A TREE SEEDLING GREENHOUSE: DESIGN AND COSTS

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INTRODUCTION

The following report provides information on a sample design of a modular greenhouse system for growing forest seedlings. The system consists of four quonset greenhouses, a headhouse and a lathhouse. The main function of the headhouse is to provide an enclosed area for seeding operations. The lathhouse provides a shaded holding area for seedlings awaiting outplanting. The design objective was to provide an efficient, highly mechanized system.

The report includes information on seedling production objectives, the environmental requirements for the seedlings, the structures needed to provide the necessary environment, the equipment needed for the operation, initial costs and operating costs.

The greenhouse site location chosen for the sample design is Bozeman, Montana. The species considered is ponderosa pine. The cropping objectives are to produce two crops per year.

The environmental factors to be controlled are root zone moisture, plant nutrients, temperature, humidity, CO_2 level and light for photoperiod manipulation.

A quonset was chosen for the structure type. This type of structure was chosen because of its low initial cost, ease of construction and the non-permanence of this type of structure.

There are basically three (3) types of covering material for greenhouses. These are glass, rigid plastic, and plastic film. The double layer polyethylene film was chosen for the sample design because of its low initial cost and the simplicity of attachment to the supporting structure. Inflation of the double layer, provides support strength which enables the cover to be attached only at its perimeter.

The general layout plan is shown in Figures 1, 2a and 2b. This plan was chosen because it makes efficient use of the building materials and headhouse space.

The system was designed to minimize the moving of materials by hand. A pallet system was designed to move seedlings into and out of the greenhouse on tracks. A fork lift would be used to handle the pallets in the headhouse and to move them to the lathhouse.

The seedlings would be grown in styrofoam containers called styroblocks.

A peat-vermiculite mix was chosen as a growing medium. These materials can be obtained sterile, so that on site sterilization is not required.

The greenhouse environment would be controlled automatically by the use of thermostats, humidistats and timers.

Watering would be done automatically by means of an overhead traveling sprinkler. Plant nutrients would be applied in the water.

Photoperiod control would be accomplished with incandescent lamps which have built in reflectors.

A gas-fired forced-air heating system was chosen to provide uniform temperature control at low cost. Heated air is forced through polyethylene convection tubes suspended in the ceiling. Air is returned to the heater from the floor.

Summertime cooling would be provided by exhaust fans drawing air through evaporative cooling pads.

The seeding operation consists of mixing peat moss and vermiculite, filling the styroblocks with the mix and adding seeds by means of an automatic seeding machine. The seedling containers would be moved to and from the seeding station with a fork lift.

When the seedlings reach a height of about six inches they would be moved from the greenhouse to the lathhouse.

The proposed lathhouse structure consists of polypropylene shade fabric suspended from poles.

The assumption was made that due to the high mechanization, one man could operate this greenhouse system with part-time help.

The greenhouse temperature would be monitored by sensing equipment connected to a telephone line. This would allow the greenhouse to operate unattended outside of regular working hours.

The initial cost of the complete facility is estimated to be $120,230. Annual fixed costs were estimated assuming the system would be operated as a private enterprise, so taxes and insurance costs were included. The annual fixed cost was estimated to be $22,650. The depreciation period varied from one to thirty years. The annual operating cost was estimated to be $28,870. The total annual cost is estimated to be $51,520.

The cost per seedling for a 1,640,000 annual seedling crop is estimated to be 3.1¢.

SCOPE OF THE DESIGN AND ANALYSIS

1. Seedling Production Objectives
2. Seedling Environmental Requirements
3. Covering Material
4. General Layout and Configuration
5. Space Requirements of the Greenhouse
6. Cooling Requirements
7. Ventilation Requirements
8. Heating Requirements
9. CO_2 Provision
10. Equipment Controls
11. Growing Method
12. Watering and Fertilizing System
13. Lighting for Photoperiod Control
14. Growing Material Requirements
15. Head House Requirements
16. Lath House Requirements
17. Cost Analysis

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1.0 Seedling Production Objectives

The objectives of the growing operation are to produce two crops per year of Ponderosa pine seedlings. One crop will be started from seed in the spring. A portion of this crop will be outplanted in the fall with the remainder being outplanted the following spring. The other crop will be started from seed in the fall. The entire crop will be outplanted the following spring. Details on these objectives are given in tables 1 and 2. The growth schedules and environmental recommendations given in these tables were provided by Dr. Richard Tinus. (18)

2.0 Seedling Environment Requirements

2.1 Greenhouse environmental requirements -

Environmental factors to be controlled are root zone moisture, plant nutrients, temperature, humidity, CO_2 level and light for photoperiod manipulation. Details on seedling environment requirements are given in tables 1 and 2. (18)

2.2 Lathhouse Environment Requirements -

Water with nutrients
Mulch for frost protection
Wind protection
Shade, bright sky with no direct sun
Low temperature

3.0 Covering Material

There are basically three (3) types of covering material for greenhouses. These are glass, rigid plastic and plastic film.

There are several factors to consider in selecting a type of covering material.

1) Solar energy transmitting properties
2) Heat transfer properties
3) Weatherability
4) Susceptability to vandalism
5) Support structure required
6) Ease of construction
7) Condensation
8) Cost

Table 1.
SUMMER CYCLE
Recommended Conditions for Growth of Ponderosa Pine in Small Containers

		April	May	June – July	Aug – Sep – Oct	Nov – Dec – Jan – Feb – March	April
Growth Stage		Germination	Early Growth	Late Growth	Natural hardening	Full dormancy & hardness	
Operations		Fungicide if needed	Thin to 1 per pot if needed		Move crop to Lathhouse; Outplant; Collect Seed	Clean & test seed; Assemble & fill pots, seed pots; Stratify if needed; Move next crop to greenhouse	Outplant until June
Temp °F Day	OK	70-75	75-80	78-85	80-90 declining with the season	50-60	
	Optimum	65-70	70-75	72-78	70-80 declining with the season	30-50	
	OK	60-65	65-70	65-72	60-70 declining with the season	20-80	
Night	OK	70-73	70-75	70-75	65-70 declining with the season	40-45	
	Optimum	65-70	65-70	65-70	55-65 declining with the season	30-40	
	OK	60-65	60-65	60-65	40-55 declining with the season	20-30	
						To maintain dormancy keep max. night temp. below 45, max. day temp. below 60.	
Rel. Hum. (%)	OK	80-90	70-80	70-80	70-80		
	Optimum	60-80	50-70	50-70	50-70		
	OK	50-60	40-50	40-50	40-50		
Light -	Daylight	50% Sunlight	50-90% Sunlight	50-90% Sunlight	Bright skylight, no direct sun	Bright skylight, no direct sun	
	Supplemental	None	40 ft-c incandescant or equiv. at least 1 part in 30 throughout night. No dark period over 30 min.	40 ft-c incandescant or equiv. at least 1 part in 30 throughout night. No dark period over 30 min.	None	None	
Nutrition -	Water	Often light keep Moist	As needed. Surface should dry. Rootball moisture stress maintained at 0.5-3.0 bars	As needed. Surface should dry. Rootball moisture stress maintained at 0.5-3.0 bars	Leach thoroughly Dry to 10-15 bars (Aug); As needed. Surface should dry. Rootball moisture stress maintained at 0.5-3.0 bars	As needed. Surface should dry. Rootball moisture stress maintained at 0.5-3.0 bars	
	Fertilizer	None	None / Complete. High N, pH 5.5-6.0 Conductivity 1800-2400 mhos. Rinse foliage.	Complete. High N, pH 5.5-6.0 Conductivity 1800-2400 mhos. Rinse foliage.	Complete. Low N, high PK, pH 5.5-6.0 Conductivity 1800-2400 mhos. Rinse foliage & piping Water with high N just before shipment	Complete. Low N, high PK, pH 5.5-6.0 Conductivity 1800-2400 mhos. Rinse foliage & piping Water with high N just before shipment	
CO_2 level		Atm. level	1000-1500 ppm whenever vents are closed during daylight hours	1000-1500 ppm whenever vents are closed during daylight hours	Normal atmosphere	Normal atmosphere	

Table 2.
WINTER CYCLE
Recommended Conditions for Growth of Ponderosa Pine in Small Containers

		Aug	Aug–Sep	Oct–Jan	Feb	March	April–May	June–July	Aug
Growth Stage		Germination	Early Growth	Late Growth	Bud Set	Cold Harden	Maintain dormancy & hardiness	Flush after outplanting	
Operations			Fungicide if needed; Thin to 1 per pot if needed			Move crop to lathhouse	Ship & outplant	Assemble & fill pots Seed pots	Move next Crop to Greenhouse
Temp °F Day	OK	70-75	75-80	78-85	70-75	45-60	45-60		
	Optimum	65-70	70-75	72-78	65-70	35-45	32-45		
	OK	60-65	65-70	65-72	60-65	32-35	25-32		
Night	OK	70-75	70-75	70-75	65-70	38-44	38-45		
	Optimum	65-70	65-70	65-70	60-65	35-38	32-38		
	OK	60-65	60-65	60-65	55-60	32-34	25-32		
Rel. Hum. (%)	OK	80-90	70-80	70-80	70-80	70-80	70-80		
	Optimum	60-80	50-70	50-70	50-70	50-70	50-70		
	OK	50-60	40-50	40-50	40-50	40-50	40-50		
Light -	Daylight	50% Sunlight	50-90% Sunlight				Bright skylight no direct sun		
	Supplemental	None	40 ft-c incandescant or equiv. at least 1 part in 30 throughout the night. No dark period over 30 min.		None				
Nutrition -	Water	Often light keep moist	As needed. Surface should dry. Rootball moisture stress maintained at 0.5-3.0 bars		Leach thoroughly Dry to 10-15 bars	As needed. Surface should dry. Rootball moisture stress maintained at 0.5-3.0 bars			
	Fertilizer	None	Complete. High N, pH 5.5-6.0 Conductivity 1800-2400μmhos. Rinse foliage & piping			Complete. Low N, high PK Rinse foliage & piping Water with high N just before shipment			
CO_2 level		Atm level	1000-1500 ppm whenever vents are closed during daylight hours			Normal atmosphere			

Glass -

The outstanding advantages of using glass are its high light transmitting property and low transmission of heat waves. However, it requires a strong and costly support structure. It is also susceptable to weather and vandalism damage.

Plastic Film -

On the plastic film materials, polyethylene has properties which make it the most practical to use as a cover for supported structures. It is very low in initial cost. It requires only a light weight support structure.

The double layer, air inflated film cover has come into wide spread use. With this scheme, installation of the cover is very simple. It also reduces the condensation and drip problem.

There are three (3) salient disadvantages in using polyethylene material. It allows a relatively low level of light transmission. With the double layer only about 70% of the incident light passes through. It allows a relatively high transmittance of long wave thermal radiation. Hence, it does not trap solar energy as well as glass unless moisture has condensed on it. It could cause a disposal problem because of its short life, since it will not decompose readily in the absence of sunlight.

Rigid Plastic -

Rigid Plastic reinforced with fiberglass has some distinct advantages. It requires only a simple support structure with a quonset type greenhouse. It is not highly susceptible to hail or wind damage. It has long life, up to 20 years, with the best grades. Its light transmittance is comparable to glass. However, rigid plastic is considerably higher in initial cost than plastic film. It is also quite flammable.

Sample Design Cover -

The double layer polyethylene film was chosen for the sample design because of its low initial cost and the simplicity of attachment to the supporting structure.

Table 3. Transmittance of sunlight by covering materials (11)

	Average transmittance 0.4 - 0.7 micron (visible)
Window glass	89%
Polyethylene film	73%
Fiberglass (15% acrylic modified tedlar coated)	90%

Table 4. Degree of protection against radiative heat loss for covering materials (8) (6)

Material	Percent protection
Window glass (94 mil)	93
Polyethylene film (no condensation)	26
Fiberglass	99

Table 5. Comparison of greenhouse covering costs (8)

Material	Initial Cost ¢/Sq. Ft.	Installation Labor Cost ¢/Sq.Ft.	Years Expected Life	Maintenance Cost, Avg. Per Year	Cost Per Year Per Sq. Ft.
Poly (4, 6 mil)	1 to 1½¢	1½ to 2¢	1	-	2½ - 3½¢
Poly UV (4, 6 mil)	2 to 2½¢	1½ to 2¢	2	-	2 - 2½¢
Fiberglass, 15% acrylic modified					
(4 oz.)	20 to 25¢	1½ to 2¢	8 - 10	1½¢	3 - 3½¢
(5, 6 oz.)	30 to 35¢	1½ to 2¢	12 - 15	1½¢	2¼ - 2½¢
Tedlar Coated, (5, 6 oz.)	40 to 55¢	1½ to 2¢	15 - 20	½¢	2½ - 3¢
Glass	50¢	2 to 3¢	30+	1 - 1½¢	2 - 3¢

4.0 General Layout and Configuration

There are several factors which affect the layout.

1) Orientation in relation to sun angle
2) Shadows from structures
3) Basic structure type
4) Heating method
5) Cooling method
6) Material handling efficiency
7) Economic feasibility

4.1 Basic structure type

The polyethylene film covered quonset was chosen because of its low initial cost, ease of construction and the non-permanence of this type of structure.

4.2 Greenhouse layout

The general layout plan is shown in Figure 1 and Figure 2. This plan was chosen because it makes efficient use of building materials and headhouse space. Also, the path of exhaust air is free of obstructions.

