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COMMUNITY GEOTHERMAL TECHNOLOGY PROGRAM

BOTTOM HEATING SYSTEM USING GEOTHERMAL POWER FOR PROPAGATION

Conducted by

James C. Downing

1990

PREFACE

This is a report of work performed for the Community Geothermal Technology Program, a small grant program administered jointly by the Hawaii Natural Energy Institute and the State of Hawaii Department of Business, Economic Development and Tourism.

This project was one of five funded under the second phase of the program, which was awarded in 1988. Funds for this phase were provided by the U.S. Department of Energy, the County of Hawaii, and donations from private businesses.

The opinions expressed in this report are those of the author, and are not necessarily shared by the program administrators, funding agencies, or others involved in the program. Responsibility for the accuracy of the data provided in this report lies with the author.

The enthusiasm, talents, and efforts of the grantees are much appreciated, and I look forward to continuing to work with them and with future users of geothermal heat and by-products.

Andrea Gill Beck, Administrator
Community Geothermal Technology Program

Hawaii Energy Extension Service
Dept. of Business, Economic Development & Tourism
99 Aupuni St. #214
Hilo, HI 96720

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INTRODUCTION

Leilani Foliage is a commercial nursery, certified for live plant export, established in 1985 and specializing in palms. A major cost in the business is the purchase of palm seeds. Prices can vary from as little as $4.00 a thousand to $300.00 a thousand (Table 1). Germination rates vary widely too, depending on the species of seed, freshness, and temperatures. The goal of our project has been to develop and study a bottom-heating system in a greenhouse utilizing geothermal energy to aid germination and speed growth of different varieties of palms.

We were awarded $11,350 from the first phase of the Community Geothermal Technology Program to perform our research and received this grant in 1986. Under the second phase of the program, we received $3,610 to continue our research in 1988. We completed our project in September 1989.

We were concerned with the different growth rates of seeds at different media temperatures. We collected data from two sites: the greenhouse at Noi'i O Puna (the Puna Geothermal Research Center) and a similar greenhouse without bottom heat at Leilani Foliage.

In previous years, in an experiment we funded ourselves, Leilani Foliage had used a propane-fired bottom-heating greenhouse system to aid germination. The design was similar to the one constructed for the geothermal experiment, except that the hot water was supplied by a standard residential gas water heater installed at the greenhouse. The cost for bottom heating with propane was discouraging, however, and this greenhouse, through still in use, is not currently heated. Heating costs will vary with the weather, but were approximately 10.5 cents per square foot per month.

Our project has been successful. We learned that the heat made a dramatic difference with certain varieties, such as the *Areca catechu* (betelnut) with an 82 percent germination rate with heat, 0 percent without heat. With other varieties the germination rates were much closer. The results are detailed in Appendix B.

We remain very interested in geothermal bottom heating and would like to expand our heated greenhouse to a commercial size should sufficient acreage at a competitive price and with access to hot geothermal fluids become available.

SUMMARY OF WORK

GREENHOUSE CONSTRUCTION

In February 1986 we began by ordering material for our project. We built a 10-foot-by-20-foot greenhouse next to the geothermal laboratory building, Noi'i O Puna, operated by the Natural Energy Laboratory of Hawaii (NELH) as part of its Puna Geothermal Facility. Most stages of the construction of the greenhouse went smoothly. The greenhouse is a simple fiberglass structure (Photo A, Appendix C). Inside are three raised wooden benches and an overhead sprinkler system. The benches are overlaid with corrugated fiberglass roofing material. The plumbing system, purchased from the Biotherm Company in California (Photo B, Appendix C), distributes the hot water through the tubing that runs along the depressions in the corrugations the length of the benches within the greenhouse. The plastic flats of seed are placed on top of the corrugated material, above the tubing on the benches.

The source of heat was geothermal brine from the HGP-A well, which was run through NELH's heat exchanger inside the Noi'i O Puna laboratory building. Fresh water from the county water supply was heated by this means, ideally to 110° to 120° F, and pumped to our greenhouse next to the lab building. A small, used residential electric water heater was installed at the greenhouse to provide backup heating.

The water then entered the Biotherm system, which was made of CPVC and rubber tubing. These materials are chemical resistant and won't deform beneath the weight of the seed flats. A thermostat-operated circulation pump was installed to control the flow of hot water within the greenhouse. After heating the growing media to an ideal of 90° F, the water exited the greenhouse at about 95° F and was recirculated to the heat exchanger.

