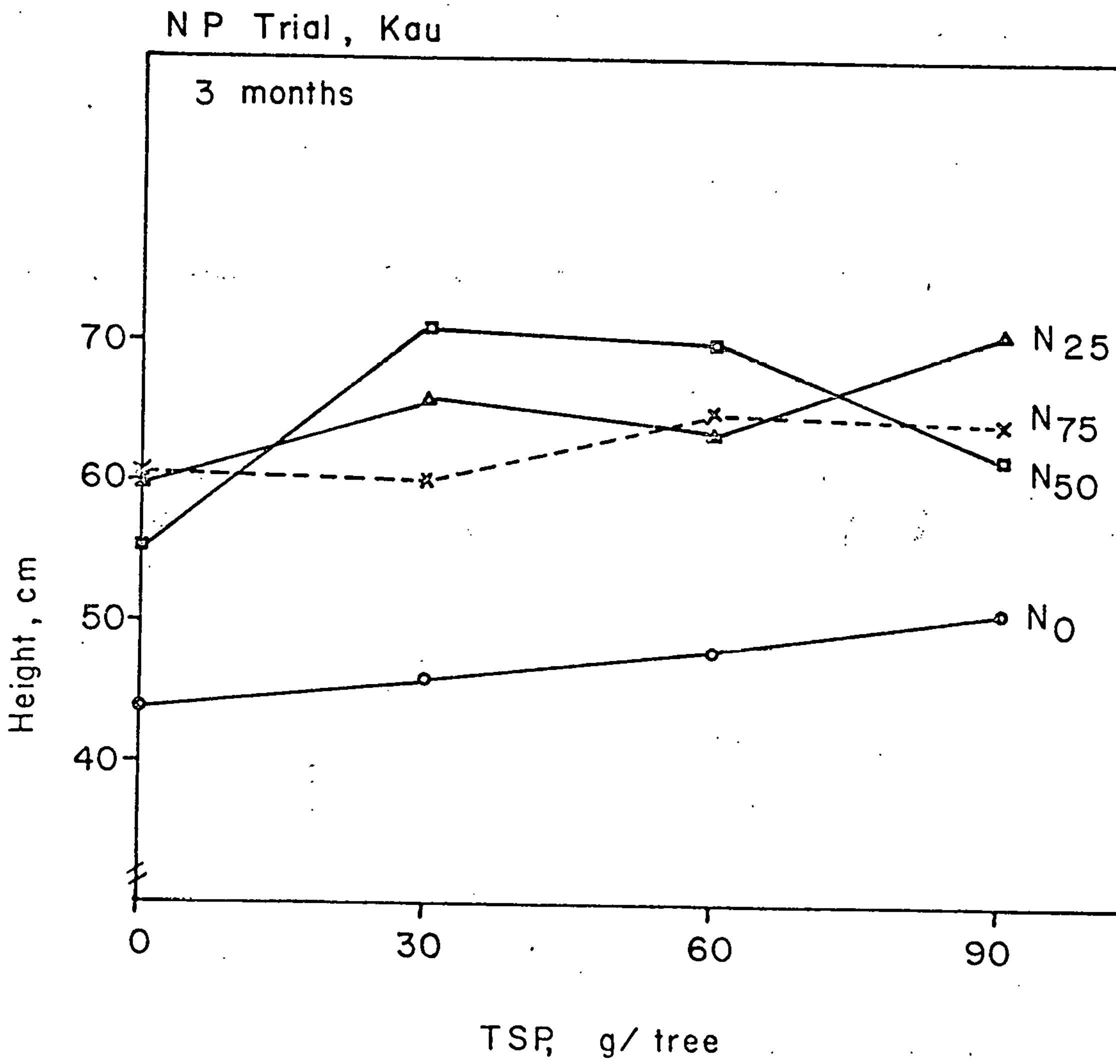
The 16 fertilizer treatments are a 4 x 4 factorial with 4 levels of nitrogen (0, 25, 50, and 75 b/tree of urea) and 4 levels of phosphorus (0, 30, 60, and 90 g/tree of treble superphosphate)(Table 8).

Results and Discussion

Height at 3 months tended to increase with increasing levels of nitrogen (Graph 14); however this effect was not significant (95% level). No significant response to phosphorus was observed; however a significant (95% level) interaction effect was found.

At 3 months, the treatment with the greatest height was 25 g/tree of urea plus 60 g/tree of treble superphosphate (Graph 14). These levels of nitrogen and phosphorus are very close to that in the standard fertilization practice (113 grams/tree of DC-153).

The requirement for nitrogen and phosphorus at the Ka'u site will probably be much lower than along the Hamakua coast because of the higher soil fertility at Ka'u (Table 4). Three months, however, is too soon to draw conclusions about the required fertilizer amounts.



Graph 14. The effect of 16 fertilizer treatments on the height of E. saligna 3 months after outplanting at the Ka'u site.

Species Screening Trial at Ka'u

The objective of this experiment is to determine the optimum biomass species on the Alapai and Kiloa soil series at the Ka'u site.

Materials and Methods

Four species of Eucalyptus and one of Acacia were outplanted at a 1.5m x 1.5m spacing in June, 1980. The species were: E. saligna, E. microcorys, E. citriodora, E. botryoides, and A. mangium.