The pallet tracks in the greenhouses are long enough so that thinning can be accomplished by separating the pallets.

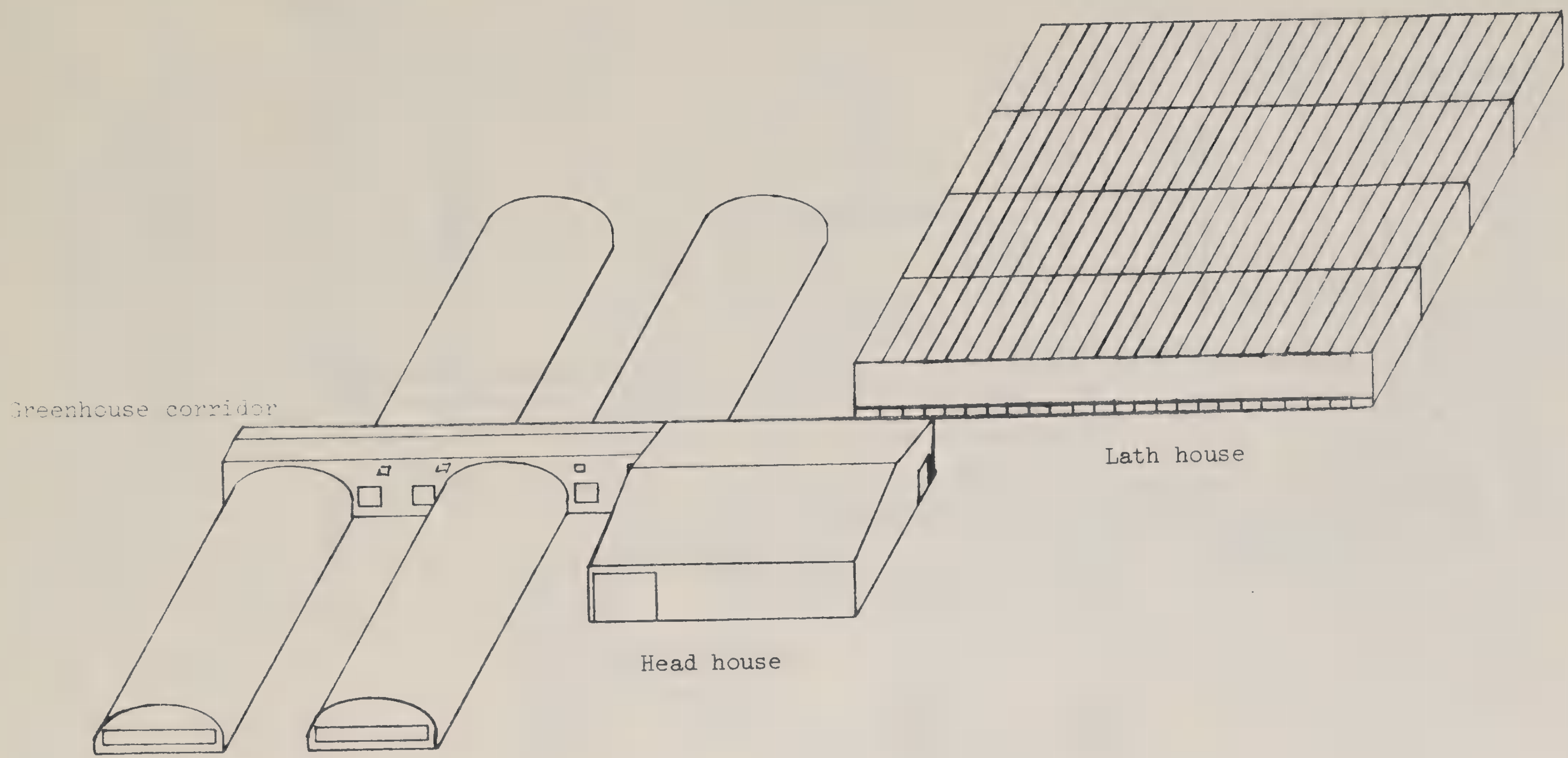


Figure 1. Greenhouse system.

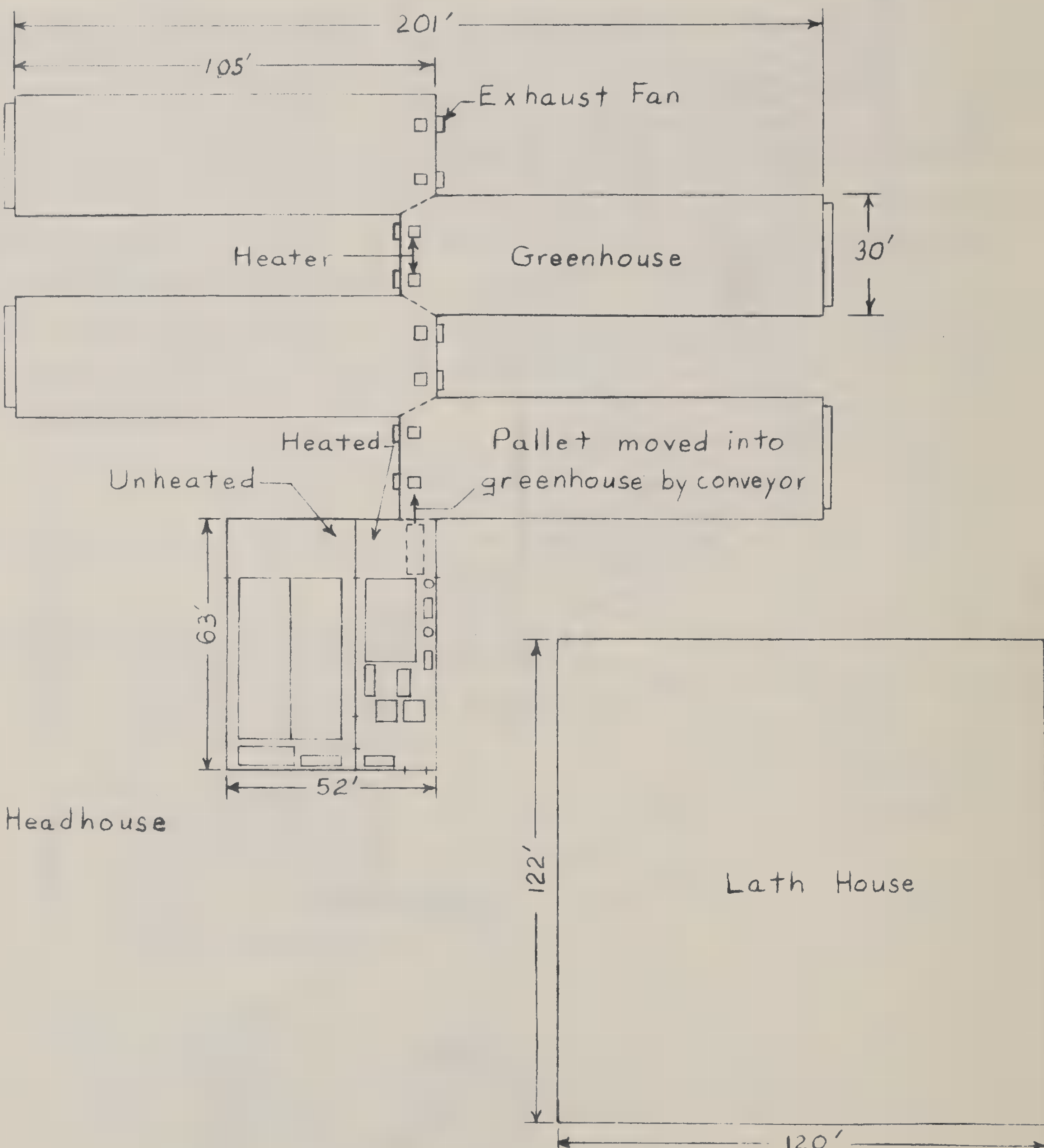


Figure 2a. Greenhouse system layout.

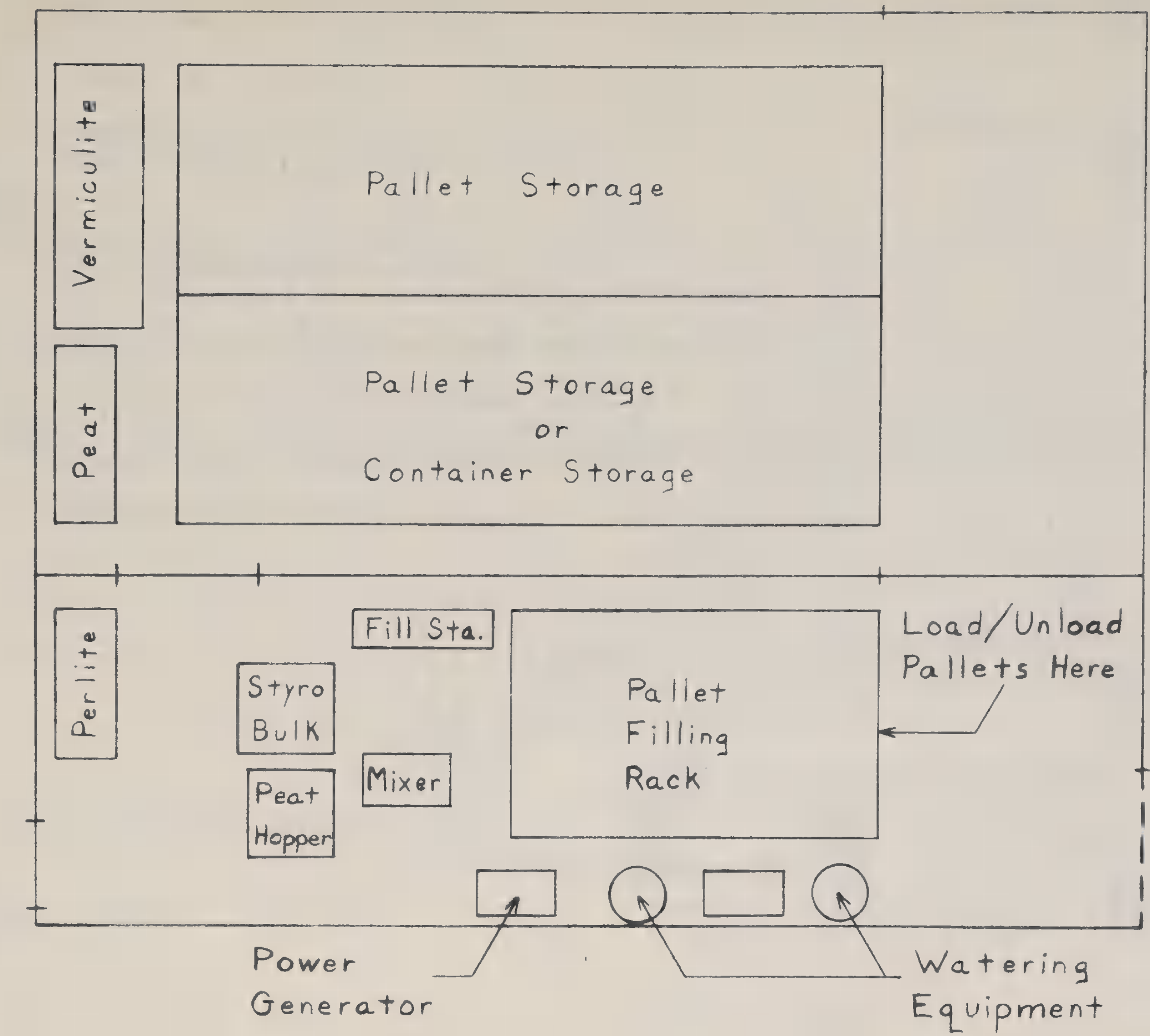


Figure 2b. Head house layout.