DATA GATHERING

By mid-October 1986 the greenhouse was completed, the plumbing installed, and the system turned on. Unfortunately, the first heat exchanger installed by NELH did not provide enough warmth and required close monitoring to prevent its shutting down. We had flats of seed in the greenhouse which benefited from these months of intermittent heat, but we were unable to collect reliable data. We needed a more constant heat source.

In late April 1987 a new and more reliable heat-exchanging system was installed. We then began research, collecting data on the new palm seed we had prepared. We used different varieties than originally proposed because we had to use seed which was fresh and available. Freshness of the seed is the most important factor in determining germination. We experimented on about 30 varieties of palms and with two other ornamentals (*Lea rubrum* and *Strelitzia nicolai*). Once we had a reliable system, we spent two to three hours weekly monitoring the seeds and maintaining the house. We continued to prepare new seed.

We compared two sites: the Noi'i O Puna greenhouse heated by geothermal fluids with media temperatures of 85° to 95° F and the Leilani Nursery propagation house with media temperatures no lower than 60° F. We were concerned with the difference in growth rates of palms at these different media temperatures.

All seed husks were removed when possible. The seeds were then placed in a 17-inch-by-18-inch plastic flat which contained a growing medium. For Phase I a 50:50 mixture of fine black cinder and peat moss was used. In Phase II the mix was 50:50 perlite and peat moss. An adequate moisture level was maintained at both sites, as well as a regular pesticide spraying program.

We collected three types of data: 1) length of time from planting to first evidence of germination, 2) length of time from planting to transplant maturity, and 3) percent of germination. The data of first evidence of germination was taken when five sprouts had emerged from the media in a given flat. For most species, transplant maturity was when the second leaf matured. Percentage of germination was determined by count at the time of transplanting. All dates and counts have been recorded on the data sheets in Appendix B. We have included photographs of palms grown at both sites in Appendix C.

For Phase II of our project no changes were made in the greenhouse setup, planting method, or data gathering. The second phase of the funding allowed for additional tests on 16 palm varieties.

PROBLEMS ENCOUNTERED

Most of the problems encountered during our experiment had to do with the reliability of hot water delivered from Noi'i O Puna. As previously mentioned, the original heat exchanger installed by NELH was inadequate. In addition, the backup electric water heater was too small and could not adequately supply hot water. As a result, it was not used after NELH replaced its laboratory heat exchanger, even though the hot water supplied by that equipment was also unreliable.

The unreliable heat supply was complicated by the failure of the circulation pump thermostat due to corrosion, which we suspect was related to the trace hydrogen sulfide emissions at the laboratory. After the thermostat became inoperable, the water temperature varied from around 80° F — almost ambient temperatures — to as high as 130° F. The resulting growing media temperatures varied from 70° to 90° F. However, no problems with palm growth due to overheating were identified. It is likely that steady heating would provide more reproducible results.

It is also worth noting that, despite the greenhouse's proximity to the geothermal fluid disposal ponds and resulting trace hydrogen sulfide emissions, no damage to our palms was seen. On the contrary, the palms grown at Noi'i O Puna were, on the whole, healthier and more vigorous than those grown at Leilani Foliage as controls, a fact which we attribute to the beneficial effect of bottom heating.

Other problems were related to the design of the system. The irrigation sprinklers did not supply water evenly throughout the greenhouse, and the method of laying the hot water tubes along corrugations beneath the seed flats could be improved by burying the tubes in a substance such as perlite to provide more even heating. There were also intermittent leaks of the Biotherm system, some of which were due to the roots of one palm species, *Chamaedorea elegans*, penetrating the tubing.

In several cases we received what we believed were bad seed from our suppliers. However, to obtain a credit from the suppliers, the seed must be planted and poor germination demonstrated. The bad batches of seed should be taken into consideration when evaluating our growth data. The plantings which we believe used old seed are noted in our data sheets in Appendix B. In addition, some rats caused damage to the seeds of one species planted at Noi'i O Puna, so data comparing heated versus unheated growth for certain batches of these seeds were not available, as noted in Appendix B.