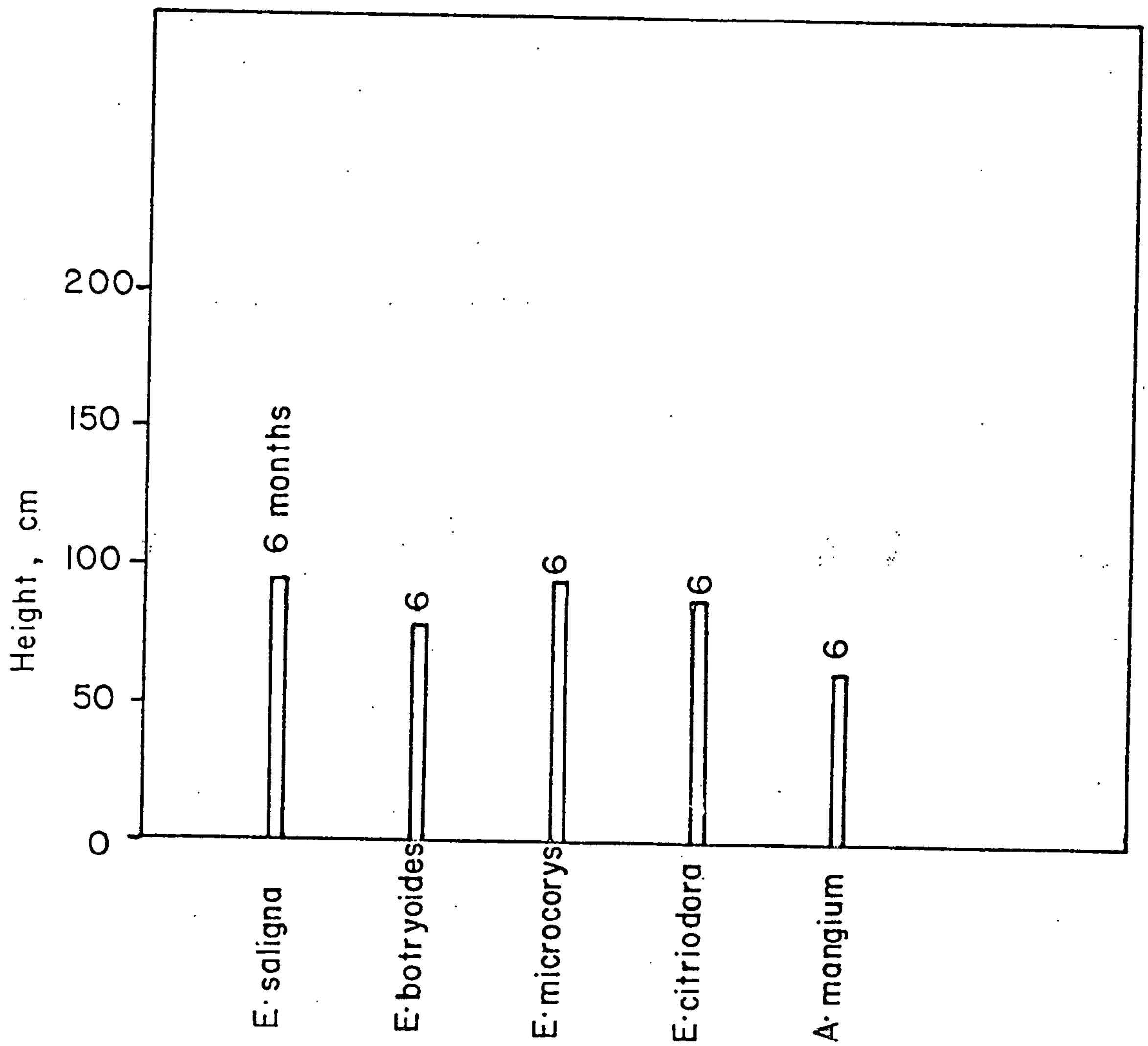
This experiment follows a randomized complete block design with 5 treatments, and 4 replicates on the Kiloa soil series and 4 on the Alapai soil series. Plot size is 13.5m x 13.5m with 81 trees per plot. The inner 25 trees are measured, surrounded by 2 border rows.

Results and Discussion

Eucalyptus saligna and E. citriodora were significantly taller at 6 months (95% level) than the other tree species (Graph 15). Next tallest was E. botryoides, which was significantly taller than E. microcorys. Finally, Acacia mangium was significantly shorter at 6 months (95% level) than the other 4 species (Graph 15).

Six months is too early to draw definite conclusions about the fastest growing species. All that can be said is the E. saligna and E. citriodora had a very rapid initial growth.

Kau Species Trial



Graph 15. Heights of five different tree species at the Ka'u site.

PROVENANCE STUDY

A major concern in biomass plantation establishment with Eucalyptus species in Hawaii is the seed source or genetic quality of the seed. The sources and species of the original Eucalyptus introductions are poorly documented. Many plantings were made by ranchers, sugarcane growers and amateur horticulturists. Often several species were tried in the same planting and those trees that grew well here were used as sources of seed for subsequent plantings. Thus if the flowering times of various species overlapped there was ample opportunity for different species to hybridize. And indeed many young Eucalyptus stands in Hawaii today are variable enough to suggest that they are of interspecific origin, while other stands are highly uniform as though of closely related (or inbred) origin. To begin a tree improvement program for fast-growing Eucalyptus it seemed clear that we would have to establish a more clearly defined genetic base.