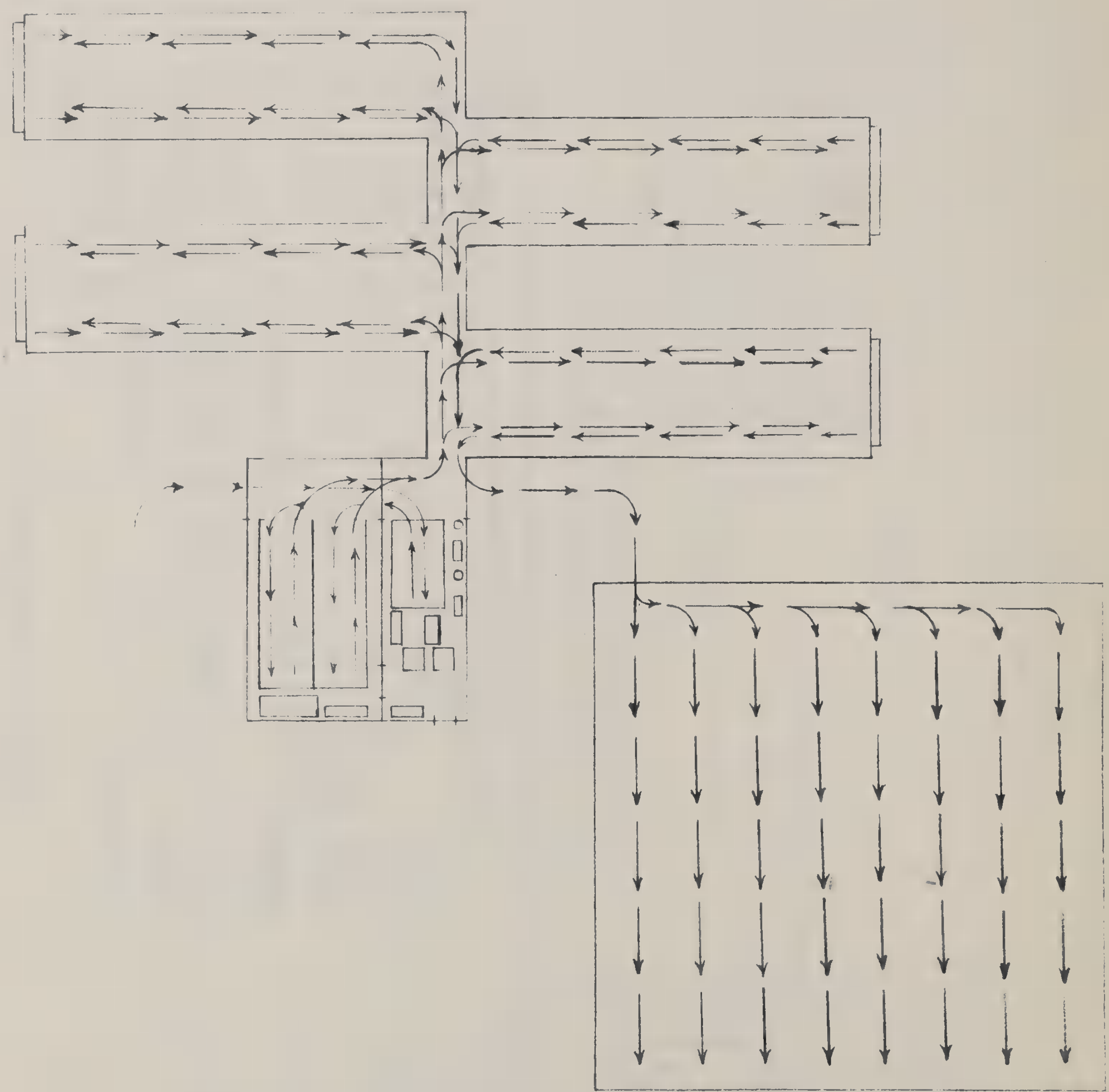


Figure 2c. Pallet movement diagram

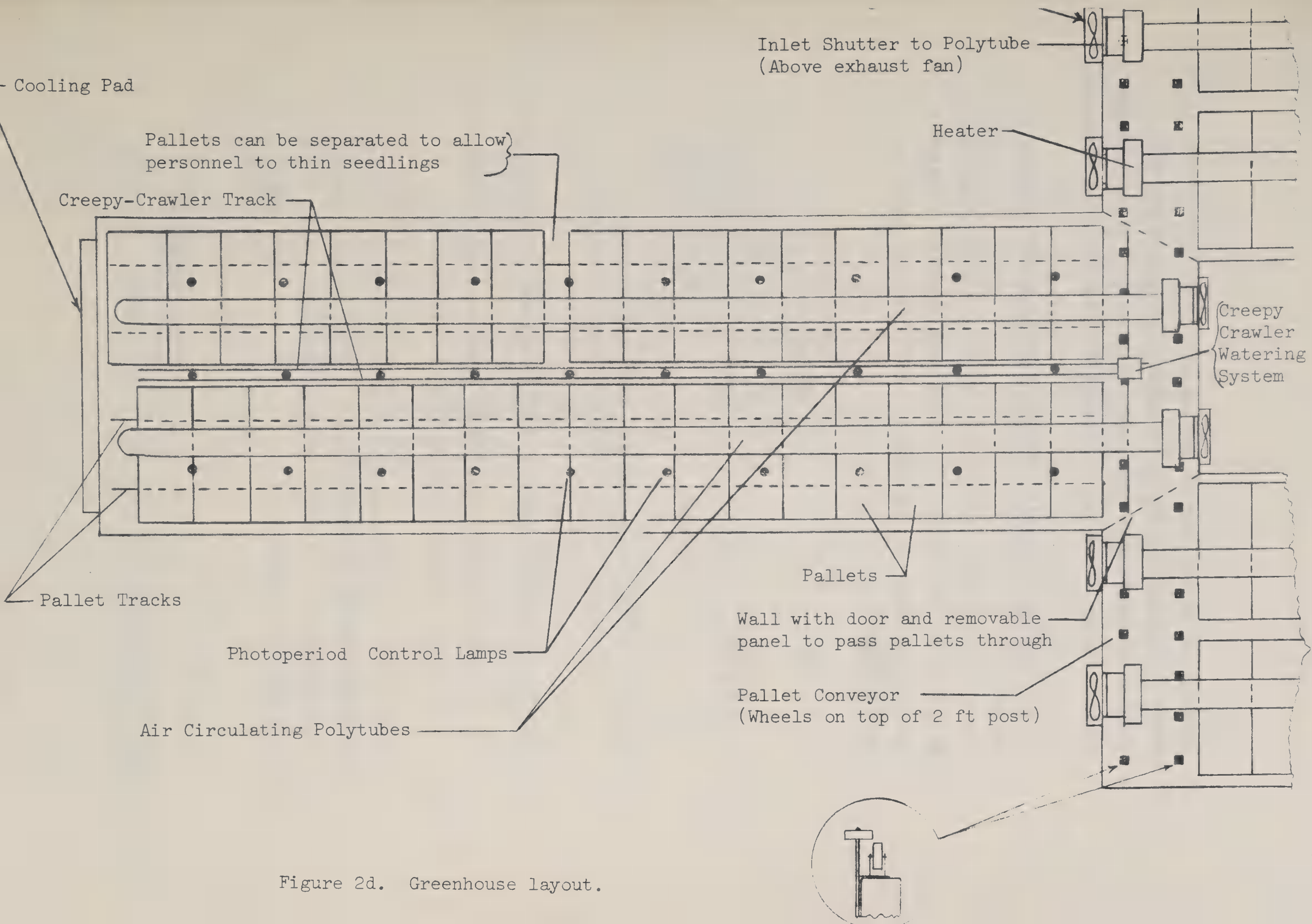


Figure 2d. Greenhouse layout.

4.3 Orientation in relation to sun angle -

Since year-around operation is planned maximum light transmission is needed when the days are short and the sun remains low in the sky. Thus the sun angle is considered for December.

During December the solar energy arriving at the greenhouse is only sufficient to be effective between about 9 a.m. and 3 p.m. During this time the sun altitude varies from 10.7° at 9 a.m. to 22.3° at noon, as measured from the horizontal. The bearing angle varies between 41.5° east of south to 41.5° west of south.

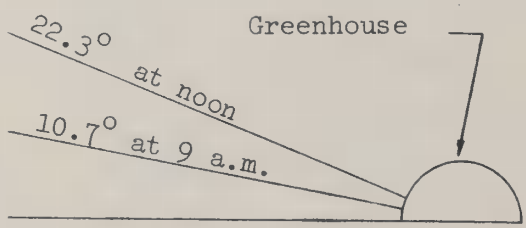


Figure 3. Altitude Angle (December)

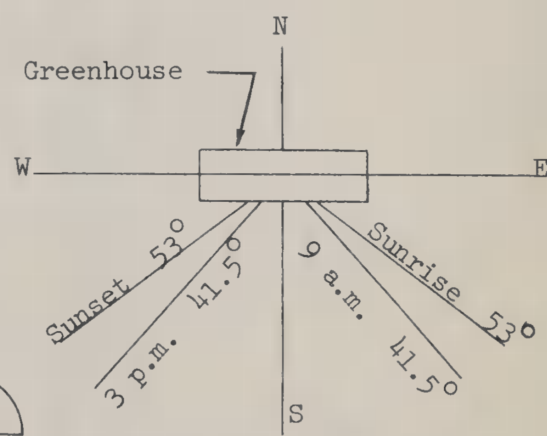


Figure 4. Bearing Angle(December)

The sun angle, as shown in Figure 3 and Figure 4, indicates that an east-west ridge line orientation is necessary.

At Bozeman, during December, the forenoons are predominantly more cloudy than the afternoons. (7) To take advantage of this phenomena, a slight cant of the ridge line to the northwest would be required.

4.4 Structure shadows -

Plants will be at about 2.5 ft. above ground level.

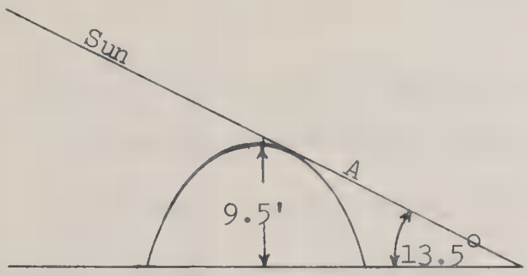
Greenhouse is 30 feet wide and 12 feet high.

Rooftop height above plants is 9.5 feet.

4.41 Greenhouse shadows -

To limit space to a reasonable value, design for no shadow after 9:30. At 9:30 a.m. the altitude angle is about 13.5°. The bearing angle is about 35.5°.

Length of shadow along line A in Figure 6 -



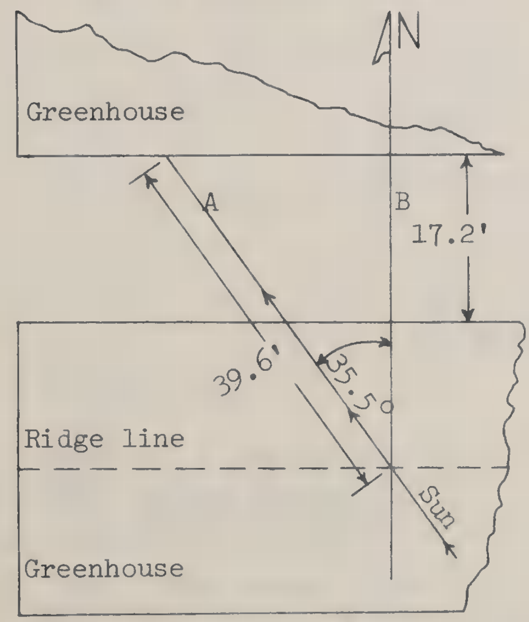
$$y = \frac{9.5}{\tan 13.5^\circ}$$

$$y = \frac{9.5}{.24}$$

$$y = 39.6 \text{ ft.}$$

Figure 5. Shadow length along line A in Figure 6 below. (Dec.)

Length of shadow perpendicular to the ridge line, along line B -



$$z = 39.6 \cos 35.5^\circ$$

$$z = 39.6 \times .814$$

$$z = 32.2 \text{ ft.}$$

Minimum space, m -

$$m = 32.2 - 15$$

$$m = 17.2 \text{ ft.}$$

Figure 6. Shadow length perpendicular to greenhouse ridge line. (Dec.)

4.42 Greenhouse corridor shadow -

There will be a small amount of shadowing in one corner of two of the four greenhouses during early forenoon and late afternoon. This shadowing can be minimized by using fiberglass to cover the corridor.

The above analysis was made with the assumption that the greenhouse site has no slope in any direction. The site should be level except in case of a natural south slope.

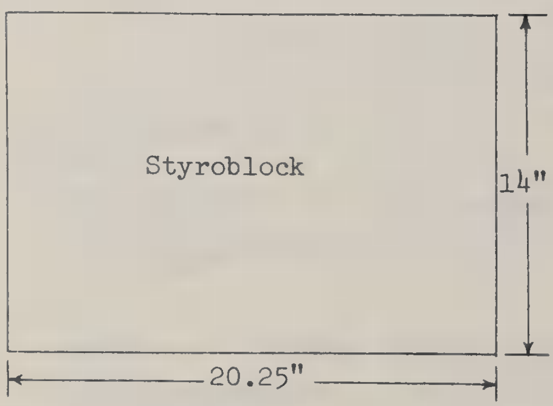
5.0 <u>Greenhouse Space Requirement and Pallet Size</u>

Provide space for near to one million trees per crop.

Houses are available commercially 30 feet wide and 96 feet long.

Trees are to be grown in styrofoam containers called styroblocks. The styroblocks are to be placed on pallets, which can be rolled into and out of the greenhouse on permanent tracks.

Dimensions of an available styroblock container -



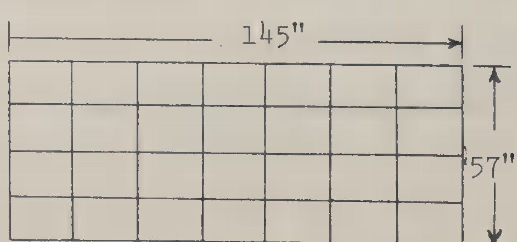
192 holes per block

Holes - 16 x 12

5.1 Pallet Size -

A convenient size of pallet is considered to be about 12'x4'.

1) Consider the following styroblock layout -



4 x 14" = 56"

7 x 20.25" = 141.75"

Allow ¼ inch space between each block

Pallet dimensions - 4'9" x 12'1"

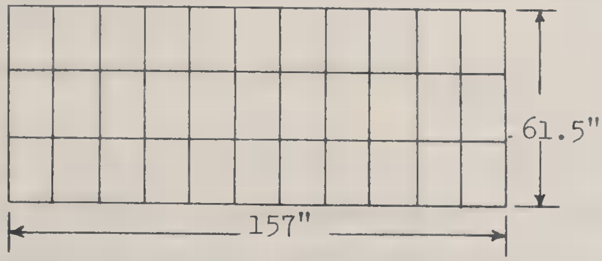
This allows 3 feet of aisle with 1½ ft. space at each wall. Allowing 2 feet between pallet and cooling pad, provides 94 feet of growing area.