DISCUSSION OF RESULTS

The results of our study show that, for most of the varieties of seed tried, germination was significantly aided by the bottom heat. Germination was improved to some degree in every case by the heating, and in most cases the growth rate also benefited significantly. For a few varieties the germination rates were nearly the same at both sites, although in some cases other factors (such as reduced growing time or particularly expensive seeds) make bottom heating favorable for these species as well. For a number of varieties germination was very poor with or without heat, which was almost certainly due to the poor quality of those batches of seed.

The quality of the seed is vital to good germination and growth, and seed quality varies widely in the commercial nursery business. Although seeds can be physically inspected (i.e., cut open and examined for a viable embryo) before planting, this is not our usual practice because it is very labor-intensive and also does not guarantee that a typical cross-section of the batch is tested. Rather, it is accepted practice to plant all seeds, even those suspected of being poor quality, and to demonstrate from the germination rate whether the seeds were fresh. Our experience with many palm varieties over the years provides the background for a judgement on whether the seeds' germination was adequate since we know approximately what to expect of each variety.

It is not uncommon to get bad seed, as can be inferred from the number of poor responses listed in the data sheets of Appendix B. Reliable suppliers will refund money spent on seed which is demonstrated to be of poor quality. Seed can be spoiled for a variety of reasons, including age, harvesting before it is ripe, or drying practices. Some varieties, such as *Ravenea rivularis* from Madagascar, are viable for only two weeks; most species average two months and are thus more tolerant of shipping delays. Some palm seeds, such as those of *Chamaedorea elegans*, must be dried at moderate temperatures under cover rather than in the heat of full sun exposure, and others need no drying at all. The frequency with which we obtain seeds of poor quality emphasizes the importance of improving the germination rates by bottom heating.

There are several major economic benefits of bottom heating:

1) Higher germination rates — with more plants germinating seed money is not wasted, and sales income is increased;

2) Faster growth — with the palms ready for transplanting several months earlier than normal, bottom heating leads to faster sales and product turnover;

3) Uniform size — the heating causes even growth, which means the plants are easier to market; and

4) Improved health — because of the better growing conditions in the bottom-heated flats, the palms were healthier and less susceptible to disease.

The price of ornamental palm seeds has a wide range (Table 1). With a variety such as *Trachycarpus fortunei*, which costs $4 for 1,000 seeds, a poor germination rate has less of an economic impact than with an expensive palm, such as *Areca catechu* (betelnut), which cost $300 per 1,000 seeds. We planted *Areca* twice during the first phase of the project and found tremendous improvement in germination with the bottom heating: in one planting 82 percent of the heated seeds germinated, while none of those planted in unheated flats sprouted at all. A later planting, perhaps with fresher seeds, showed 87 percent of the heated seeds sprouting, while only 33 percent of the unheated seeds germinated. In the latter case, it could be said that, for every 1,000 *Areca* seeds planted in both heated and unheated flats, $201 was "wasted" on the unheated batch while only $39 was lost in seeds that didn't germinate in the heated flats.

Palm varieties which responded well to bottom heating are listed in Table 2, and all results are detailed in Appendix B.

Two things we would do differently on the project are the bench design and the irrigation. By burying the hot tubing in a material such as perlite, the heat could be more evenly distributed and a more constant moisture level maintained. To improve the irrigation system, we would use a misting system actuated by a moisture sensing device rather than by a timer.

Table 1. Approximate Cost of Seed for Selected Ornamentals

Areca catechu	$300.00/thousand
Phoenix reclinata	150.00/thousand
Lea rubrum	50.00/thousand
Pigafetta filaris	50.00/thousand
Veitchia merrillii	35.00/thousand
Archontophoenix cunninghamiana	30.00/thousand
Cocothrinax	30.00/thousand
Bismarkia noblis	28.00/thousand
Pritchardia pacifica	20.00/thousand
Arecastrum romanzoffianum	10.00/thousand
Trachycarpus fortunei	4.00/thousand
Livistona rotundifolia	25.00/pound
Livistona chinensis	5.50/pound

Table 2. Ornamental Species Showing Significant Improvements in Growth Rates and/or Germination with Geothermal Bottom Heating