Our initial emphasis is on Eucalyptus saligna and E. grandis. E. grandis will give our program a source of disease resistance to the Eucalyptus stem canker that is found in Kauai County, Hawaii.

In 1978, we began establishing small rangewide provenance tests of E. saligna and E. grandis. We obtained from CSIRO, in Australia, 10 collections each of the two species (Table 17). We obtained an additional 15 E. grandis collections made by I. P. Burgess near Coffs Harbour, Queensland (Table 18).

As of January 1980, we have used these seeds to establish four test plantations on C. Brewer lands. Two of the plantings are identical. They each contain the 20 seedlots from CSIRO (Table 17), and are laid out in randomized complete blocks with 12 replications of plots of four trees each. The first planting (established in September 1979) is near Akaka Falls, the northeast coast at 340 m elevation an area with 5100-mm annual rainfall.

The second planting (established in November 1979) in the Ka'u area is on the southwest coast 100 km south of the first site at about the same elevation, but with only about 2500 mm annual rainfall. The rainfall is fairly evenly distributed throughout the year at both sites. The mean annual temperature is about 22^{o} C at the sites and neither site has ever recorded a temperature below 9^{o} C. We plan to establish two more plantings of these same seed sources by June of 1981.

The third established planting on Hawaii was planted in January of 1980 and consists of the 10 CSIRO E. grandis seedlots (Table 17) and the 15 Coffs Harbour E. grandis seedlots (Table 18). The 25 seedlots are planted in a completely randomized design with 95 replications of 1-tree plots. The site is near the first (Akaka Falls) E. saligna/grandis planting. We have repeated this study in August of 1980 near Ka'u, but with the 25 E. grandis seedlots in 12 replications of 4-tree plots.

By the middle of 1981 we will have established six test plantations containing over 8000 source identified seedlings.

We have taken height measurements on the two oldest plantings after six months and one year in the field. After one year the Ka'u planting of E. saligna and E. grandis averages about 2.4 times taller than the same seed sources planted at Akaka Falls. But there is very little difference between the species or among the seed sources within either planting. The overall height of the Ka'u planting is 4.5 meters while the Akaka Falls planting averages 1.9 meters.

Future measurements will include height, diameter and wood density. We will wait until these future measurements are completed before we determine the best selection criteria for trees to use in our short rotation plantations.

Table 17. Seedlots of *Eucalyptus saligna* and *E. grandis* obtained from CSIRO, Australia, and used in provenance tests, Hawaii, 1980

CSIRO seedlot number	Location	Lat°S	Long °E	Alt(m)	Mother trees
		Eucalyptus saligna			
7786	Windsor N.S.W.	32°55'	159°33'	300	12
10225	Cessnock N.S.W.	32°54'	151°24'	300	8
10733	Raymond Terrace N.S.W.	32°42'	151°43'	9	–
7808	Bulahdelah N.S.W.	32°20'	152°12'	210	12
11605	N. Raymond Terrace	31°55'	151°48'	225	39
11894	Gladfield Qld	28°00'	152°23'	1020	–
11756	Clifford Qld	28°30'	151°50'	240	–
12145	Connondale Qld	26°44'	152°31'	600	–
12064	S. of Calliope Qld	24°23'	151°00'	800	1
11025	S.W. Rockhampton Qld	23°49'	149°03'	860	4
		Eucalyptus grandis			
7810	Bulahdelah N.S.W.	32°20'	152°13'	120	11
7823	Coffs Harbour N.S.W.	30°10'	153°08'	18	12
11243	Tyalgum N.S.W.	28°27'	153°12'	100	6
10774	E. of Gympie Qld	26°14'	152°47'	400	6
12143	Crediton Qld	21°09'	148°30'	700	9
11035	N.W. of Cardwell Qld	18°08'	145°37'	600	4
12423	Tinaroo Falls Dam area Qld	17°11'	145°36'	800	13
12422	S.F.R. 310 Gadgarra Qld	17°15'-17°17'	145°42'	680 700	20
12381	Wondecla area Qld	17°23'-17°27'	145°27'-145°28'	980 1040	13
12409	Ravenshoe area Qld	17°42'	145°28'	940	26

Table 18. Eucalyptus grandis seedlots from Coffs Harbour Queensland, Australia, used in provenance studies in Hawaii, 1980.