Twenty pallets along one side with 40 per house.

Number trees = 40x28x192 = 215,000 trees/house.

Trees per crop = 4x215,000 = 860,000 trees/crop.

2) Consider alternate styroblock layout-



3 x 20.25" = 60.75"

11 x 14" = 154"

Allow ¼ inch space between each block

Pallet dimensions - 5'1½"x13'1"

This allows a 2 ft. aisle with 1 ft. space at each wall.

18 pallets along one side with 36 per house.

3.5 feet between pallet and cooling pad.

Number Trees = 228,000/house.

Trees per crop = 910,000 trees/crop.

The difference in width between these two layouts is small; therefore, the 13' by 5' pallet appears to be the better choice. 100,000 more trees per year can be produced with the larger pallet.

6.0 Greenhouse Cooling Requirement

Factors affecting cooling:

1) Peak solar energy input at the greenhouse in the summer time.
2) Transmittance of solar energy by the covering material (interior light level).
3) Weight of the air which is dependent on the elevation.
4) Wet bulb temperature.

6.1 Sizing cooling system by rule-of-thumb -

1) Figured on the basis of one air change per minute.
2) Only a height of 7 feet up from the ground is considered. Air above that is not cooled.

The rule of thumb method may result in a cooling system that is too small or too large. (1)

Air flow by rule-of-thumb -

Air flow = 7 'x3,120'^{2}

Air flow = 21,800 cfm

6.2 Sizing cooling system by the method presented in the ACME Manufacturer's Handbook -

This method is based on a basic air flow of 8 cfm per square foot of floor area. The maximum light intensity is assumed to be 5,000 ft-c. This basic flow rate is multiplied by a correction factor which takes into account elevation, interior light intensity, allowable greenhouse temperature increase and fan to pad distance when less than 100 feet.

Correction factor, $F = F_{elev} \times F_{light} \times F_{temp}$

Elevation - Bozeman - 4800 feet

from Table 1, $F_{elev} = 1.18$

Light - Clear sky illumination at noon in the summer at Bozeman is about 7,160 ft-c. Two layers of plastic film will pass about 70% of this.

Illumination = 5,000 ft-c

$F_{light} = 1$

Temperature - A wet bulb temperature is used which will not be exceeded more than 5 percent of the total hours between June 1 and September 1 for a normal summer.

$T_{wb} = 61^oF$

Assume the efficiency of the cooler is 80-85% and the incoming air can be cooled to within 4^oF of the wet bulb temperature.

Air temperature from cooler = 65°F

Allowable house temperature -

Assume house temperature can be allowed to rise to 80°F which is 5°F over the recommended maximum temperature.

Allowable temperature rise = 15°F

$F_{temp} = 7/15 = 0.47$

Total Correction Factor -

$F = 1.18 \times 1.4 \times 0.47 = F = 0.555$

Air Flow Required -

Air Flow = 30 x 104 x 8 x 0.55

Air Flow = 13,800 cfm

This method does not take into account the evapotranspiration of the particular crop being grown. Since evapotranspiration can absorb about 50% of the heat load within a typical greenhouse, the cooling system could be too small if the evapotranspiration is significantly below this assumed value.

To determine the required size of the cooling system more precisely, the actual evapotranspiration level for the high heat load conditions must be accurately determined.

6.3 Determine cooling system size from solar heat load -

Evaporative cooler size is based on the average maximum temperature and the average maximum solar radiation. The heaviest heat load will probably occur in August during germination of the fall crop.

6.31 Estimate of solar energy input from weather data - (7)

The average of the maximum levels of solar radiation will be used as the design level of solar energy input.

Radiation levels for Bozeman on hot summer days (daily average)

Extreme conditions - 800 Langley/day

Average maximum - 650 Langley/day

1 Langley/min = 1 cal/min-cm^2

= 221 BTU/hr-ft^2

= 7000 foot-candles

Design solar radiation valve -

Day length is about 15 hours

650 Langley/day is equivalent to about 160 BTU/hr-ft^2

Design solar radiation level = 226 BTU/hr-ft^2

About 70% of this energy will pass through the double layer plastic film.

Greenhouse heat load = 158 BTU/hr-ft^2

6.32 Design conditions for Bozeman - (7)

Assume that the house temperature can be permitted to rise 5°F above the recommended valve of 75°F.

Outside dry-bulb temperature	90°F
Outside wet-bulb temperature	65°F
Maximum house temperature	80°F
Maximum relative humidity	90%
Solar radiation	158 BTU/hr-ft^2

6.33 Evaporative cooler size calculations -

A portion of the solar radiation entering the greenhouse becomes latent heat. Typically about 50% of the input solar radiation is converted to latent heat. In the germination stage of growth the level of evaporation will be relatively low. The portion of the total solar energy input which is converted to latent heat is assumed to be 25%.

Wet bulb depression is 25°

Assume the air cooler has an efficiency of 80%.

Temperature cooled air = 90 - 25 x 0.80 = 70°F

Permissible temperature rise = 80°F - 70°F = 10°F

Initial enthalpy = 30.0 BTU/lb dry air

Final enthalpy = 33.2 BTU/lb dry air

Change in enthalpy h -

h change = 33.2 - 30.0 = 3.2 BTU/lb dry air

$$\text{Air Flow} = \frac{158 \text{ BTU/hr - ft}^2}{3.2 \text{ BTU/lb dry air}} = \frac{49.4 \text{ lb air}}{\text{hr - ft}^2}$$

$$\text{Total Air Flow} = \frac{49.4 \text{ lb}}{\text{hr-ft}^2} \times 3120 \text{ ft}^2 = 154{,}000 \text{ lb/hr}$$

Specific Volume Incoming Air = 14.06 ft^3/lb

Total Air Flow = 154,000 lb/hr x 1 hr/60 min x 14.06 ft^3/lb

Total Air Flow = 36,000 cfm

Pad Size -

Recommended size 1 ft^2/150 cfm (12)

Pad area = 36,000 cfm x 1 ft^2/150 cfm = 240 ft^2

The largest practical size of vertical pad which can be placed in the end of the greenhouse would be 6 foot high and 26 feet long. The largest practical pad area is 156 ft^2.

Maximum air flow = 23,400 cfm

Because of this restriction in pad size, the temperature must be allowed to go higher or moisture must be made available in the greenhouse for evaporation. A workable compromise might be to allow both to increase.

Allow the house temperature to rise to 82°F. Assume that with frequent watering the sensible heat load can be reduced to 60%.

Change in enthalpy = 4.9 (See Figure 8)

$$\text{Air Flow} = \frac{158\ \text{BTU/hr-ft}^2}{4.9\ \text{BTU/lb air}} = 32.2\ \text{lb air/hr-ft}^2$$

Total Air Flow = 32.2 lb/hr-ft^2 x 3120 ft^2 = 100,000 lb/hr

$$\text{Total Air Flow} = \frac{100{,}000}{60} \times 14.06 = 23{,}500\ \text{cfm}$$

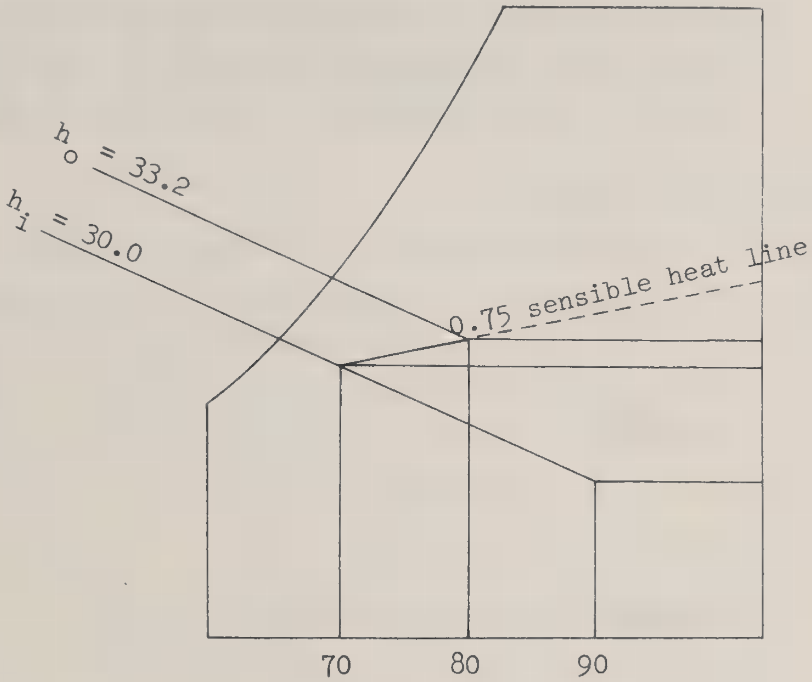


Figure 7. Psychrometric solution to heat load, 75% sensible heat.

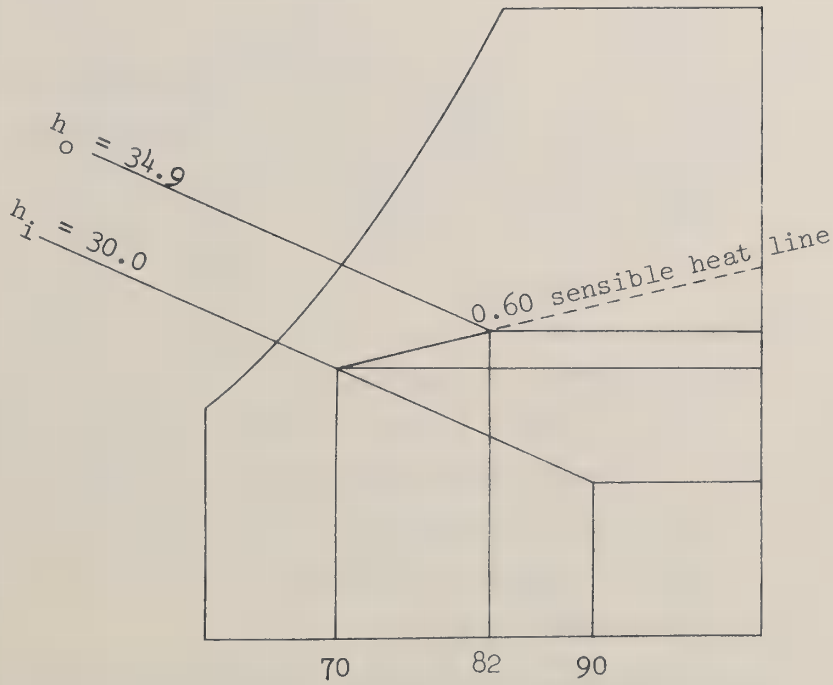


Figure 8. Psychrometric solution to heat load, 60% sensible heat.

High temperature control can be improved by using a cooling system with higher efficiency than the vertical pad system can provide. Higher efficiency can be obtained from a horizontal pad system such as that shown in Figure 9.

6.4 Fan selection -

The fan selected should be one which has been tested and rated by AMCA (Air Moving and Conditioning Association). The fan is selected on the basis of certified air delivery at 0.1" static pressure due to the resistance of the pads. The size and number of fans used is determined by the required air flow, flow distribution and the available wall space.

Required Air Flow = 23,400 cfm

Use two 12,500 cfm fans, one with 2-speed.

This air flow can be provided by a 42" fan with a ½ HP motor. Motor needs to be rust protected.

Can use an ACME Model DC 42G and a DC 42G-2S 115/230 V. The fan is equipped with wall housing,wall housing guard and shutter.

Shutters can be operated manually, automatically (open when fan is on) or motorized. The motorized type can be used in conjunction with the fresh air convection tube system. With a 230 volt system, smaller wire size can be used.

6.5 Pad system design -

Factors affecting pad design:

1) Pad needs to be continuous along the end of the greenhouse. Blank spaces will cause hot spots.
2) Correct pad size.
3) Thickness and density.
4) Proper location.

Vertical pads have become standard for greenhouse cooling systems. However, a system with horizontal pads has recently been developed which has some advantages over the vertical pad.

High temperature control can be improved considerably by using a cooling pad system which will provide a larger pad area than the conventional vertical pad. One means of doing this is to use a horizontal pad system such as that shown in Figure 9.

Advantages of the horizontal pad -

1) No salt accumulation problems.
2) Birds do not pick out pad material.
3) Settling of pads does not cause void areas which cut down on efficiency and allow insects and other flying objects to enter.

6.51 Pad size -

Recommended size is one square foot of pad for eavery 150 cfm air flow. (12)

$$\text{Pad size} = \frac{1\ \text{ft}^2}{150\ \text{cfm}} \times 23{,}400\ \text{cfm}$$

$$\text{Pad Size} = 156\ \text{ft}^2$$

$$\text{Pad Height} = 6\ \text{ft}$$

$$\text{Pad Length} = 268$$

This can be provided by 4, 1.5 ft x 28 ft horizontal pads. See Figure 9.