Aiphanes caryotafolia
Archontophoenix cunninghamiana (seaforthia)
Areca catechu (betelnut)
Arecastrum romanzoffianum (queen palm)
Bismarkia noblis
Carpenteria accuminata
Caryota mitis
Chamaedorea elegans
Chamaedorea falcifera
Chrysalidocarpus lucubensis
Chrysalidocarpus lutescens
Cocothrinax
Lea rubrum
Licuala spinosa
Livistona chinensis (Chinese fan palm)
Livistona rotundifolia (footstool palm)
Livistona rotundifolia luzonensis
Neodypsis decaryii
Phoenix canaryensis
Phoenix reclinata
Phoenix robellini
Pigafetta filaris
Pritchardia pacifica
Ravenea rivularis
Roystonea regia (royal palm)
Strelitzia nicolai
Trachycarpus fortunei (windmill palm)
Veitchia merrillii (Manila palm)

APPENDIX A

BUDGET SUMMARY, PHASE I

Cost Category	Amount from Grant	Amount from Cost Sharing	Total
EQUIPMENT	$0.00	$0.00	$0.00
MATERIALS AND SUPPLIES			
Plumbing system	$1,169.64	$0.00	$1,169.64
Irrigation parts	372.07	0.00	372.07
Greenhouse building material	1,633.97	0.00	1,633.97
Seed	5,568.64	2,494.39	8,063.03
Planting supplies	0.00	631.00	631.00
Subtotal	$8,744.32	$3,125.39	$11,869.71
SALARIES			
Construction labor	$130.00	$0.00	$130.00
Systems installation labor	217.00	0.00	217.00
Operational labor	800.00	1,600.00	2,400.00
Transport labor	0.00	1,296.00	1,296.00
Subtotal	$1,147.00	$2,896.00	$4,043.00
OTHER COSTS			
Transport, delivery charge	$110.00	$90.00	$200.00
Film and developing	10.00	45.00	55.00
Leilani Foliage space ($5.00/sq. ft./year)	18.68	900.00	918.68
Required insurance	120.00	0.00	120.00
Facility use fee: $100/mo. x 12 mo.	1,200.00	0.00	1,200.00
Subtotal	$1,458.68	$1,035.00	$2,493.68
TOTAL	**$11,350.00**	**$7,056.39**	**$18,406.39**

APPENDIX B

DATA SHEETS
(Alphabetical Order)

Seed-Plant Name	Site*	No. Flats Planted	Date Planted	Date Germination Begins	Date Transplant Maturity	Germination % Count	Notes
Aiphanes	NP	1	7/5/88	10/14/88	12/27/88	31%	
caryotafolia	LP	1	7/5/88	2/12/88	6/1/89	2%	
Archontophoenix	NP	2	10/21/87	12/15/87	2/1/88	68%	
cunninghamiana	LP	3	10/21/87	12/28/87	4/4/88	42%	
(seaforthia)							
Areca	NP	2	1/23/88	2/10/88	3/28/88	82%	
catechu	LP	1	1/23/88	—	—	0%	
(betelnut)							
Areca	NP	9	4/1/88	5/12/88	8/1/88	87%	
catechu	LP	2	4/1/88	7/10/88	10/4/88	33%	
(betelnut)							
Arecastrum	NP	8	9/24/87	11/3/87	2/8/88	48%	
romanzoffianum	LP	2	9/24/87	12/1/87	3/15/87	0.3%	
(queen palm)							
Arecastrum	NP	1	2/21/88	5/2/88	8/10/88	22%	
romanzoffianum	LP	1	2/21/88	6/28/88	10/1/88	2%	
(queen palm)							
Arecastrum	NP	10	10/9/88	12/1/88	4/1/89	37%	
romanzoffianum	LP	1	10/9/88	1/4/89	8/23/89	3%	
(queen palm)							
Bismarkia	NP	8	7/18/87	9/15/87	2/19/88	62%	
noblis	LP	4	7/18/87	10/20/87	6/2/88	21%	
Blue latan	NP	4	2/20/88	4/25/88	7/28/88	2%	bad
	LP	2	2/20/88	5/7/88	9/3/88	0.3%	seeds
Carpenteria	NP	4	1/10/89	4/1/89	11/1/89	29%	
accuminata	LP	1	1/10/89	—	—	0%	
Caryota	NP	5	11/16/88	1/4/89	4/1/89	71%	
mitis	LP	4	11/16/88	1/29/89	6/3/89	23%	