Seed-lot[1/]	Catchment system	Tributary	Location of sampling site	Latitude °S	Longitude °E	Altitude (m)	Long. dist. to sea (Km)
EK	Hunter River	Minmi Creek	0.5 Km N.W. of Minmi	32°52'	151°39'	31	18.9
EL	Camden Haven - Stewarts River Complex	Herons Creek	Queens Lake S.F.	31°55'	152°48'	30	6.4
EM	Camden Haven - Stewarts River Complex	Black Creek	Lorne S.F.	31°39'	152°32'	250	27.4
EN	Macleay River	Clybucca Creek	Tanban S.F.	30°52'	152°53'	30	11.3
EO	Macleay River	Hickeys Creek	Nulla Five days S.F.	30°43'	152°32'	200	41.8
EP	Mary River	Yabba Creek	Brooloo S.F. 135	26°37'	152°25'	519	67.6
EQ	Clarence River (Orara Branch)	Halfway Creek	Newfoundland S.F.	29°55'	153°07'	76	14.5
ER	Clarence River (Orara Branch)	Taylor Creek	Orara East S.F.	30°13'	153°06'	123	7.2
ES	Clarence River (Orara Branch	Dry Creek	Orara West S.F.	30°15'	152°57'	183	17.7
ET	Clarence River (Northern Branch)	Bean Creek	Yabba S.F.	28°34'	152°36'	396	94.9
EU	Clarence River (Nymboida Branch)	Morora Creek	Wild Cattle Creek S.F. (Cascade)	30°14'	152°51'	580	32.2
EV	Kalang River	Lower Kalang River	Newry S.F.	30°31'	152°58'	6	15.5
EW	Bellinger River	1 Km below Dardanelles Creek	Bellingen River S.F.	30°27'	152°37'	100	66.0
EX	Bonville/Pine Creek	Lower Pine Creek	Pine Creek S.F.	30°24'	153°03'	6	3.3
EY	Bonville/Pine Creek	Upper Bonville Creek	Tuckers Knob S.F.	30°22'	153°00'	107	17.1

1/ Seedlot letters assigned by Institute of Forest Genetics, Placerville, California.

NURSERY STUDIES

Lime Plus Micronutrients Trial

The purpose of this experiment was to determine the effect of lime and micronutrients on E. saligna seedling growth in the nursery.

Materials and Methods

Eucalyptus saligna seed was sown in March, 1980 into potting media with 8 different amounts of amendments. This experiment followed a randomized complete block design with 8 treatments and 5 replicates. The treatments were a 4 x 2 factorial with 4 rates of dolomite (0, 1.20, 2.39, 4.78 g/l) and 2 rates of MicroMax (0, 0.6.8 g/l) (Table 19).

Each treatment per replicate contained 200 "pine cell" seedlings and 30 seedlings were measured for height and root, stem, and leaf dry weights 2 months after sowing.

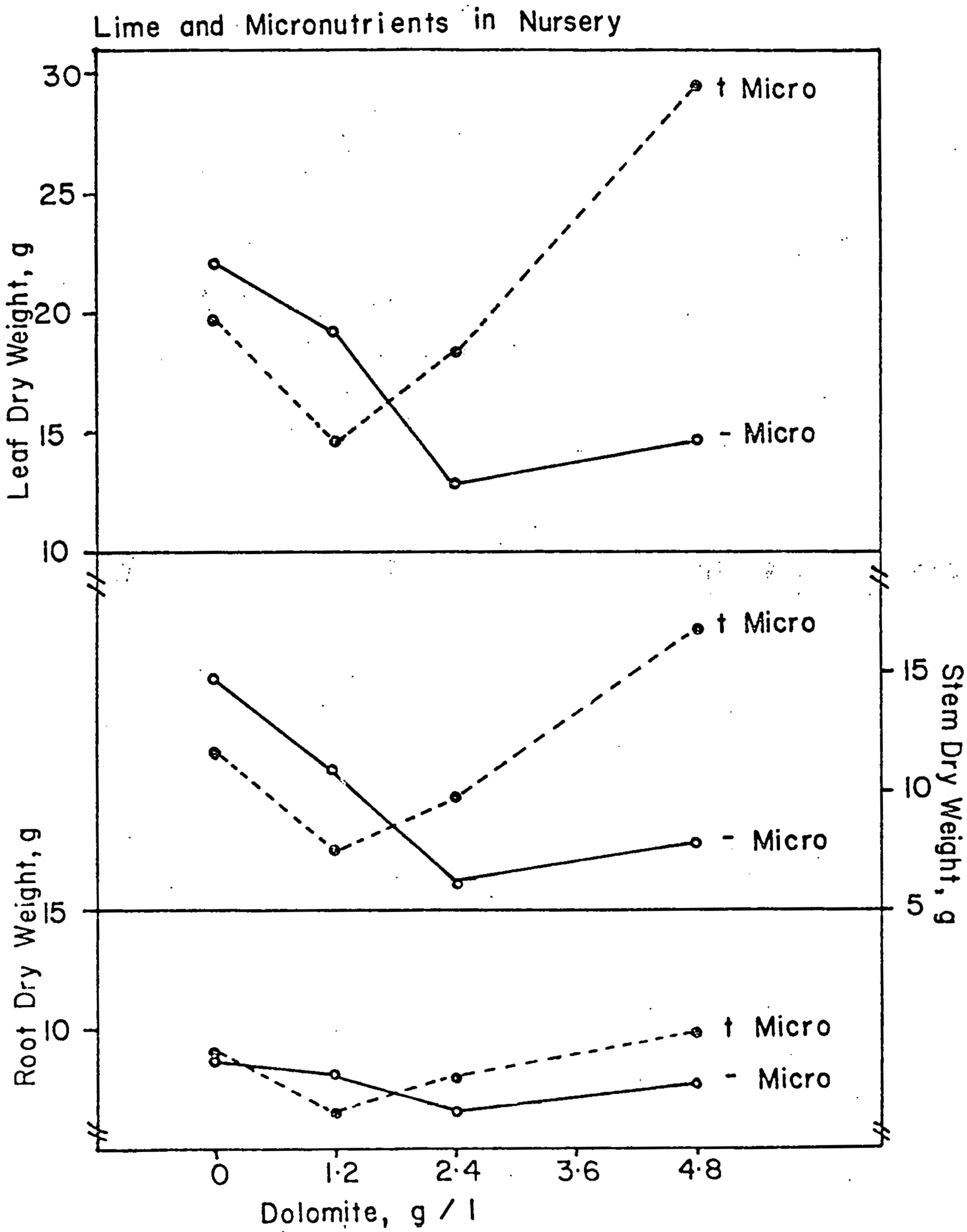
Results and Discussion

The treatment that resulted in the tallest, healthiest seedlings with the greatest dry weights contained 0.68 g/l of MicroMax and 4.78 g/l of dolomite (Graph 16). This treatment, which had the highest level of dolomite and MicroMax, had significantly greater (95% level) leaf dry weights and heights compared to all the other treatments.