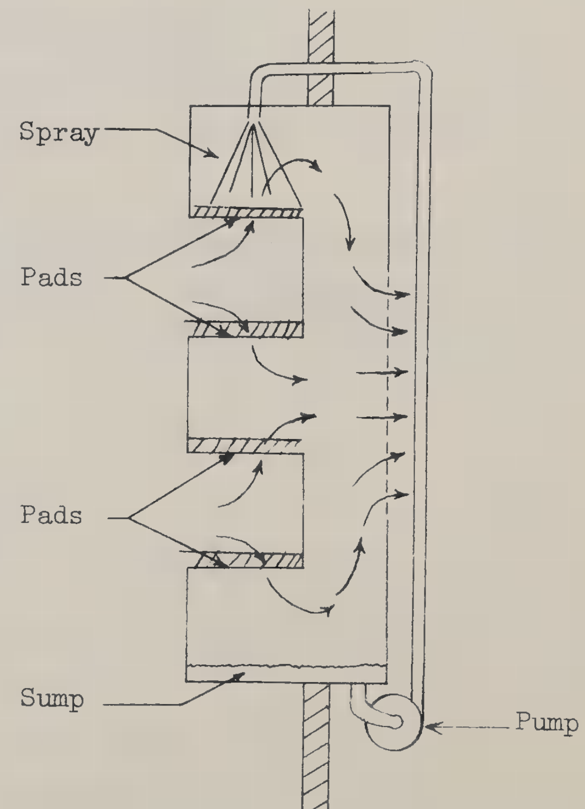


Figure 9. Horizontal pad.

7.0 Winter Ventilation System

Requirements of ventilation system:

1) Small to moderate quantities of air are required.
2) Flow must be turbulent for good mixing.
3) Flow must be ample to remove excess solar heat.
4) Cold air must be brought in without producing cold drafts on plants.
5) All parts of the greenhouse need to be at the same temperature.

Under average conditions, 1½ to 2 cfm per square foot will hold the house temperature within 15°F of outside temperature.

A Modine Flora-Guard Heating/Ventilation system was chosen to provide uniform greenhouse temperatures in a cold climate. The air handling capacity of all "Flora-Guard" systems is fixed at the same cfm. The number of units required for ventilation is determined by the size of the greenhouse. Two units are required for a 30 ft by 104 ft greenhouse.

8.0 Heating System

The Modine "Flora-Guard" is a cold climate system with two poly tubes and a heater intake hood to lift cold air from the floor. Modine claims no more than 3°F temperature variation from the design temperature at bench level, even at the walls. This result was obtained with outside conditions of 0°F, cloudy with an 8 mph wind. House width was 34 feet.

Two poly tubes are recommended for house widths greater than 30 feet. Due to the extreme winter conditions at Bozeman, a "two polytube" system will be considered for the 30 foot house width of the sample design.

Heating capacity is determined from the total exposure area and a heat transfer coefficient established for a glass house with a correction factor for other covering materials. A correction factor is also applied for wind above 15 mph. In addition, there will be some heat loss at the perimeter through the soil.

Outside design temperature	-20°F
Minimum house temperature	60°F
Temperature difference	80°F
House circumference	44 feet
House length	104 feet
96 ft double film cover	
18 ft single layer fiberglass	

Cover factor - double plastic $c = 0.7$

single fiberglass $c = 1$

Wind factor - design wind under 15 mph $w = 1.0$

Heat transfer coefficient for the I/O temperature difference of 80°F is 1.15, V = 1.15.

$$\text{Heat load} = (A_1C_1 + A_2\ C_2)\ \ (T_1 - T_2)\ \ V + \text{perimeter heat loss}$$

8.1 Heat loss calculations

Double-layer film section -

$$H_d = 44\text{ ft} \times 96\text{ ft} \times 0.7 \times 80^\circ\text{F} \times 1.15$$

$$H_d = 272{,}000\text{ BTU/hr}$$

Fiberglass cover section -

$$H_f = (353\ ft^2 + 497\ ft^2) \times 80^oF \times 1.15$$

$$H_s = 78{,}200\ BTU/hr$$

Perimeter heat loss -

with the soil perimeter insulated the heat loss is assumed to be 0.5 BTU/hr-ft-^oF (3).

$$H_p = 0.5\ BTU/hr\text{-}ft \times 255\ ft \times 80^oF$$

$$H_p = 1020\ BTU/hr.$$

Total heat loss -

$$H_t = H_d + H_f + H_p$$

Heat load = 351,000 BTU/hr

Heat output per unit = 176,000 BTU/hr

8.2 Heater selection -

Modine model GHG 230 has a capacity range of 100,000 to 184,000 BTU/hr at 2,000 feet elevation. The capacity is reduced 4% for each 1,000 feet elevation above sea level.

Heat input - Minimum 125,000 BTU/hr
Maximum 230,000 BTU/hr

Elevation reduction - $4\% \times \frac{4800}{1000} = 19\%$

Heat input - Minimum 101,200 BTU/hr
Maximum 186,300 BTU/hr

Heat output - Minimum 80,800 BTU/hr
Maximum 149,000 BTU/hr

This unit does not have sufficient capacity at 4,800 feet elevation.

Next larger unit - GHG 350

Heat input at 2,000 ft - Minimum 240,000 BTU/hr
Maximum 350,000 BTU/hr

Rating at 4,800 ft

Heat input - Minimum 194,000 BTU/hr
Maximum 283,500 BTU/hr

Heat output - Minimum 155,000 BTU/hr
Maximum 227,000 BTU/hr

This heater will meet the requirement. The capacity required is obtained by burner orifice selection.

9.0 Additional CO_2 Provision

Sources of CO_2:

1) Bottled CO_2
2) Dry ice.
3) CO_2 produced by micro-organisms.
4) Burning sulfur-free gaseous fuel such as natural gas, LP gas, propane or kerosene.

All methods of providing CO_2 are not feasible in this greenhouse operation. Bottled CO_2 and dry ice are expensive. The cost of providing CO_2 with dry ice, is about ten times the cost of providing CO_2 with propane. The burning of fuel to provide CO_2 is a practical method in common use.

Special burners are available for releasing CO_2 from the fuel combustion process. The amount of CO_2 released by the burning process is adjustable and metered. The generator can be controlled by a timer.

Good results have been obtained with the CO_2 generator placed at the air return inlet to the air circulation system.

A heat exchanger can be installed to expell heat from the CO_2 generator to the outside to avoid heating the house.

The CO_2 generator chosen for the sample design is a Johnson, manufactured by the Johnson Gas Appliance Company.

10.0 Automatic Controls for Heating and Cooling - (2)

General comments on controls for greenhouse equipment:

Thermostats are used to turn fans and pumps on and off. A humidistat can be used to control the pump of the cooling pad system and to control the exhaust fans.

Air should be circulated over the thermostats and humidistats. This can be done with a small blower that moves the air with a velocity of at least 500 ft/min.

Each thermostat and humidistat should have a manual switch. A safety disconnect switch should be located near each fan and pump.

Cooling pad vents should be motorized and controlled by thermostats.

Fans - Exhaust fans should be controlled by individual thermostats, in stages. A two speed fan should be controlled by a two stage thermostat. Each fan stage should be set at progressively higher temperatures. The first stage fan should be set at least $5^{o}F$ above the setting of the thermostat that controls the heating system, to avoid overlap of heating and cooling.

Exhaust fan shutters should be controlled automatically to prevent back drafts caused by wind.

Pumps - Cooling pad pumps should be controlled by humidistats and thermostats wired in series. A thermostat should be used for the main pump control. The thermostat should be set to stop the cooling pad pump before all the fans are shut off so that the pad can dry out to prevent mold and deterioration.

Dehumidification - The relative humidity can be reduced by bringing in cool outside air that has a lower water vapor content. This requires both the ventilating system and the heating system working in conjunction. Both humidistats and thermostats are needed to control the dehumidification process.

Shields - Thermostats, humidistats and thermometers should be shielded from the direct rays of the sun. Wood which is 1/2 inch thick will provide a sufficient shield.

Wintertime Cooling - During fall, winter and spring, when the house temperature becomes too high, a thermostat can be used to open a motorized shutter on the inlet of the jet tube recirculating system and to turn on an exhaust fan. When the desired temperature is reached the thermostat closes the inlet shutter and turns off the exhaust fan.

Control Voltage - Control circuits are presently being used which operate at line voltage or a considerably lower voltage. The low voltage system can be installed at reduced cost because of the more stringent installation requirements associated with line voltage systems. The low voltage system reduces the shock hazard.

The control system price will be based on the lower voltage system.

10.1 Fan and pad cooling system control - (2)

Equipment to be controlled:

1 - single speed exhaust fan
1 - two speed exhaust fan
1 - cooling pad pump
2 - exhaust fan shutters
1 - cooling pad shutter

Five sensing devices should be used in the control operation, one humidistat and four thermostats. Three of the thermostats are to be used for exhaust fan control. One thermostat is to be used for cooling pad pump control and pad shutter control. The humidistat will be used in controlling the cooling pad pump.

Let the thermostats which control the exhaust fans be labeled T_1, T_2, and T_3. Let the thermostat which controls the cooling pad pump be labeled T_p. These thermostats should be set at different temperatures, in ascending order. Temperature differentials should be small, on the order of $2^{o}F$. As the temperature in the house increases, first T_1 will turn on the two-speed exhaust fan at low speed. With further increase in temperature this fan is switched to high speed by T_2. With still further rise in temperature T_p will turn on the cooling pad pump. With still further rise in house temperature, T_3 turns on the second exhaust fan.

In the case where house temperature and humidity are too high, a humidistat H, is set to limit the humidity. As the exhaust fans are turned on due to rising house temperature, the thermostat T_p is prevented from turning on the cooling pad pump by the humidistat H.

The actual number of thermostats can be reduced by incorporating single stage thermostat functions into a multi-stage thermostat.

10.2 Wintertime heating and ventilating equipment control -

See Section 7 for information on the heating and ventilating system.

Equipment to be controlled:

1 - single speed exhaust fan
1 - two speed exhaust fan
2 - exhaust fan shutters
2 - ventilating shutters
2 - gas fired heaters

An additional thermostat is needed to control the heaters, T_h. T_h and the first stage exhaust fan thermostat can be interlocked so that the exhaust fans cannot operate while the heater is on.

During winter time, T_1, in addition to controlling the exhaust fan, controls the vent shutters that admit outside air into the polytube. A recirculating fan in the polytube system runs continuously.

High humidity is controlled by the same means as during summer ventilation. However, air inlet is through the polytube vent instead of the cooling pads.

A heating-ventilating sequence might be as follows:

> At 64°F heating is required - T_h turns on heaters; 65°F to 85°F, no heating or cooling; at 86°F cooling is required - T_1 turns on the low speed fan; temperature continues to rise - at 87°F, T_2 turns the fan on full speed; temperature continues to rise- at 88°F, T_3 turns on the second fan full speed. The fans are shut off in reverse sequence as the temperature drops.

10.3 Day-time to night-time temperature settings -

With 10°F difference between required daytime and nighttime temperatures an automatic change-over from day to night settings is desirable. This requires an additional thermostat, with a nighttime setting, to control the heaters. A timer and a relay could be used to switch control to the appropriate thermostat.

10.4 Seasonal change-over -

In the summer time, the polytube fans are kept off and the outside air inlet to the polytube is kept shut. The seasonal change in operating equipment can be made by means of a summer-winter switch.

10.5 Summary of heating and cooling control equipment -

The following equipment is required for heating, cooling and ventilating equipment control.

3 - exhaust fan thermostats
2 - heater thermostats
1 - humidistat
1 - day-night timer (this could be the same timer used for control of the CO_2 generator)
1 - day-night relay
1 - 500 fpm suction blower

11.0 Growing Method

A styrofoam container was chosen to hold the trees. This type of container is reusable. Also, it can be seeded by machine.

A peat-vermiculite mix was chosen as a growing medium. With this mix no sterilization will be required for either of the mix materials. However, used containers should be sterilized.

Nutrients are supplied in the water. Nutritional requirements can be found in Tables 1 and 2.

12.0 Watering and Fertilizer Systems

12.1 Watering system equipment -

Getting uniform water distribution is a problem encountered with greenhouse watering systems. A traveling sprinkler system has been chosen to provide uniform watering. The system chosen is marketed by Master Grower Systems Division of the Hatcher Sales Company. It is referred to as a "Creepy Crawler". The basic feature of the system is a boom which travels over the plants, spraying water downward. The boom is propelled by a drive mechanism which travels on the tracks down the center of the house. A hose supplies water to the boom from the center of the greenhouse. The hose is dragged along the floor, moving with the sprinkler boom.

Equipment required:

1) sprinkler boom
2) track
3) propelling motor and mechanism
4) hose
5) controls

12.2 Sprinkler system operation -

The sprinkler operates automatically.

The sprinkler rests at the cooling pad end of the house. The hose is fed from the center of the house. The sprinkler applies water and nutrients while traveling one way. On the return trip only water is applied to rinse the nutrients out of the sprinkler system. A micro-switch could be placed at some point along the track near the end of the track for the purpose of switching to water only. The switch could be placed so that the system clears by the time the sprinkler reaches the end of the track. When turning on the system, the timer must turn on the nutrient flow in time for the nutrient to reach the nozzles before the sprinkler starts to move.

12.3 Required flow rate -

A peat-vermiculite mix will take water slowly when dry. However, if already moist, the intake rate will be about 3-4 inches per hour. (9)

Sprinkler travel speed = 7.5 ft/min

Length of travel = 94 ft

Travel time = 12.5 min

Apply ½ inch water per watering

Apply ¼ inch water per run

Area water is applied to in one minute:

Area = (13x13) 7.5 = 195 ft^2

Colume applied in one minute:

Vol = 195 ft^2 x 0.25/12 = 4.06 ft^3/min

Flow rate = 30.4 gal/min

Four houses together require 122 gal/min

12.4 Nutrient supply system -

The nutrient solution can be mixed in bulk and stored or it can be mixed at the time of application by a metering-mixing device. The premixed method requires considerable space in the head house if stored above ground. If buried, it requires a rather involved construction. Therefore, the metering method appears to be more desirable since no large storage facility is needed.