* NP - Noi'i O Puna (bottom heated)
LP - Leilani Propagation House (unheated)

Seed-Plant Name	Site*	No. Flats Planted	Date Planted	Date Germination Begins	Date Transplant Maturity	Germination % Count	Notes
Chamaedorea	NP	20	5/25/88	8/1/88	11/23/88	77%	
elegans	LP	10	5/25/88	10/28/88	4/7/89	58%	
Chamaedorea	NP	35	8/6/88	11/1/88	2/15/89	69%	
elegans	LP	4	8/6/88	2/5/89	7/6/89	52%	
Chamaedorea	NP	7	5/20/87	9/8/87	—	0.3%	bad
ernestii augusti	LP	1	5/20/87	9/20/87	—	0%	seeds
Chamaedorea	NP	6	1/27/88	4/1/88	7/31/88	61%	
falcifera	LP	1	1/27/88	—	—	0%	
Chrysalidocarpus	NP	4	1/10/89	3/2/89	5/28/89	77%	
lucubensis	LP	5	1/10/89	4/7/89	7/10/89	52%	
Chrysalidocarpus	NP	4	7/5/88	8/1/88	10/6/88	82%	
lutescens	LP	6	7/5/88	8/16/88	11/23/88	71%	
Cocothrinax	NP	1	2/20/88	4/15/88	7/6/88	31%	
	LP	1	2/20/88	—	—	0%	
Copernica	NP	1	3/2/88	4/29/88	6/28/88	2%	bad
cerifera	LP	1	3/2/88	—	—	0%	seeds
Cyrtostachys	NP	3	2/28/88	—	—	0%	bad
lakka	LP	1	2/28/88	—	—	0%	seeds
Laccospadix	NP	6	4/9/87	7/6/87	1/14/88	43%	
	LP	1	4/9/87	7/17/87	1/15/88	40%	
Lea rubrum	NP	4	12/23/87	1/15/88	5/1/88	12%	
	LP	1	12/23/87	—	—	0%	
Licuala	NP	1	9/3/88	4/7/89	9/10/89	48%	
spinosa	LP	1	9/3/88	6/2/89	2/4/90	6%	
Livistona	NP	2	2/6/88	3/8/88	4/29/88	85%	
chinensis	LP	2	2/6/88	5/3/88	6/1/88	63%	
(Chinese fan palm)							
Livistona	NP	4	2/20/88	2/29/88	7/14/88	56%	
chinensis	LP	18	2/20/88	4/29/88	9/3/88	29%	
(Chinese fan palm)							

* NP - Noi'i O Puna (bottom heated)
LP - Leilani Propagation House (unheated)

Seed-Plant Name	Site*	No. Flats Planted	Date Planted	Date Germination Begins	Date Transplant Maturity	Germination % Count	Notes
Livistona	NP	4	7/11/87	8/23/87	12/21/87	0.2%	bad
rotundifolia	LP	2	7/11/87	—	—	0%	seeds
(footstool palm)							
Livistona	NP	11	12/24/87	2/19/88	3/29/88	31%	
rotundifolia	LP	4	12/24/87	3/15/88	5/25/88	2%	
(footstool palm)							
Livistona	NP	4	4/1/88	5/14/88	7/26/88	69%	
rotundifolia	LP	1	4/1/88	6/1/88	8/23/88	48%	
(footstool palm)							
Livistona	NP	3	1/10/89	3/16/89	5/29/89	58%	
rotundifolia	LP	1	1/10/89	5/2/89	8/1/89	14%	
(footstool palm)							
Livistona	NP	2	1/23/88	2/25/88	3/28/88	36%	
rotundifolia	LP	1	1/23/88	—	—	0%	
luzonensis							
Neodypsis	NP	10	7/5/88	7/27/88	10/6/88	79%	
decaryii	LP	3	7/5/88	8/11/88	11/23/88	43%	
Neodypsis	NP	8	7/21/87	9/29/87	1/30/88	1%	bad
lestelliana	LP	4	7/21/87	10/17/87	1/15/88	2%	seeds
Normanbya	NP	6	8/11/88				crop
	LP	2	8/11/88				failure
Phoenix	NP	4	6/20/88	8/1/88	9/14/88	80%	
canaryensis	LP	2	6/20/88	8/14/88	9/25/88	73%	
Phoenix	NP	1	7/11/87	8/14/87	1/11/87	3%	bad
reclinata	LP	1	7/11/87	8/22/87	2/15/88	1%	seeds
Phoenix	NP	1	10/21/87	11/15/87	3/10/88	74%	
reclinata	LP	1	10/21/87	1/2/88	4/28/88	53%	
Phoenix	NP	10	2/20/89	5/27/89	8/19/89	78%	
robellini	LP	2	2/20/89	7/28/89	10/3/89	69%	
Pigafetta	NP	2	1/27/88	2/9/88	3/22/88	58%	
filaris	LP	2	1/27/88	3/13/88	5/11/88	41%	