Seedlings that lacked MicroMax appeared to branch more profusely with cup-shaped leaves that had scalloped margins. Quereshi (1978) reported that copper deficiency on E. tereticornis was accompanied by deformation of the leaf blades with irregular leaf margins. He found that zinc deficiency resulted in stunted, cup-shaped leaves and stunted plant growth.

Table 19. Rates of fertilizers and amendments used in the lime plus micronutrients test and pH of the potting media.

Treatment	Osmocote g/l	MicroMax, g/l	Dolomite, g/l	Osmocote N, g/l	Osmocote P_2O_5, g/l	Osmocote K_2O, g/l	Dolomite Ca, g/l	Dolomite Mg, g/l	pH
1	3.55	0	0	0.50	0.50	0.50	0	0	3.9
2	3.55	0	1.20	0.50	0.50	0.50	0.22	0.12	--
3	3.55	0	2.39	0.50	0.50	0.50	0.43	0.24	--
4	3.55	0	4.78	0.50	0.50	0.50	0.86	0.48	6.2
5	3.55	0.68	0	0.50	0.50	0.50	0	0	3.7
6	3.55	0.68	1.20	0.50	0.50	0.50	0.22	0.12	4.6
7	3.55	0.68	2.39	0.50	0.50	0.50	0.43	0.24	4.4
8	3.55	0.68	4.78	0.50	0.50	0.50	0.86	0.48	4.4



Graph 16. The effect of micronutrients and lime on E. saligna root, stem and leaf dry weights.

Foliar analysis showed that levels of copper and zinc were significantly lower (95% level) in treatments without MicroMax. It is probable that seedlings grown without the addition of MicroMax were deficient in copper and zinc.

Mag Amp Trial

The purpose of this experiment is to compare the effect of Osmocote (14-14-14) and MagAmp (7-40-6) on *E. saligna* growth in the nursery.

Materials and Methods

Eucalyptus saligna seed was sown in December, 1980 into potting media with 5 different fertilizer treatments. One treatment had Osmocote with MicroMax and dolomite, while the other 4 treatments had MagAmp with varying rates of hydrated lime and MicroMax.

This experiment follows a randomized complete block design with 5 treatments and 4 replicates. Each treatment in a replicate contains 200 "pine cell" seedlings, and after 3 months, 30 seedlings will be sampled for height and dry weight.

Results and Discussion

No data has yet been collected.

Container Size Trial

The purpose of this experiment was to compare the growth of *E. saligna* in three different nursery containers.

Materials and Methods

Eucalyptus saligna seed was sown in July, 1980 into 3 different sized containers (66 cm^3, 132 cm^3, 165 cm^3). This experiment followed a randomized complete block design with 3 treatments and 4 replicates.

Each treatment in a replicate contained 200 seedlings and 20 seedlings were sampled for dry weight 3 months after sowing.

Results and Discussion

Root dry weights were similar among all the treatments; however stem and leaf dry weights were much greater for the Stubby (132 cm^3) and Supercell (165 cm^3) containers (Graph 17). This increased shoot growth resulted in top-heavy seedlings that had to be pruned before outplanting. Different fertilizer regimes are being tested to increase the root to shoot ratio, and reduce the problem of top-heavy seedlings.

Mycorrhizae Inoculation Trial

The purpose of this experiment is to determine whether the fungus *Sclerodema verrucosum*, is mycorrhizal on *Eucalyptus saligna* and *E. grandis*.

Materials and Methods

Fruiting bodies of *Sclerodema verrucosum* were collected from 1 year old plantings of *E. saligna* and *E. grandis* at the Ka'u site. *Eucalyptus saligna* and *E. grandis* seed were sown in October, 1980, either with or without a dusting of spores and into media with or without fruiting bodies.