Size of nutrient injector -

The Anderson Ratio Feeder model DPM-16N will handle flow for all 4 sprinkler systems operating at once. Cost of this model is $1,877.00. Model DPM-5N will handle flow for 1 sprinkler system. Cost of this model is $824.00. Use Model DPM-5N with a cam timer. Water one greenhouse at a time.

Other equipment -

1 - mixing tank (42 gal)

3 - gate valves

1 - globe valve

1 - check valve

4 - solenoid valves

450 feet of 1 3/4 inch plastic line

12.5 Water distribution system -

The diagram of the distribution system is shown in Figure 10

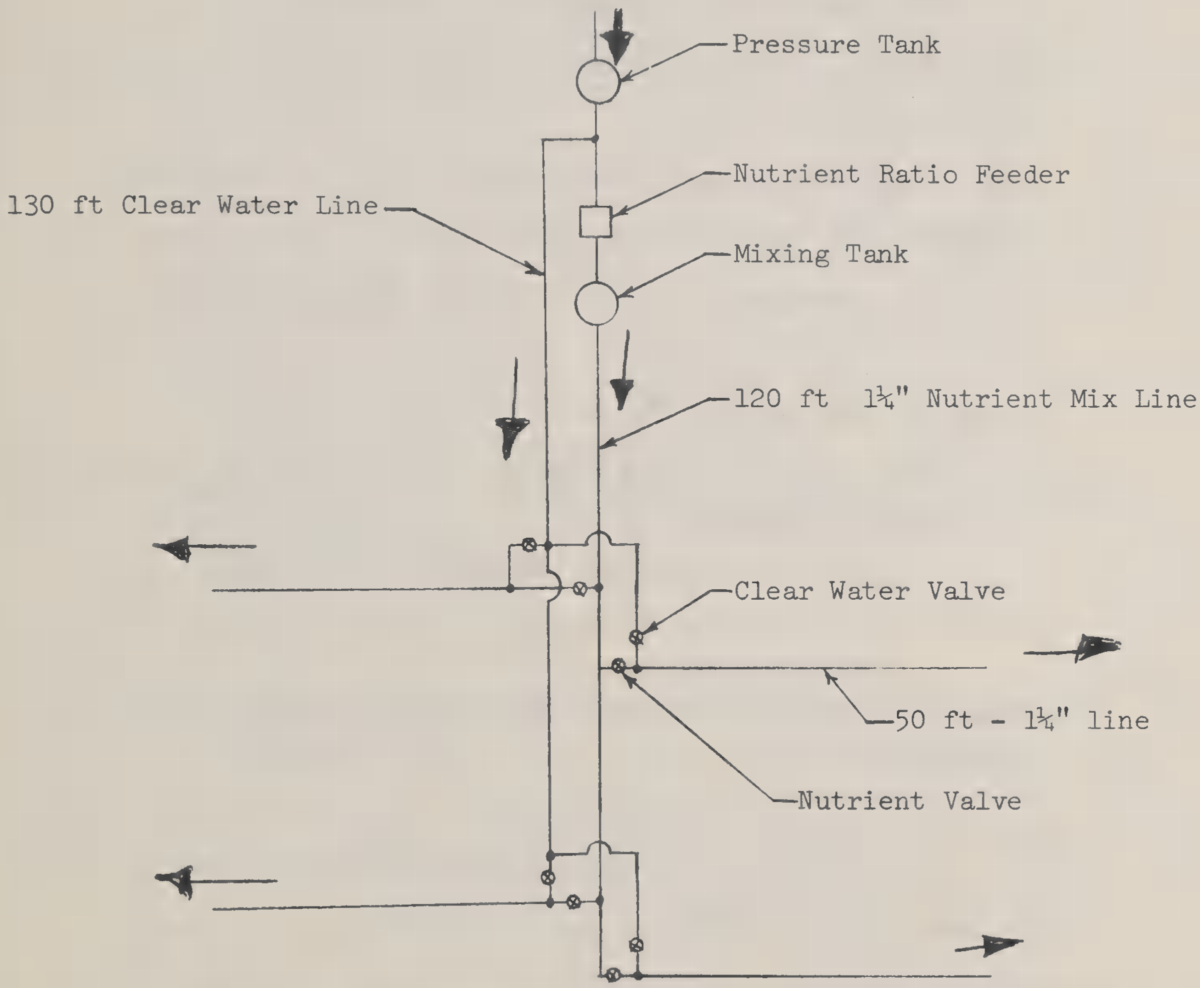


Figure 10. Water distribution system.

13.0 <u>Lighting for Photoperiod Control</u>

Light intensity required - 40 ft-c

Light must be on at least 3% of the dark period

Longest dark period must be no more than 30 minutes

Area to be illuminated -

Growing area each side = 1200 ft^2

Total growing area = 2400 ft^2

13.1 Lighting information from authorities in the lamp industry -

1) High-wattage lamps are more efficient than low-wattage lamps of the same voltage and life rating. A 150-watt, 120 V general lighting service lamp produces 34% more light than three 50-watt 120 volt lamps. Low-voltage lamps are more efficient than higher-voltage lamps. (19)

2) Four 250-watt PS-30 type lamps can replace sixteen 100-watt ordinary tungsten lamps.

   Life of the PS-30 lamp is 5000 hours. Life of the ordinary tungsten lamp is 1000 hours. (6)

3) The PS-30 type lamp is recommended for this greenhouse application. (5)

   Rules of thumb for the PS-30 -

   Lamps are generally placed on 10 ft centers at 8 feet above the plants.

   1) The 150-watt PS-30 will provide 13-15 ft-c.
   2) The 250-watt, PS-30 will provide 33-35 ft-c with fair uniformity.

   Three rows of the 250W PS-30 should work for this application of 40 ft-c.

13.2 Consider the 100-watt ordinary tungsten lamp -

100-watt tungsten lamps will provide 40 ft-c if lamps are placed on the basis of 8 watts/ft^2 at a 4 foot height.

Wattage for one house -

$$\text{Wattage} = 8 \text{ watts/ft}^2 \times 2400 \text{ ft}^2 = \underline{19{,}200 \text{ watts}}$$

Number of lamps required -

$$\text{Number of lamps} = \frac{19{,}200 \text{ watts}}{100 \text{ watts/lamp}}$$

$$\text{Number of lamps} = \underline{192}$$

13.3 Consider the 250 watt, PS-30 lamp -

The recommended 10 foot spacing at 8 foot height will provide 33 ft-c. Therefore, a 9 foot spacing with a 7 foot height should provide 43 ft-c.

Place lamps on 9 foot spacings.

There will be 3 rows of lamps, with 10 lamps per row, 30 lamps per house.

Total wattage = 30 x 250 = 7500 watts

With 3 rows of lamps, one row will need to be in the center of the house.

The preceding calculations show that the PS-30 type lamp is more efficient than the ordinary tungsten lamp. Also, fewer lamps and less wiring material is needed. Therefore, the PS-30 will be used in the design.

13.4 Lamp circuit and power load -

Divide the lamp system into 3 circuits and use a cyclic lighting system to control the lights.

Power load per circuit = 2500 W

Current load per circuit = 20.8 amp

Since the current load diminishes with distance, size 12 wire will be large enough.

14.0 Growing Material Requirements -

Perlite is recommended for covering the growing mix material. (18) To provide some space for the perlite the peat-vermiculite mix will have to be compressed slightly after filling.

Allow 3/8 inch depth for perlite.

There will be 4 inches of depth for the peat-vermiculite mix.

In the filling operation the holes can be filled level full with the peat-vermiculite mix. The mix could then be shaken or pressed down to provide the 3/8 inch space on top for the perlite. This would reduce the mix volume in the hole to 90% of the original fill volume.

14.1 Vermiculite quantity and storage area-

Volume of one hole = 0.00131 ft^3

912,384 holes per crop

Total mix Vol. = 1190 ft^3 = 44.3 yd^3

Vermiculite volume needed is half of the total volume.

Vermiculite Vol. = <u>600 ft^3</u>

Add 10% to the volume, so the storage volume is 660 ft^3.

Set the storage height at 7 feet

Floor Area = <u>94 ft^2</u>

Vermiculite Storage Area - 6 ft x 15.5 ft

14.2 Peat quantity and storage area-

The mix contains 50% peat. When stored in a bale the volume of the peat is reduced to 40% of its loose volume.

Peat Loose Vol. = 600 ft^3

Peat Baled Vol. = 240 ft^3 (40 bales)

Add 10% to the baled volume so the storage volume is 264 ft^3

Floor Area = <u>37.7 ft^2</u>

Peat Storage Area - 11 ft. x 3.5 ft.

14.3 Perlite quantity and storage area -

The volume of perlite required is one eleventh of the volume of peat-vermiculite mix.

Perlite Vol. = <u>110 ft^3</u>

Allow storage area for a year supply, thus doubling the required storage volume.

Perlite Vol. (1 yr.) = 220 ft^3

Floor Area = <u>31.4 ft^2</u>

Perlite Storage Area - 4 ft. x 8 ft.

15.0 Head House Requirements

Guidelines for head house operation:

1) Peat is dry and dusty. It should be moistened. The mixing operation is greatly facilitated by moistening the peat a day or two beforehand.

2) Peat wets very slowly.

3) A suggested amount of moisture is that which will result in a couple of drops of moisture coming out of the peat when squeezed in the hand. (4)

   The question arises as to whether or not this amount of moisture will cause germination. One authority feels this would not be a problem because the pine seed is slow in taking water. Seeds should not germinate under these conditions. (21)

4) The peat may come in large chunks and may need to be ground so that it will mix well with other material.

15.1 Seeding operation -

Assume planting is to be done in 20 working days.

For one crop there are 4752 containers to be filled.

Daily Fill = 238 containers/day

240 containers per day would work well. These could be hauled from the storage area to the fill area in one bundle. The container bundle would be made up of 18 layers of containers with 12 containers per layer in a 3 by 4 pattern. The bundle dimensions would be 4.7 ft. by 5.6 ft. by 8.25 ft. high.

There would be no stacking of the container bundles in the storage area. The bundles could be stored on wooden pallets which would facilitate moving them with a fork lift.

15.11 Equipment required for mixing -

It's desirable to add some water to the peat and vermiculite during the mixing operation. A mixer and two conveyors are needed for the mixing operation.
One conveyor would be used to load peat into the mixer, the other conveyor would be used to transfer the mix from the mixer to the fill station. The peat could be carried from storage by hand and dumped into a hopper. Vermiculite can be dumped directly into the mixer.

Peat and vermiculite amounts can be measured by fill depth in the mixer.

Water can be metered into the mix by means of a time clock and an electric valve.

Volume of material for one day -

$$\text{Vol} = 0.00131\ \text{ft}^3/\text{hole} \times 192\ \text{hole} \times 240\ \text{container/day}$$

$$\text{Vol} = 60.4\ \text{ft.}$$

After filling, the material is compacted to 90% of its loose volume. The uncompacted volume will then be 1.11 times the compacted volume.

$$\text{Vol. Loose} = 60.4 \times 1.11$$

$$\text{Vol. Loose} = 67.0 \text{ ft}^3/\text{day}$$

The peat and vermiculite could be mixed in a Davis horizontal batch mixer. Mixing is accomplished by the action of augers and agitators in a horizontal tank. The model S-5 has a capacity of 28 cubic feet. The daily volume could be mixed in 3 batches. A mixer with capacity to handle the daily requirement in a single batch would cost $1073. A smaller machine would cost $670.

For convenience the peat hopper should be large enough to hold 5 bales. The hopper volume should be 80 ft^3. The order of the dimensions of the hopper would be 5 ft. x 5 ft. x 3 ft. deep.

15.12 Filling and seeding operation -

A stack of containers could be placed near the filling station. The 240 container stack would be moved from storage by means of a fork lift. Containers would be taken from the stack and placed at the filling station by hand. Fill material would be conveyed from the mixer and allowed to pour into the container. The material would then be jolted to settle it. Spilled mix material can be collected below the conveyor and returned to the mixer.

The container can be moved by conveyor to the seeding station. Seeding can be done with a Fricke seeding machine in two operations.

The container can then be moved to the perlite station. After being covered with perlite the container can then be placed on the steel pallets by hand.

The quantity of perlite needed for one day is about 9 cubic feet.

15.13 Pallet handling -

Pallets can be placed on a rack for the seeding operation. The rack can be designed such that the pallets move to the seeding station by gravity. Four pallets could be loaded on to the rack at one time. The pallets would be moved with a fork lift.

15.14 Storage of pallets and seedling containers -

Storage of seeded containers -
Seeded containers require inside storage. The storage area would be unheated.

The number of pallets required for one crop is 144. If the pallets, with seeded containers, are stored 9 high they will make up 16 stacks. These stacks could be stored in two rows. The length of a row would be 41 feet. See figure 2. When the containers are stored empty, some of the empty steel pallets could be stored outside. The space inside would be used to store bundles of empty styro-foam containers.

Storage of empty containers -

If the empty containers are bound into bundles, with 240 containers in each bundle, containers for one crop would make up 20 bundles.

Bundle is 4.7 ft. x 5.6 ft. x 8.25 ft. high

With three bundles side-by-side in the pallet storage area, the storage area would be 7 bundles long.

Storage area for bundles - 14 ft. x 40 ft.

