proximately 1½ hr. and must also be done when the fire is completely out in the fire chamber. This could also be considered a disadvantage as it may have to be done once during very cold weather at the peak of the heating season.

In summary, our wood-burning furnace has proven to be very economical, clean and safe. It is our belief that a wood-burning furnace can save one a minimum of 50% and a maximum of 80%. One statistic that bears this out is the fact that wood cost per 100,000 BTUs is $0.15 as compared to a fossil fuel cost of $0.73 per 100,000 BTUs[1].

The following trade publications give additional information on wood-burning furnaces:

Greenhouse Grower, April 1984: Energy:Dollars & Sense
Grower Talks, April, 1985: Fuel:Some New Answers
Florist Review, March, 1985

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[1] Florida Furnace Corp., Box 637, Apopka, Florida 32703.

AN INNOVATIVE APPROACH TO THE USE OF BOTTOM HEAT

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The idea of bottom heat in rooting cuttings is not new. The major drawbacks for most systems are the cost of installation, the purchase of equipment, and the maintenance. The system developed at Tawakoni Plant Farm has proven to be cost-effective and has returned the original investment more than twice in its first year of use. It was very easy to install and was built out of materials readily available through local supply firms. The goal was to install a system not so much for protecting liners, but more for rooting cuttings during the winter months. Both objectives have been achieved with this system. Admittedly, the winter of 1983-1984 was a deciding factor in building the system. That year almost ⅓ of all rooted liners were lost to freezing, causing serious planning, financing, and organizing problems. This system has the potential to alleviate losses of that nature and expand the propagation season to a year-round endeavor.

MATERIALS AND METHODS

The propagation department of Tawakoni Plant Farm consists of eight 30 × 96 ft. quonset-type greenhouses with 30% shade coverings. All greenhouses were covered with inflated double poly, four mil on the bottom and six mil on the top, to conserve heat during the winter. Five of the eight houses are for holding rooted liners. The other three are divided in half with separate controls for misting frequency and duration. After subtracting aisle space, six 1100-ft.^{2} mist beds are utilized. One of these six beds was used for construction of the bottom heat system.

After removing the irrigation system, construction was begun by cleaning, raking, and smoothing the gravel floor of the greenhouse. This was followed by placing four layers of Vis-Queen six mil poly on the gravel to serve as insulation.

Three header pipes were required in order to provide for circulation of the heated water. These were constructed from 2-in. PVC pipe with reduction tees on one-ft. centers for the supply and return pipes and tees on 6 in. centers for the opposite end. Two pipes were needed for the supply and return side of the system. The supply header was placed on the Vis-Queen with 13 inserts for tubing runs. The return header was placed immediately above the supply header. It consisted of 12 inserts for tubing, also on one-ft. centers, but was staggered in relation to the supply header, yielding an overall 6 in. spacing between tubes. All 25 tubing runs were 96 ft. long and were connected to the opposite header. Since all tubing was connected to one header at the opposite end of the bed, a consistent water temperature was achieved through mixing; ½ in. black polyethylene tubing was used because it is inexpensive and provides excellent heat exchange. The tubing was then anchored using 12-in. pieces of wire bent over the tubing and driven into the ground at six to 8-ft. intervals. Sand was then placed in at a depth of 3 in. to insure an even distribution of temperatures.

The water was heated with a propane-fired, Comfortzone swimming pool heater rated at 267,000 BTU's per hour. It is equipped with a pressure-sensitive switch to prevent heating when the water pressure is less than 2 psi or greater than 6 psi. The pump is a Sta-Rite ¾ hp. 230 volt swimming pool pump with 1½-in. inlet and outlet. It has a flow rate of 5 lb./in.^{2} pressure, which makes plumbing repairs almost non-existent. Both the heater and the pump are connected to a thermostatically-controlled relay. The thermostat is one of a special application, opening the circuit on temperature rise and closing on temperature drop. It is monitored by a remote probe placed in the sand. The pump and heater are activated when the temperature drops below 60°F and are shut off when the temperature reaches 63°F.

The system is supplied with a 50-gal. reservoir tank, which was filled once upon construction. Water is pumped out through the bottom of this tank, into the heater, through the system, and is returned to the top of the reservoir tank. The tank is equipped with a ¾ in. opening in the top that remains open to prevent excessive pressure build-up. Since the water temperature is quite hot coming out of the heater, CPVC pipe is recommended between the heater and the supply header and between the heater and the pump. The heater, pump, and reservoir tank were placed on a 4 × 9 ft. concrete slab just outside the greenhouse and covered with a wooden shed for protection from wind and rain.

IMPLEMENTATION

On November 5, 1984, a test was conducted with 23 tree and shrub cultivars. All cuttings were direct-stuck into rose pots and placed under the intermittent mist. Rooting percentages ranged from 100% on some cultivars to 0% on others, which bears out the fact that winter propagation is not for all plants. However, the overwhelming success of several important cultivars has proven beyond doubt that the assets of the system outweight its costs. In addition, it must be pointed out that the east Texas area had a late winter in 1984, with unusually warm temperatures into December. This should be considered as a contributing factor in the success of such plant materials as photinia and Indian hawthorne.