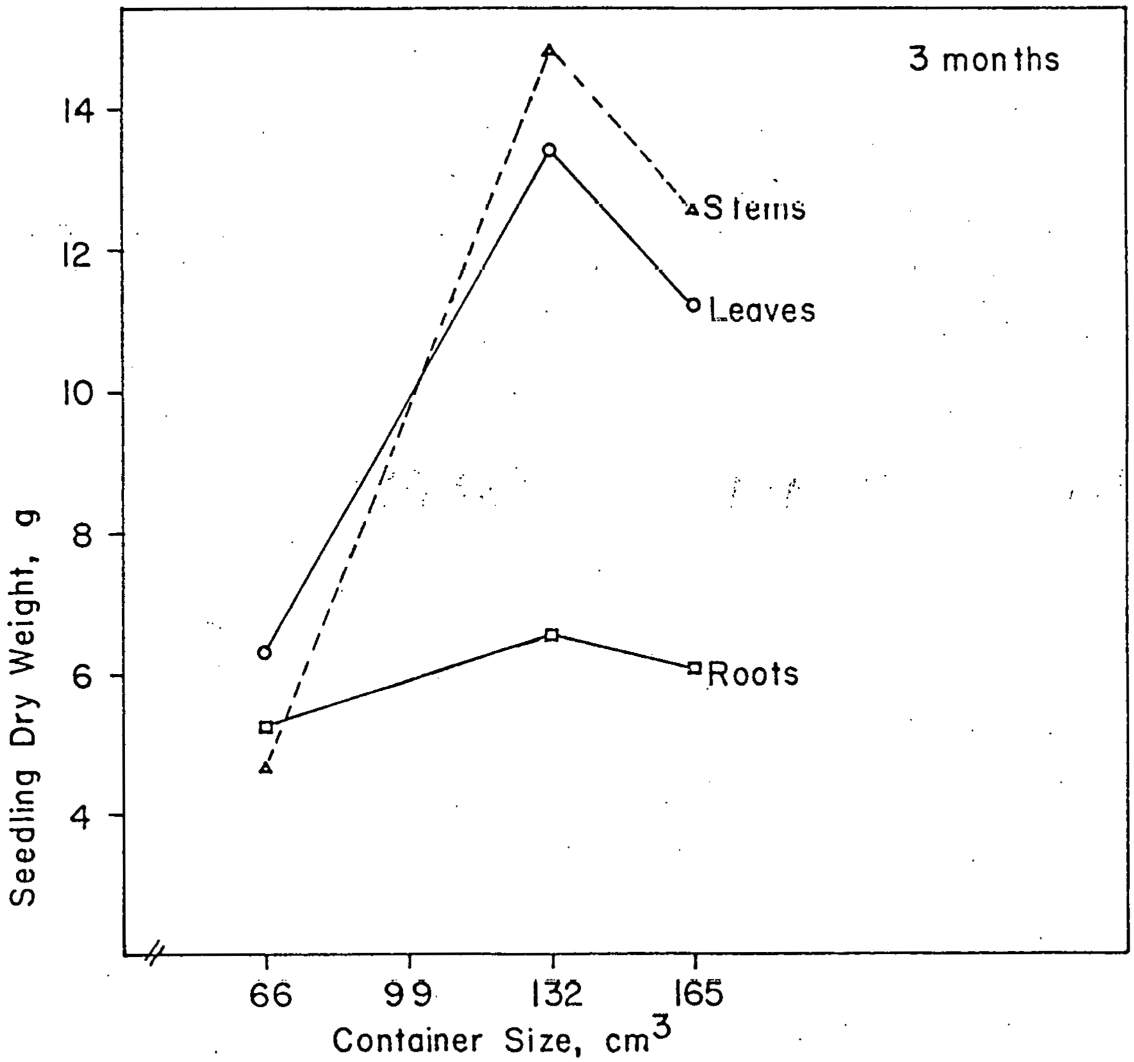
This experiment follows a randomized complete block design with 6 treatments and 4 replicates. Each treatment in a replicate contains at least 5 "Supercell" seedlings.

Results and Discussion

The seedlings were measured for height 2 months after sowing. It was noted that seedlings in the media with fruiting bodies tended to be shorter and have smaller diameters than the controls. After 4 months, the seedlings will be examined for mycorrhizal infection and then conclusions may be drawn.

The research area of mycorrhizal relationships with eucalyptus is one that needs further investigation. Mycorrhizae can increase the surface area of the tree roots and as help in the absorption of phosphorus and microelements. Eucalyptus seedlings inoculated in the nursery with mycorrhizae could have reduced fertilizer requirements and mortality in the field.

Container Size Comparison



Graph 17. Comparison of root, leaf and stem dry weights of E. saligna seedlings 3 months after sowing in 3 different container sizes.

PUBLICATIONS, PRESENTATIONS AND VISITATIONS

Close contacts with Federal, State and County of Hawaii officials which include Hawaii Congressmen, State Officials and Legislators, U. S. Forest Service, Hawaii Forestry Service, U. S. Soil Conservation Service, Farm Bureau and State of Hawaii Energy Extension Service, to name a few.

Presentations and tours were made to numerous professional (Hawaii Island School Teachers, Hawaii Sugar Technologist, Association of University Women, Zonta), civic (Kiwanis, Rotary and Chamber of Commerce), and business organizations (C. Brewer & Co., Ltd. in Hilo and Honolulu), Ka'u Sugar Company), as well as St. Joseph's Elementary School, Hilo High School and University of Hawaii Hilo classes. We have assisted with the East-West Center study groups, environmental (Honua Hawaii), career educational development (Holomua) and benevolent groups such as the Girl Scouts.

We have been filmed for educational television by Belgian and Japanese productions and the subject of numerous articles for local, state and national publications.

Two updated fact sheets were issued (4/15/80 and 9/15/80) and circulated along with a colored brochure (12/1/80). Participation in three Energy Forums and two Energy Conferences was accomplished and a Static Display was exhibited in Hilo's major shopping complex commemorating the 75th anniversary of the County of Hawaii and featuring alternate energy projects. The static display is now being displayed in the other major districts of the island.

Contribution was made at the U. S. Wild Life Conference and the National Conference on Renewable Energy Technologies in the form of a slide presentation as well as chairing a working group at a two-day working conference on Forestry and Related Natural Resources of Hawaii.