This area takes up only half of the seeded container storage area.

An additional 7 bundles would be stored in this area because of 1/3 of the fall crop to be held over until spring.

These large bundles could be wrapped in old plastic film which has been removed from the greenhouses. With the bundles wrapped in plastic they could be moved outside during the seeding operation.

The containers could also be sterilized while in the plastic wrapped bundles. The sterilization would be accomplished with a gas. This task could be conducted outside.

16.0 Lath House Requirements

For lath house environmental requirements, see Section 2.1.

16.1 Lath house space required

Space is required for one full winter crop plus one third of the summer crop.

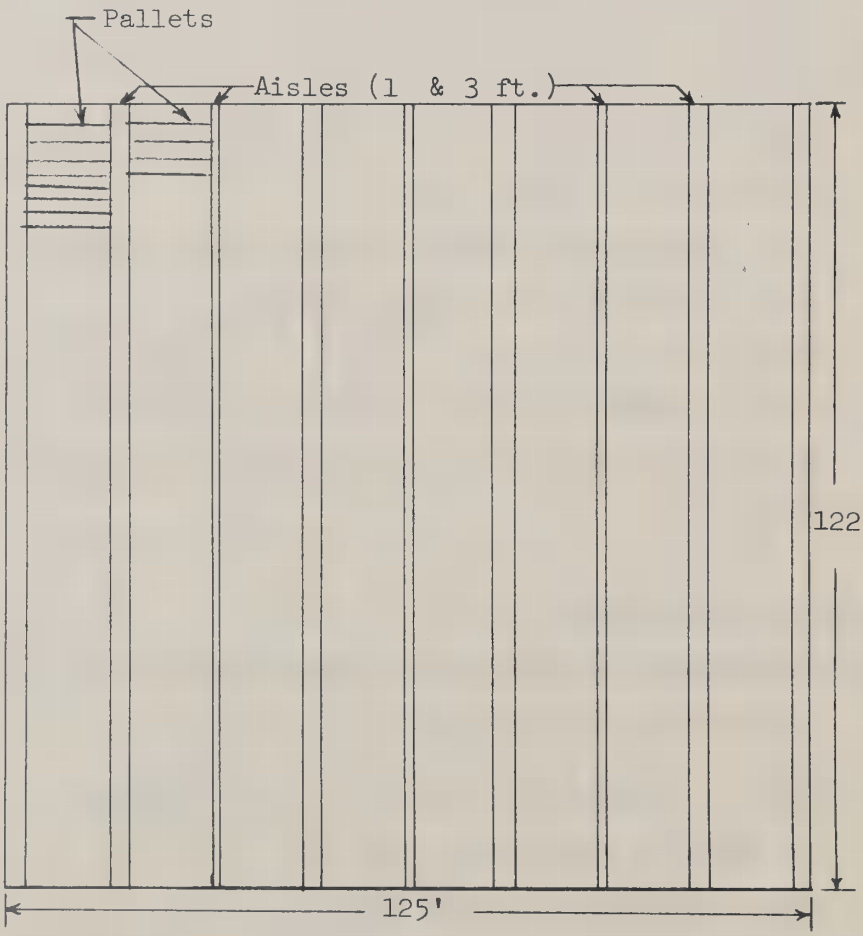
Space for one crop = 9600 $ft.^2$

Space for 1 1/3 crop = 12,800 $ft.^2$

192 pallets needed for one and a third crops.

16.2 Lath house layout -

Place pallets in 8 rows, 24 pallets long, as in figure 11.



gure 11. Lath house pallet placement.

16.3 Lath house design -

A wooden lath house was first considered. The basic idea in the design was to have the roof made up of 12 inch boards standing on edge. The boards were to be spaced about a foot apart. The purpose of this scheme was to provide complete shade without incurring a snow load.

This structure would be rather costly.

Estimated material cost	-	$ 9,000
Estimated labor cost	-	$ 2,000
Total structural cost	-	$11,000

Shade fabric was chosen as an alternative, to provide a lower cost structure. See figures 12 and 13.

16.31 Shade fabric information (14) -

1) Tensile strength -

Prop-a-lite	- 310	lb./in.	lengthwise
	95	lb./in.	crosswise
Saran	- 185	lb./in.	lengthwise
	50	lb./in.	crosswise

2) Methods of fastening -

1. Fabric may be fastened by the use of gromets every 12-18 inches. A tape is first attached to edge.

   The tie point is as strong as the material.

Cost of tape attached is 9.4 cents per foot.

Gromets are 4.2 cents each.

2. Hog rings may also be used. This method is similar in strength to the gromet method.

16.32 Design of lath house with shade fabric -

Polypropylene woven fabric was chosen because it has higher strength than Saran. The shade cover can be made of 5 foot strips of prop-a-lite.

To keep the structure simple in construction use poles approximately 5 feet apart, in rows 30 feet apart.

The fabric strips can be placed in a vertical position to provide total cover from the sun from September 21st to March 22nd. After March the snow load should not be accumulative. The maximum expected snow level after this time is about 15 inches. (7)

The ratio of water depth to snow depth for Bozeman is about 1/15. (7) One inch depth of water weighs about 5 pounds per square foot.

Pole spacing and fabric hanging -

The sun angle on March 21st is 45°.

Hog rings can be used as a method of fastening the fabric to the supporting cable.

Assume that edge fold and fabric sag will shorten the span of the fabric by about 6 inches. Pole spacing and fabric hanging will be as shown in figure 12.

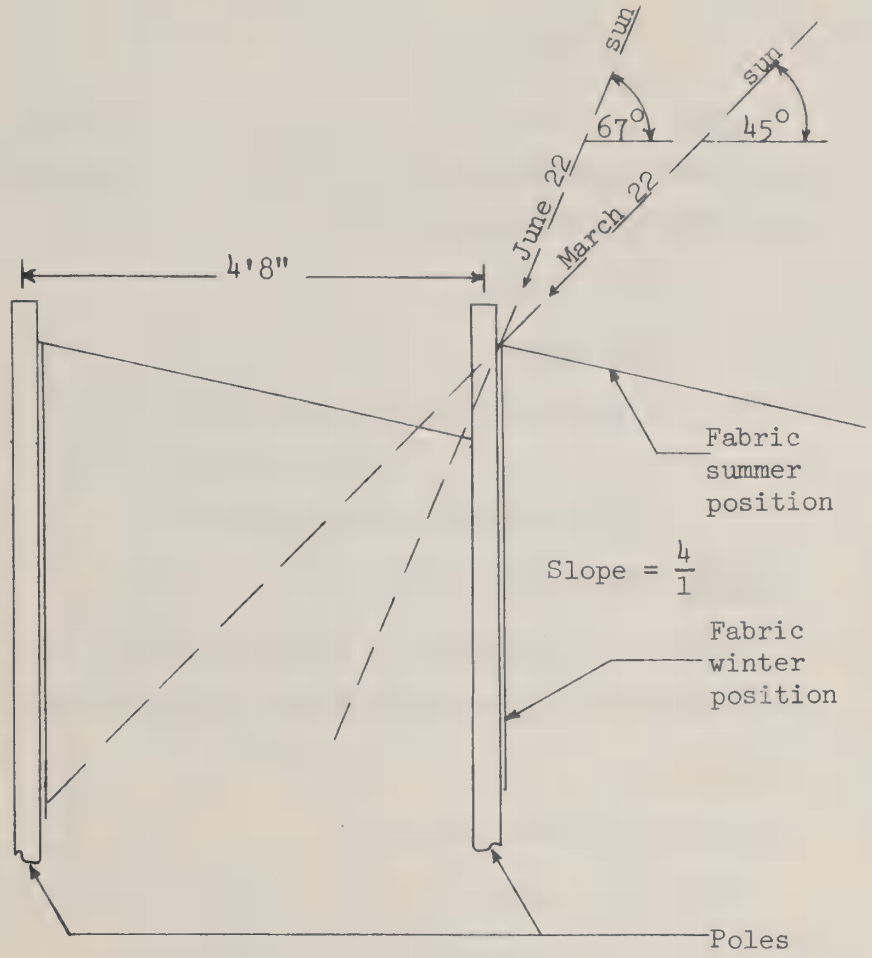


Figure 12. Fabric placement.

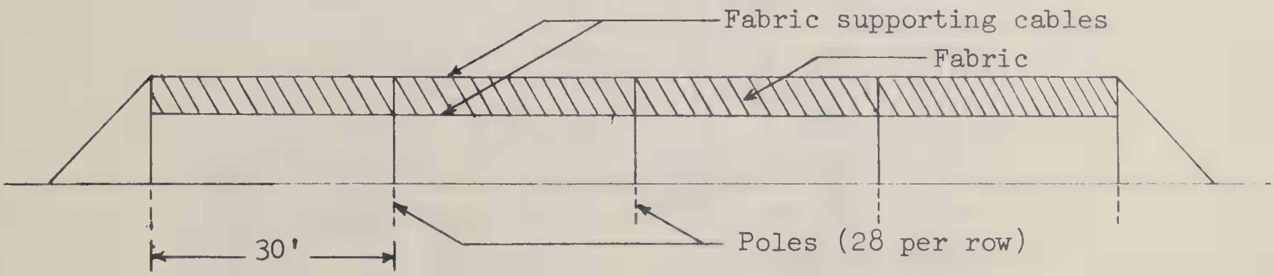


Figure 13. Fabric support system.

There would be 5 rows of poles with 28 poles per row as shown in figure 13.

Total poles = 140

Hog rings -

Cable fasteners - 2 j-bolts per pole
Total j-bolts - 280

Cable anchors - 56 anchors

Fabric required for roof -

Twenty-eight strips are required for the lath house roof. The strips would be 120 feet long.

Total material = 16,800 ft^2

Hardware required for roof -

Cables - 2 cables every 4.5 ft.

Total cables - 56

Length one cable - 160 ft.

Total cable length - 9000 ft.

Fabric required for walls -

Space from top of roof shade fabric to the ground is 11.5 feet.

A 1 foot space can be left at the bottom. Fabric which is 11 feet wide can be used to cover the remaining 10.5 feet.

Total wall fabric - 3980 ft^2

Hardware required for walls -

The fabric can be fastened to 3 cables, one at the top, one at the bottom and one in the middle.

Quarter inch cable can be used with the cable fastened to poles every 4.5 feet along the side walls and every 10 feet along the back wall.

Poles are required to support wall cover along the back wall of the lath house. These poles could be spaced every 10 feet.

Additional poles - 8 poles

Cable - Total length - 1086 ft

Cable fasteners - 3 fasteners per pole

Total fasteners - 201

16.33 Lath house sprinkler system -

Area to be watered is 125 ft by 122 ft, as shown in figure 14.

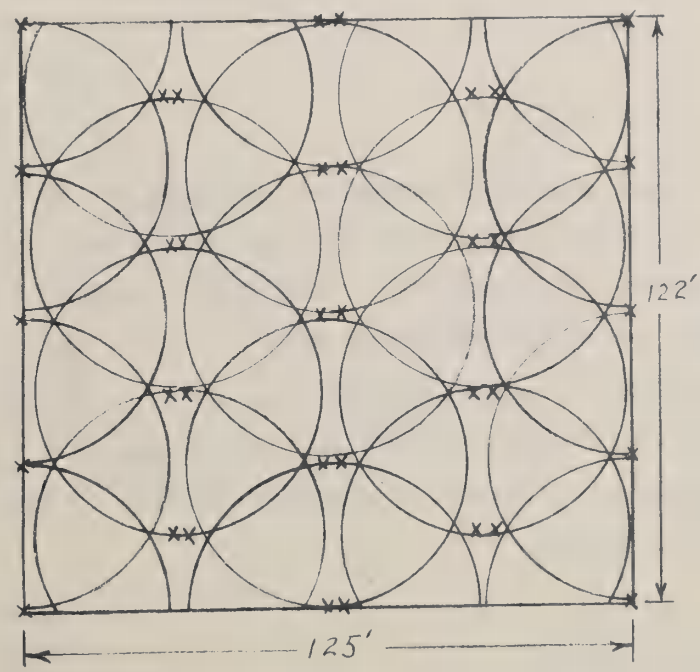


Figure 14. Sprinkler coverage in lath house.

Place sprinkler head every 30 feet.

Area to be covered by one nozzle is 900 ft^2.

A low angle nozzle must be used, 20 degrees or less.

The amount of water to be applied is 0.25 inches per hour.

Sprinkler heads must go within the pole rows. Therefore, all sprinkler heads should be part circle type because of poles being every 5 feet.

Sprinkler head flow rate -

$$\text{Head flow} = \frac{900\ ft^2}{2} \times \frac{0.25}{12}\ ft/hr \times 7.48\ gal/ft^3 \times 1\ hr/60\ min$$

Head flow = 1.2 gpm

Part circle sprinkler head -

The rainbird model 25 AS FP-TNT sprinkler head should work in this application. It requires 40 psi pressure with a 1.65 gpm flow rate.

Total flow -

Total flow = 59.4 gpm

The flow requirement could be reduced by dividing the sprinklers into two groups. With only half of the sprinklers on at a time and a flow rate of 30 gpm, the ratio feeder used in the greenhouses could serve the lathhouse also.

Lathhouse and greenhouse watering schedules will likely be different due to the different environments. A separate timer will be needed to provide independent cycling of the lathhouse watering system.

An interlocking circuit will have to be incorporated to prevent the greenhouse watering system and the lathhouse watering system from operating at the same time. This can be accomplished with two interlocking relays.