* NP - Noi'i O Puna (bottom heated)
LP - Leilani Propagation House (unheated)

Seed-Plant Name	Site*	No. Flats Planted	Date Planted	Date Germination Begins	Date Transplant Maturity	Germination % Count	Notes
Pritchardia	NP	6	6/6/87	6/27/87	8/14/87	82%	
pacifica	LP	2	6/6/87	7/17/87	10/10/87	59%	
Pritchardia	NP	6	1/10/89	3/18/89	5/24/89	48%	
pacifica	LP	1	1/10/89	5/13/89	7/28/89	19%	
Ravenea	NP	8	3/21/88	—	—	0%	bad
rivularis	LP	2	3/21/88	—	—	0%	seeds
Ravenea	NP	9	3/26/88	4/25/88	6/12/88	0.5%	bad
rivularis	LP	2	3/26/88	5/4/88	6/12/88	0.1%	seeds
Ravenea	NP	10	10/15/88	11/6/88	4/5/89	62%	
rivularis	LP	1	10/15/88	11/22/88	5/12/89	41%	
Red latan	NP	1	2/20/88	4/30/88	6/18/88	12%	bad
	LP	1	2/20/88	6/2/88	8/16/88	2%	seeds
Roystonea	NP	4	10/27/87	12/8/87	4/2/88	49%	
regia	LP	4	10/27/87	12/13/87	5/1/88	19%	
(royal palm)							
Strelitzia	NP	4	1/27/88	2/29/88	not avail.	due to rat	damage
nicolai	LP	6	1/27/88	3/5/88	6/2/88	47%	
Strelitzia	NP	8	1/9/89	2/7/89	4/5/89	72%	
nicolai	LP	1	1/9/89	2/28/89	4/20/89	63%	
Thrinax	NP	3	10/21/87	1/18/88	5/25/88	0.4%	bad
acanthcoma	LP	1	10/21/87	—	—	0%	seeds
Trachycarpus	NP	1	10/21/87	11/8/87	2/8/88	22%	
fortunei	LP	1	10/21/87	12/1/87	4/2/88	19%	
(windmill palm)							
Trachycarpus	NP	10	6/26/88	9/14/88	11/25/88	68%	
fortunei	LP	2	6/26/88	10/1/88	12/28/88	21%	
(windmill palm)							
Trachycarpus	NP	7	11/16/88	12/10/88	4/10/89	80%	
fortunei	LP	1	11/16/88	1/4/89	5/18/89	63%	
(windmill palm)							
Veitchia	NP	1	2/20/88	3/20/88	4/29/88	87%	
merrillii	LP	1	2/20/88	4/2/88	5/25/88	41%	
(Manila palm)							

* NP - Noi'i O Puna (bottom heated)
LP - Leilani Propagation House (unheated)