We have had the pleasure of meeting many noted and respected officials in the DOE, related businesses, national and international areas such as Belgium, Brazil, Philippines, Scotland, New Zealand, Fiji , Indonesia, Mexico, Canada, Puerto Rico and Sudan.

A trip back to Washington, D.C. to the DOE office was made in March to present a progress report on our accomplishments. I was joint by U. S. Forest Service officials Dr. Stanley Krugman, Dean DeBell and Craig Whitesell.

CHRONOLOGICAL EVENTS AND VISITATIONS

January 1980

...USDA Project Visitation.

...HSPA Project Visitation.

February 1980

...Hawaii County R&D Director - Project Visitation.

...Linda Dolan, Seattle City Light Project Manager - Project Visitation.

...University of Hawaii Hilo College of Agriculture - Slide Presentation.

...Association of University Women - Slide Presentation.

...Charles Philpott, Ass't. Pacific Southwest Director. U.S. Forest Service - Project Visitation.

March 1980

...Kona Energy Conference - Display and Slide Presentation.

...University of Hawaii Energy Forum at Ka'u - Slide Presentation.

...Kohala Field Day - Booth and Display

...Washington, D.C. - Progress Report (slide presentation) to Sarah Sprague, DOE Project Manager.

...Progress Report to Hawaii Congressmen while in Washington D.C.

...Progress Report to Bill Lambert, DOE Project Coordiantor in Oakland Office enroute to Washington, D.C.

...Kona Outdoor Circle Forum - Slide Presentation.

...Dean DeBell, Research Director, Olympia, Washington - Project Cooperative Review.

...Asaeli Tuiniavou, Fijii Forest Service, Fijian Government - Project Visitation.

April 1980

...Zonta Club - Slide Presentation.

...Marcia Reynolds (Tribune Herald), Hugh Clark (Honolulu Advertiser), Layne Thompson (Honolulu Star Bulletin) Reporters - Project Visitation with accompanying articles.

...Updated Fact Sheet for inclusion in the 1980 Energy Edition of the University of Hawaii.

...Environmental Resource Community Advisory Committee - Project Review and Visitation.

...University of Hawaii Energy Forum at Kamuela - Slide Presentation.

May 1980

...East-West Center Environmental Group Study - Project Visitation.

...St. Joseph's School Brownie Scout Troop - Nursery Visitation.

...Andrea Gill Bennett, Field Representative, State of Hawaii Energy Extension Service - Project Visitation.

...KPUA Hawaii Island Chamber Day - Radio Presentation on Project Objectives.

...Duke Perrin, Energy Planner, Los Angeles City - Project Visitation.

June 1980

...Jack Ranney, Project Technical Advisor, Oak Ridge, Tennessee - Two-day Project Visitation and Review.

...Hilo High School (120 students) - Slide Presentation.

...John Ramsey, Pacific News Special Project Editor - Project Visitation and accompanying article.

...Helen Braunstein, Oak Ridge - Project Visitation.

...Craig Morse, Energy Resources, University of California - Project Visitation.

...Linda Christanty, Ecologist from Indonesia - Project Visitation.

...Mac D. Bowan, American Carbon, Inc. - Project Review.

...Charles Philpott, Assistant Director, U.S. Forest Service, Pacific South West - Project Visitation and Review.

...Mrs. Krueger, Bank of Hawaii Researcher - Project Review.

July 1980

...C. Brewer & Co., Ltd. Board of Directors and Corporate Officers Annual Meeting - Project Review and Visitation.

...Jane Lipson, Consultant to Governor Ariyoshi based in Washing, D.C. - Project Visitation

...Jim Moureau, Dillingham Company and Dr. Bruebaker, U.H. Manoa Campus - Project Review and Visitation.

...Jane Wholly, Lilton Publication Writer, Article on Energy - Project Review and Visitation.

...Al Nakaji, Energy Coordinator of County of Hawaii - Project Visitation and update on progress.

...Mr. Sakaiya, Cinesill TV Production - Japan group filming on Energy Documentary. (Program on October 2, 1980 in Japan)

...Static Display in Kaiko'o Mall celebrating County of Hawaii 75th Anniversary and featuring alternate energy projects.

...State Representative Yoshito Takamine - Visitation & Project Review.

August 1980

...Marty Domagala, DOE Assistant Administrator Region IX - Project Visitation.

...Robert Wade Zahare, Mainland Planting Service - Project Visitation.

...Michael Buck, U.S. Forest Service - Project Visitation.

...Kipling Adams, Director of Agricultural Administration, A & B - Project Visitation.

...Hamakua Soil Conservation District Committee - Project Visitation.

...Steve Norris, Honua Hawaii - Project Visitation.

September 1980

...Energy Symposium, Hilo Panel Member, sponsored by Hawaii Economic Opportunity Council - Project Presentation.

...Bob Clayton, U.S. Forest Service - Project Visitation.

...John Rowlands, State & Private Forestry, California - Project Visitation.

...Cal Masaki, State Forestry, Honolulu - Project Visitation.

...Gaylen Kurokami, State Forestry, Kauai - Project Visitation.

...Glen Shishido, State Forestry, Maui - Project Visitation.

...Ernest Pung, State Forestry, Hawaii - Project Visitation.