Table 1 *shows an item-by-item count of test plants.*

After the initial test, larger numbers of the plants that had been successfully rooted were placed in the system. Many of these plants were stuck in 4 in. pots with 3 cuttings per pot. The idea was to produce a larger liner for direct potting into 2 and 5-gal. containers. Species tested included, *Photinia × fraseri*, *Ligustrum lucidum*, *Ilex cornuta* 'Burfordii, and *Ilex cornuta* 'Dwarf Burford'. Rooting success was impressive during December and January but declined during February and March. Table 2 shows the difference between cuttings taken early in the winter as compared with cuttings taken after the full impact of winter was in effect. Four of the five species showed definite decrease in rooting once the warm temperatures of December had subsided.

Upon rooting, these plants were hardened-off, grown out, and lined out in 2 and 5 gal. containers. All four species were successful in the 2 gal. container, growing out to salability in one season. The photinia and the *Ligustrum* were equally successful in the 5-gal. container, but the two *Ilex* cultivars proved to be too slow growing to be called successful in 5-gal. pots.

At present the program for these 4 in. liners has been expanded to include 14 cultivars for a total of 36,000 liners.

Table 1. Rooting of cuttings of 23 shrub cultivars over bottom heat during winter propagation.[1]

Species and cultivar	Percent rooted
Cleyera japonica	33
Cupressus sempervirens glauca	64
Euonymus 'Goldspot'	100
E. sp., Boxleaf form	100
Ilex cornuta 'Burfordii'	96
I. cornuta 'Dwarf Burford'	98
I. 'Nellie R. Stevens'	100
I. vomitora 'Nana'	78
Juniperus horizontalis 'Bar Harbor'	95
Mahonia bealei[2]	83
Nandina domestica compacta[3]	90
N. domestica 'Purpurea Nana'	100
N. domestica 'Woodsii'	92
Photinia × *fraseri*	100
Prunus cerasifera 'Krauter Vesuvius'[2]	0
Pyracantha 'Dwarf Red'	97
P. 'Navajo'	100
P. 'Teton'	100
Rahiolepis 'Jack Evans'	91
R. indica 'Pinkie'	96
R. indica 'Snow White'	98
Rosa banksia 'Lutea'[2]	85
Syringa × *persica*[2]	92

[1] 96 cuttings stuck except as noted
[2] 48 cuttings stuck
[3] 40 cuttings stuck

Table 2. Comparison of rooting response of five cultivars propagated at two different periods using bottom heat.

Species and cultivar	Date of Cutting 11/84 to 1/85		Date of Cutting 2/85 to 3/85	
	Number rooted	Percent	Number rooted	Percent
Hedera helix	576	100	1920	100
Ilex cornuta 'Burfordi Nana'	2020	98	3600	71
Ilex cornuta 'Burfordii'	1816	96	672	57
Ligustrum lucidum	2000	96	1000	92
Raphiolepis indica 'Jack Evans'	3216	96	5808	81

The fact that the time required to grow out many of the 2 and 5 gal. material has been reduced by a full year is very encouraging and will have a great impact on the production cost of these plants.

DISCUSSION

During November, December, and January, careful records were kept of the differences between outside temperature at

7:30 a.m., hotbed sand temperature, liner temperature on the hotbed, and liner temperature in the heated house, but not on the hotbed. As Figure 1 shows, sand temperature was fairly constant. Liners on the hotbed showed more variation but liners in the heated house — not directly on the hotbed — showed the greatest temperature fluctuation. These plants were from 5 to 15 degrees warmer than the outside temperature. The one temperature that dips for all four readings occurred on a cold, windy night when the pilot light was blown out. This situation was remedied by the addition of a wind shield on the north side of the wooden shed.