APPENDIX C

PHOTOGRAPHS

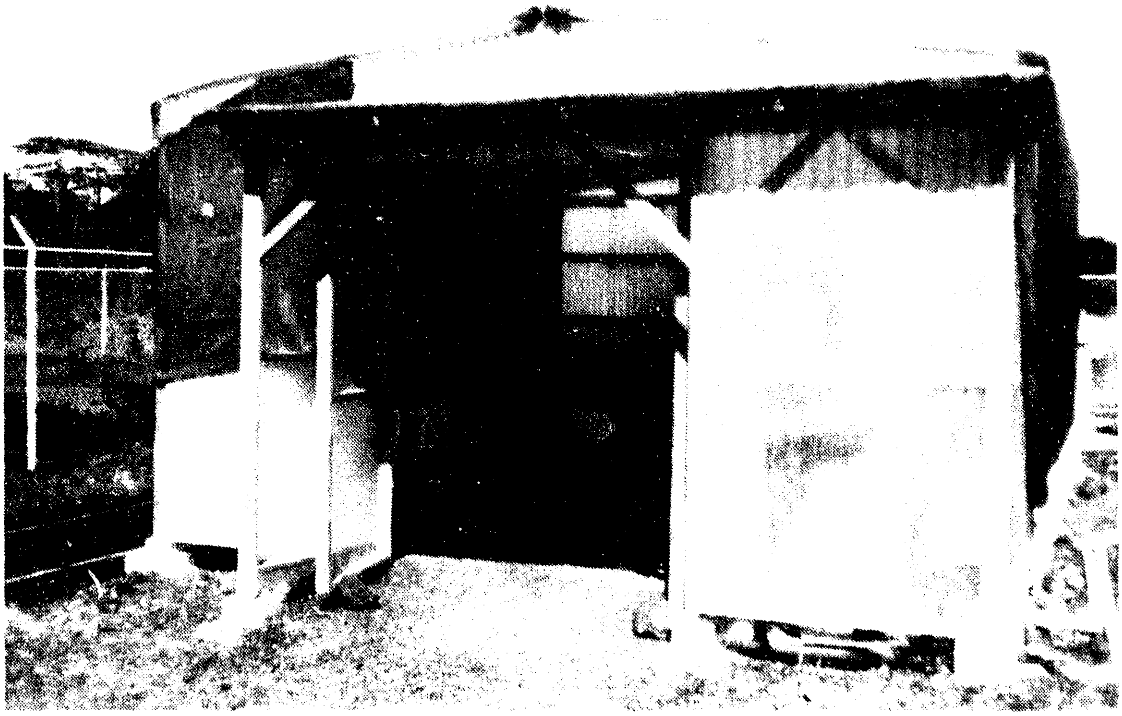

Photo A. The greenhouse at Noi'i O Puna with the raised benches and flats of sprouting palms inside.

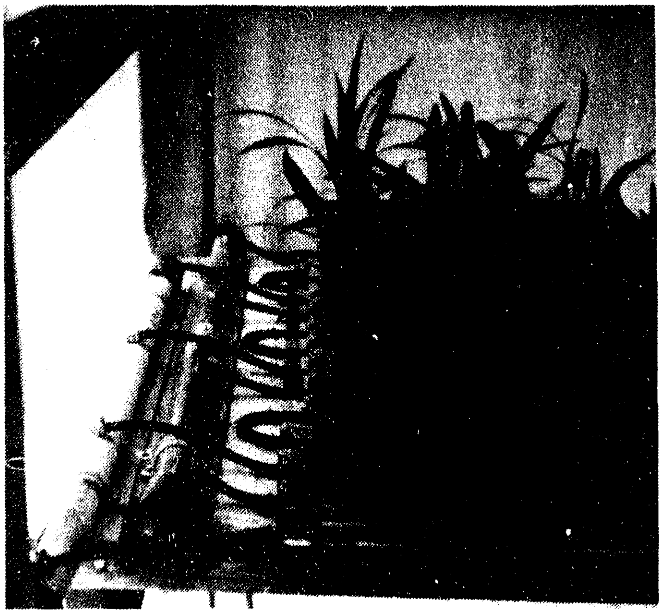

Photo B. The Biotherm system distributed hot water beneath the growing plants. The manifold and tubing are on the left.