...Update Progress Report - "Two Years Later--The BioEnergy Experience".

...Environmental Resource Community Advisory Committee Meeting - Progress Report and Visitation.

...Sergio Macasieb, Project Manager, National Power Co., Philippines - Project Visitation.

...Dr. Boner, Professor, University of Washington, U.S. State Dept. - Sponsored Visitation in conjunction with Sergio Macasieb.

October 1980

...State Forestry Wild Life Conference - Slide Presentation.

...University of Hawaii Hilo Campus Agricultural Class - Project Visitation.

...Dr. Robert Callaham, Director, Pacific Southwest - Project Review and Visitation.

...James Lee, U. H. Community College - Project Visitation.

...Honua Hawaii - Slide Presentation and Project Visitation.

...Congressman Dan Akaka - Washington Update.

November 1980

...Dr. Jean Matre, Correspondent - Project Visitation.

...Dr. Paul Yuen, Director HENA and Ralph Fujita, Manager, Technical Liaison for PRI - Project Visitation.

...North American Forestry Commission, Silverculture Study Group - Project Visitation.

*Robert Nunez, Forest Administrator, National Forest Service - Mexico

*Javier Chauelas, Research Scientist, National Forest Service - Mexico (Chiapas).

*Frank Wadsworth, Research Forester, Institute of Tropical Forestry - Puerto Rico.

*Frank Shrapshire, Hardwood Specialist, Forest Service, Jackson, Mississippi.

*James T. Arnott, Leader of Silviculture Research, Western Canada - Vancouver.

*Thomas Geary, Research Forester & Project Leader, Eucalyptus Specialist, Lehigh Acres, Florida (U.S. Forest Service).

*Robert Phares, Assistant Director, Northeastern Forest Experiment Station, Morgantaun, VA (U.S. Forest Service, Hardwood Authority).

*Roger Skolmen, Research Forester and Project Leader, I.P.I.F., Honolulu.

December 1980

...Marsha Oato, Holumua, Career Educational Development - Project Visitation and Cooperative work program.

...Gordon Chapman, Parsons of Hawaii and Kenneth Klein, DOE - Project Visitation.

...Hawaii Electric Light Co., Professional Photographer - Project Visitation to include BioEnergy Development Corp. in Annual Report

...John Quinn, Doe, Washington, D.C., Director of Planning - Project Visitation.

...National Energy Conference of Island Tour - Project Visitation (60 people).

COOPERATING AGENCIES AND PERSONNEL

Institute of Pacific Islands Forestry

Charles Hodges, Chief Pathologist
Roger Skolmen, Silviculturist
James King, Forest Geneticist
Gerry Walters, Research Forester
Janet Morse, Technical Information Specialist
George Hashimoto, Forestry Technician

State Forestry Division

Libert Landgraf, Chief Forester
Charles Wakida, District Forester
Howard Horiuchi, Assistant Forester

Soil Conservation Service

Larry Soehnen, District Conservationist
Saku Nakamura, Soil Scientist
Patrick Watanabe, Soil Conservationist
Jack Sprague, District Conservationist
Jerry Williams, Soil Conservationist
Larry Shinshiro, Soil Conservationist

University of Hawaii

Yusuf Tamimi, Soil Scientist
Samu El-Swaify, Soil Scientist
Ed Dangler, Assistant Soil Scientist
Andrew Lo, Graduate Student
Ernest Okazaki, Soil Scientist
Roger Watanabe, Assistant Specialist in Soil Science

Hawaiian Sugar Planters' Association

George Mikami, Experimentalist

Mauna Kea Sugar Company

Stephen Knox, Vice President and Manager
Ken Kunimitsu, Crop Control Superintendent
Randy Cabral, Field Superintendent
Isao Kaya, Agriculturist

Ka'u Sugar Company

Ian Bowman, Vice President and Manager
Iwao Yonemitsu, Crop Control Superintendent

Hilo Coast Processing Company

Terry Inglett, Executive Vice President & Chief Executive Officer
Larry Iwami, Power Plant Superintendent
Clarence Montgomery, Production Superintendent
Bryce Robinson, Construction Superintendent

Mauna Loa Macadamia Nut Corporation

Paul Bennett, Vice President and General Manager - Operations
Dale Anderson, Orchard Manager - Ka'u

Brewer Analytical Lab

Takashi Nonaka, Manager

Brewer Chemical Corporation

Mel Smith, Vice President, Sales
Dan Shon, Sales Engineer

Sierra Chemical

Karl Kolb, Technical Service Director

Occidental Chemical

Noel Ide, Technical Sales Representative

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...Jerry Allen, Vice President, Energy

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...Bill Lambert, Project Coordinator - Oakland Office

USDA - U.S. Forest Service

...Dr. Robert Callaham, Director - Pacific Southwest, Riverside, Calif.
...Charles Philpott, Ass't. Director, Pacific Southwest, Riverside, Calif.
...Dr. Roger Skolmen, Research Forester - Honolulu, Hawaii
...Craig Whitesell, Research Forester - Project Coordinator, Honolulu, Hawaii

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Mauna Kea Sugar Company, Inc.

...Steve Knox, Vice President/Manager, and Staff

Hilo Coast Processing Cooperative

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Mauna Loa Macadamia Nut Corp.

...Paul Bennett, Vice President/Manager, and Staff

BioEnergy Development Corp.

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