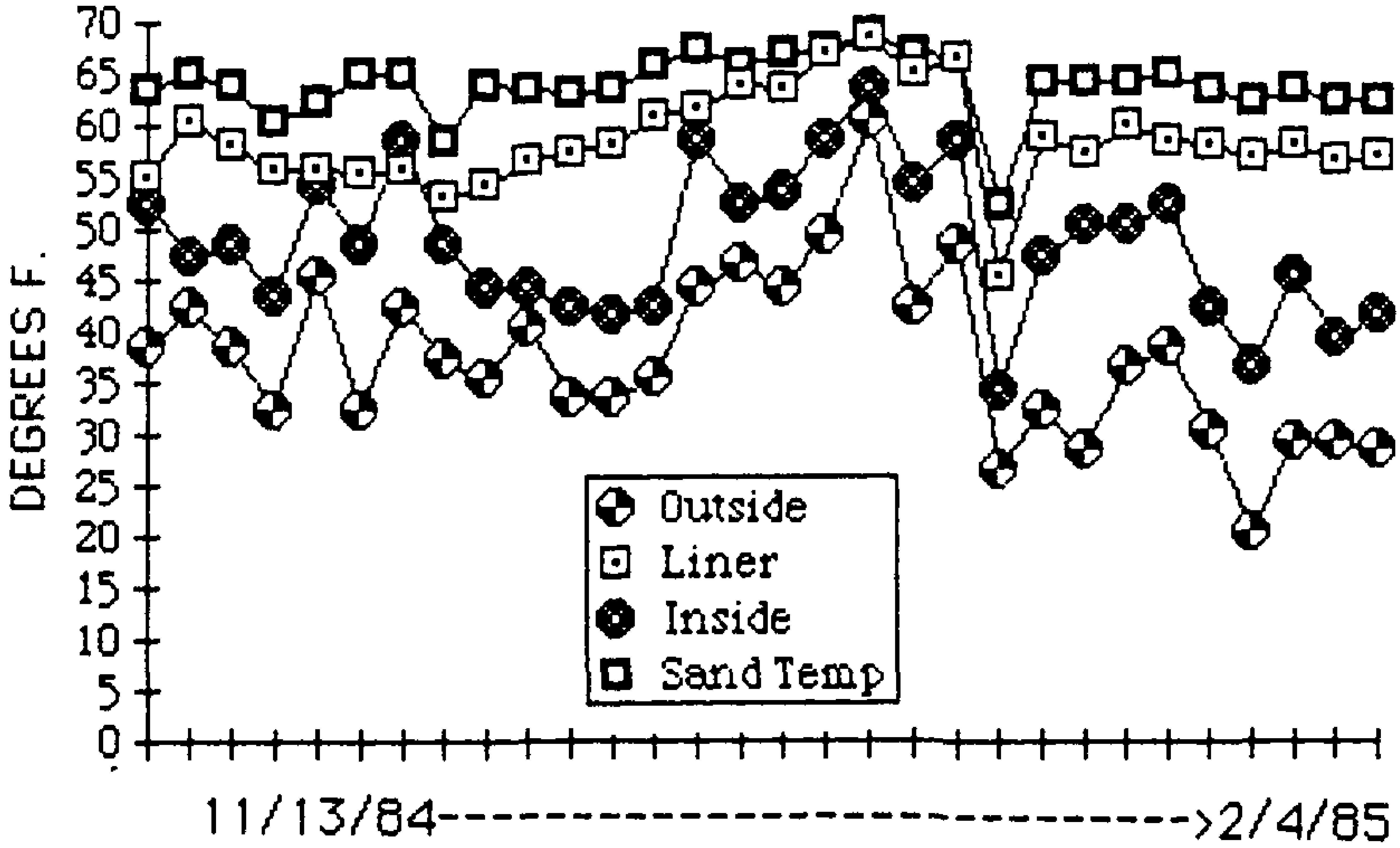

Figure 1. Temperatures measured outside and inside the propagation house and in liners with and without bottom heat.

After the original system was in use for 3 months, the results were so encouraging that a decision was made to double the size of the system. The heater did a very efficient job of keeping the liner temperature at a constant 60°F, consuming only $860 worth of propane during the entire 3-month period. The two hotbeds are used to root the cuttings, which are then moved over to the other side of the greenhouse to harden-off before planting out.

Our results formed the basis for the decision to put the new system in another house but use the same pump and heater to supply it. The idea worked well, but the thermostat was increased to 65°F in order to compensate for the additional heated area.

All in all this sytem is not the answer for everyone. It is

Note: A detailed schematic of the water flow system can be obtained from the author.

an alternative for those who want the protection and the increased flexibility of propagating in the winter months without the high cost of a commercially-designed system. Estimated cost for this system is shown in Table 3.

Table 3. Estimated installation costs for Tawakoni hotbed with respect to payback on investment.

Costs:	
Equipment cost:	
Heater, pump, reservoir tank, piping, etc.	$1769.66
Propane cost:	
Price at .88 per gal. over 4 months	868.60
Labor cost:	
Installation, cutting of plants to fill bed, mixing of soil, filling pots, etc.	780.00
Hardgoods cost:	
Pots, flats, soil, etc.	520.00
Total Costs	$3938.26
Assets:	
Cuttings stuck and placed on hotbed	19,764
Multiply by rooting percentage	× .85
Number of rooted plants produced	16,799
Multiply by lowest average market price	× 0.35
Total value of plants produced	$5879.65
Less costs	−$3938.26
Net profit in first year	$1941.39

GAS: A HEAT SOURCE FOR WINTER PROTECTION

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The purpose of this project was to find an efficient and economical heat source for our liner houses.

Before Hurricane Frederic of 1979, the houses at Cottage Hill Nursery container division were equipped with Modine heaters. After the storm we had to rebuild, so this was a good time to consider changes in heating equipment. We decided to try different heaters to make our heating more efficient and economical. We considered three posibilities:

(a) Replace Modine heaters.

(b) Use an open-flame heater topped by a container of water.

(c) Turn on the misting system during extremely cold nights.