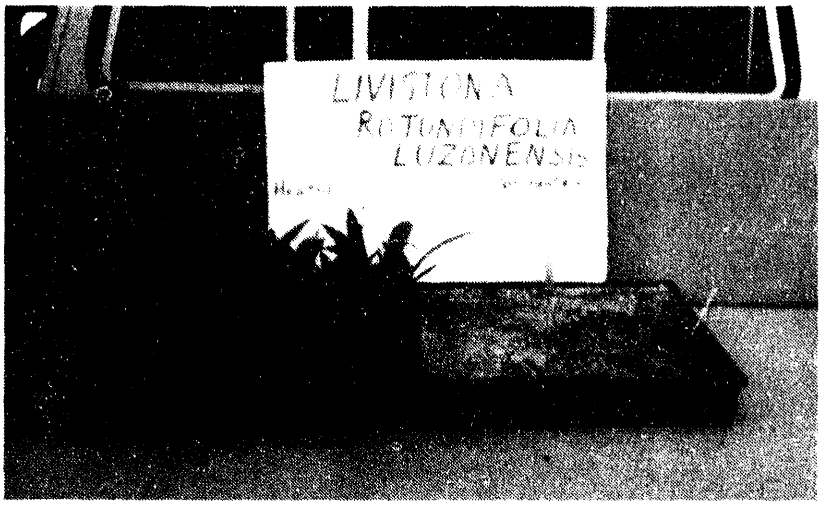

Photo C.
Livistona rotundifolia luzonensis showed significant improvement in germination with bottom heating. Photographed three months after planting, the heated flat is on the left (36 percent germination) and the unheated flat is on the right (no germination).

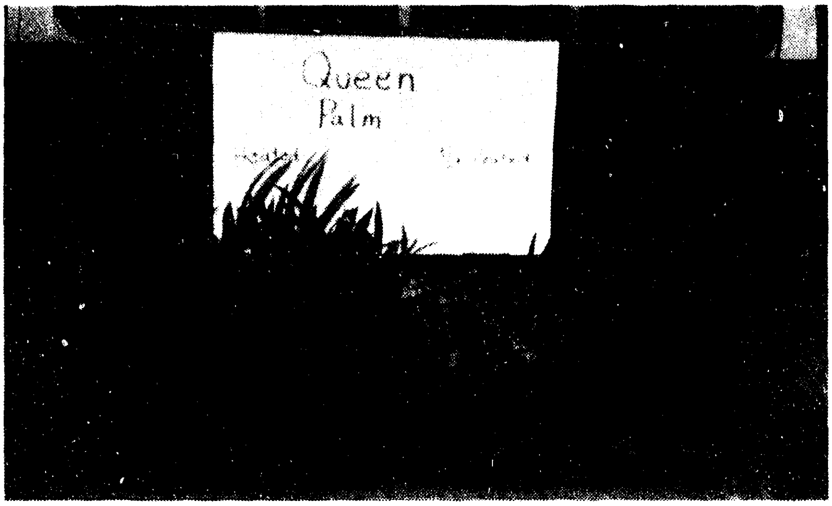

Photo D.
Arecastrum romanzoffianum (queen palm) also showed significant improvement with bottom heating. Photographed four months after planting, the heated flat (left) had 48 percent germination while the unheated flat (right) had only 0.3 percent germination.

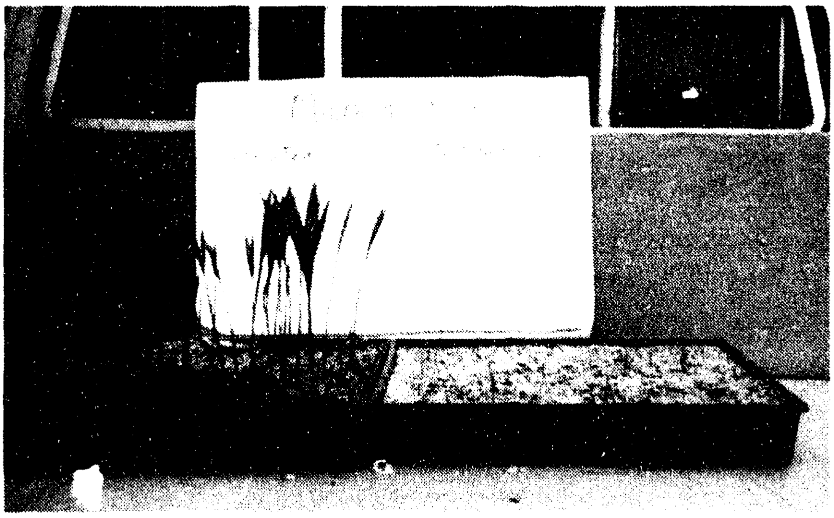

Photo E.
Veitchia merrillii (Manila palm) was another bottom heating success. Shown five months after planting, the heated flat (left) had 87 percent germination, while the unheated flat (right) had 41 percent germination.

All three palms photographed also illustrate the improved growth rates, with the heated plants reaching transplant maturity much faster than those grown in unheated media.

END

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