Equipment required for the sprinkler system -

36 - part-circle sprinkler heads with risers
170 ft - 2-inch plastic pipe
1000 ft - 1-inch plastic pipe
55 - fittings
4 - valves
1 - two-switch timer
1 - moisture sensing devices
2 - relays

120 ft. - 1 inch plastic pipe

55 - fittings

4 - valves

1 - timer

1 - DPM-10N Ratio:Feeder

2 - moisture sensing devices

1 - 120 gallon mixing tank

Cost Analysis

Cost will be analyzed in the following order:

1) Initial cost
2) Annual fixed costs
3) Annual operating costs
4) Cost per seedling

17.1 Initial cost of facilities, equipment and construction-

The initial cost will be analyzed in order as follows:

1) Cost of site preparation
2) Cost of water well
3) Cost of individual greenhouses
4) Cost of greenhouse corridor

5) Cost of the four greenhouses combined
6) Cost of head house structure
7) Cost of lath house
8) Cost of material handling equipment

17.11 Cost of site preparation -

Site preparation will consist of leveling, packing the soil, putting down a gravel base and blacktopping areas as required. The amount of gravel base required depends on the soil. The amount of gravel base is a major factor in the cost.

Amount of blacktop -

Head house floor completely blacktopped

Greenhouse aisles blacktopped (3 ft. wide)

Area blacktopped = 5280 ft^2

Blacktop Cost = $2500

Graveled area -

Lath house and driveways would be graveled. The cost includes minimum excavation, leveling, packing, gravel spreading and gravel material.

Area = 20,700 ft^2

Gravel Area Cost ≐ $2300

Total Site Preparation Cost = $4800

17.12 Cost of water well -

Cost of a 100 foot well includes a pump and a 500 gallon pressure tank.

Cost of Well = $5500

The cost of the well could be reduced by sequencing through the sprinkler lines in the lath house, thereby reducing the required flow rate delivered by the well pump.

17.13 Cost of individual greenhouses -

17.131 Structural cost -

(Cost is based on Stuppy's prices.)

1) Support structure -

The support structure includes all galvanized metal pipe and pipe stakes, for a quonset type structure.

Structure Cost = $664

2) Cover -

The greenhouse cover includes 6 mil UV inhibited plastic, 4 mil greenhouse grade plastic.

Cover Cost = $115

3) Plastic fastening strips -

The plastic fastened by a metal strip called a Polylock extrustion. The film perimeter is 268 feet.

Polylock Cost = $80

4) Redwood bottom board -

The bottom board is 2 x 6 redwood

Bottom Board Cost = $48

5) Greenhouse end section -

The end section cost is estimated from information provided by Rough Brothers.

End Section Cost = $225

6) Frost insulation -

Frost insulation can be provided by styrofoam panels which run down 2 feet below the surface at the walls. The panel thickness is one inch.

Length of insulation = 222 feet

Insulation Cost = $40

7) Total material cost -

Support structure	$664
Cover	115
Polylock	80
Bottom board	48
End section	225
Frost insulation	40
	$1172

8) Freight charge -

The freight charge is estimated to be 10% of the material cost.

Freight charge = $123

9) Construction -

The cost of construction is taken as an estimate from the Rough Brothers Company. The estimate includes heating and cooling equipment installation.

Construction cost = $1500

10) Total cost of the greenhouse structure, installed -

Total Structure Cost = $2795

17.132 Cooling equipment cost -

1) Fan system -

1 - DC 42G Fan	$133
1 - DC 42G-2s Fan	147
2 - WB42DC wall housing	68
2 - GD42 wall housing guard	22
2 - W4545MT motorized shutter	150
Cost Fan Equipment =	$520

2) Pad system -

Cost of the cooling pad system is determined for the vertical type pad. The prices include all hardware and equipment for a complete system.

The pad frames are 34 inches wide. Therefore, the pad will have to be made up of 9 frames which are 6.5 feet in height.

Pipe distribution & return	$ 79
Pump	112
Frames	87
Pad	30
Motorized shutters	525
Pad System Cost =	$833

3) Total cost of cooling system -

Fan system	$520
Pad system	833

Cooling System Cost = $1353

17.133 Cost of heating units -

The complete heating and ventilating unit includes the following:

Outlet transition
230 volt motor
Fan assembly
Controls
Outside/return air plenum
25 volt motorized outside air
Inlet shutter
150 foot poly tube with hanger
hoops

1) Cost of heater unit & other equipment -

Heater unit	$1159
Floor return duct	50
Mounting hardware	11

Total heater cost = $1220

Two heaters per house

Heating System Cost = $2440

17.134 Cost of heating and cooling equipment control-

3 - single stage thermostats	$45
1 - two stage thermostat	39
1 - humidistat	20
1 - 15 cfm fan	10
1 - relay	10
1 - summer winter switch	3

Control Equipment Cost = $127

17.135 Total cost of individual greenhouse -

Structural cost -	$2795
Cooling system -	1353
Heating system -	2440
Control equipment -	127

Cost Single Greenhouse = $6715

17.14 Cost of greenhouse corridor -

A rough estimate of cost for this type of structure, with sheet metal cover, is $1.65 per square foot. With fiberglass cover the cost would be higher. This approximation is valid for a building with a width to length ratio of about 5/6. Being long and narrow, this structure would ordinarily require more wall covering material. However, due to the greenhouses taking up a large portion of the wall space, the material required is about the same as would be used in a structure which has a width to length ratio of 5/6.

The cost will be estimated on the basis of $1.65 per square foot. Added to this cost will be the difference in cost between sheet metal and fiberglass. (12 year fiberglass). To this cost, 5% will be added because the unusual structure will likely cause more than usual difficulty in construction.

There will also be some waste material where this structure joins the greenhouses.

Floor area = 945 ft^2

945 ft^2 x \$1.65/ft^2 = \$1560

A building 31 x 30 would have the same floor area. It would also have a 5/6 width to length ratio, with the same amount of material required.

Covered area -

Roof 1030 ft^2

Walls 2806 ft^2

Total covered area = 3836 ft^2

Cost difference in covering -

Cost sheet metal = $.146/ft^2

Cost fiberglass = $.210/ft^2

Cost difference = $.064/ft^2

Additional cover cost = $246

Structure cost = $1560 + $246

= $1806

Add 5% of $1806

Estimate Structure Cost = $1896

17.15 Cost of the four greenhouses combined with common equipment -

17.151 Cost of watering system -

Traveling sprinkler	$1074
Track	60
Hose	74
Hose - cable travel suspension (100')=	185
Weight scale (sensor)	228

House equipment cost = $1,621

Cost for 4 houses $6,484

Other equipment required -

Mixer tank (42 gal)	$ 56
Valves	185
Pipes & fittings	50

Cam timer	$ 52
24-hour timer	24
Ratio feeder	824
	$1191

Total Equipment Cost = $7,675

Installation cost -

Estimated time required - 60 man hours

Rate - $6.00/hr

Installation cost = $360

Watering System Cost = $8035

17.152 Cost of cyclic lighting equipment -

Total of 12 light circuits or lamp rows

10 lamps per circuit

Equipment needed:

2 - 6 channel cam timers	$140
12 - 25 amp relays	60
1 - 24 hour timer	20
120 - lamp sockets	50
1500 ft - No. 12 wire	44
1140 ft. - ½" conduit ($.095/ft)	108
Handware	30
125 ft. - No. 6 wire	180
125 ft. - 3/4" conduit	27

Lighting Material Cost = $659

Installation cost:

120 man-hours required, at
$12.50 per man-hour

Installation Cost = $1500

Cost of Cyclic Lighting = $2159

17.153 Telephone monitoring and alarm system -

Monitoring System Cost = $ 850

17.154 Standby generator -

30 KW generator	$3300
Transfer switch	1233
Start delay	86
Transfer delay	91
Exercizer	43
Installation	375

Standby Generator Cost = $5128

17.155 Cost of CO_2 generators -

Cost of one generator system = $100

Cost of CO_2 Generators = $ 400

17.156 Cost of greenhouses and common equipment -

Greenhouses, heat and cool equip.	$26,860
Fiberglass corridor	1,896
Watering system	8,035
Cyclic lighting system	2,159
Telephone monitor	850
Standby generator	5,128
CO_2 generator	400

Total Greenhouse Cost = $45,328

17.16 Cost of headhouse -

A rough estimate of cost for this type of structure is $1.65 per square foot (20). An addition to this estimate must be made to account for the inter wall, insulation and interior paneling.

Rough estimate based on $1.65 per square foot -

Total area = 3270 ft^2

Frame & cover cost = $5400

Electrical wiring -

The cost of the headhouse electrical wiring is estimated on the basis of rough estimate for a warehouse. (7)

Rough estimate for warehouse - $1.05/$ft^2$

Electrical Cost = $3150

Inter wall frame -

650 b-ft x $.24/b-ft = $156

Ceiling of heated section -

1119 b-ft of 2 x 6 ($.235/b--ft) - $263

40 sheets 3/8" plywood ($5.60/st) - $224

Ceiling Cost = $487

Masonite paneling -

40 - 12 ft sheets ($5.75/st) - $230

15 - 8 ft sheets ($3.84/st) - $ 58

Masonite Cost = $288

Insulation -

2800 ft - insulation batting ($.102/ft)

Insulation Cost = $286

Inside doors -

Door Cost = $200

Space heater -

1 - 24,000 BTU/hr gas fired space heater

Heater Cost = $210

Toilet facility including septic tank
and hot water heater -

Toilet Facility Cost = $600

Interior construction cost (7) -

Wall framing ($205 M.F.B.M.*) - $163

Insulation installation ($.07/ft^2) - $262

Wall and Ceiling paneling ($.20/ft^2) - $737

Heat installation - $80

Interior Construction Cost = $1242

17.161 Total headhouse cost -

Pole frame & cover	$5400
Interior wall frame	156
Ceiling	487
Masonite	288
Insulation	286
Inside doors	200
Space heater	210
Toilet facility	600
Interior construction	1242
Electrical wiring	3150

Total Headhouse Cost = $12,019

17.17 Cost of lath house -

(See Section 16.0 for details)

* M.F.B.M. - Thousand Feet Board Measure

17.171 Cost of lath house structure -

148 poles ($3.63 ea.)	$ 536
1086 ft. 1/4" cable ($.062/ft)	67
9000 ft. 3/8" cable ($.12/ft)	1080
481 cable fasteners ($.70 ea.)	337
56 cable anchors ($3.15 ea.)	176
Hog rings	25
20,780 ft^2 fabric	2722
Lath house Material Cost	$4943

Construction -

Add 25% to the cost of materials for construction -

Construction Cost $1240

Total Lath House Structure = $6183

17.172 Cost of lath house sprinkler -

(See Section 16.0 for details)

36 part circle heads ($8.65 ea.)	$ 310
340 ft. plastic pipe	132
fittings	32
4 valves	56
1 timer	24

2 relays	$ 10
1 two-switch timer	40
1 moisture sensing device	20
Sprinkler Material Cost	$624

Sprinkler installation cost -

Add 20% to the cost of materials for installation

Installation Cost $125

Total Lath House Sprinkler - $749

17.173 Total Lath house cost -

Lath house structure	$6183
Lath house sprinkler	749

Total Lath House Cost = $6932

17.18 Cost of material handling equipment -

17.181 Cost of containers -

Containers are required for 2 1/3 crops

Number of containers = 11,088

Cost = $2.40/container

Total Container Cost = $26,611

17.182 Cost of pallets -

Pallet cost is estimated on the basis of $.15/pound, which includes the cost of construction.

Density of steel is 490 lb/ft^3

1 1/4 x 1 1/4 x 3/16 angle iron weighs 1.48 lb/ft

Pallet weight = 110 ft x 1.48 lb/ft
= 163#

Angle iron cost = $24.50

Cost of 4 wheels = $5

Single pallet cost = $29.50

144 pallets required in greenhouses

192 pallets required in lath house

Total Cost Pallets = $9880

17.183 Cost of pallet tracks -

Greenhouse tracks -

Tracks are 93 feet long

Total track length is 1490 feet

Track cost = $331

Posts -

Posts every 5.5 ft in the greenhouse

Post every 4 ft in the asile

Total number of posts is 350

Use 8 ft - 4 x 4 redwood but to 4 ft

Cost of single post = $3.35

Total post cost = <u>$585</u>

Wheels on posts in aisle -

3 wheels per post pair

31 post pairs

Cost per wheel is $.80

Cost of wheels = <u>$74</u>

Total track cost -

Track	$331
Posts	585
Bolts	22
Wheels	74

Total Track Cost = <u>$1012</u>

17.184 Container filling and seeding equipment -

1) Mixer -

Mixer cost	$745
Water metering devices	66

Total Mixer Cost = <u>$811</u>

2) Belt conveyor (13 ft) -

Belt conveyor Cost = <u>$378</u>

3) Chain elevator for peat -

Conveyor	$160
Motor	30
Hopper	40

Peat Conveyor Cost = $230

4) Chain elevator for moving mix to fill station -

Conveyor	$185
Motor	30
Hopper	30

Mix Conveyor Cost = $245

5) Used tractor with fork lift -

Fork Lift Cost = $1500

6) Wooden pallets for styro-blocks -

Wooden Pallet Cost = $300

7) Various items -

Perlite hopper	$ 20
Pallet loading rack	161
Vacuum seeder	750
Stratifying equipment	225
Sterilization equipment	100

Cost = $1256

Total Seeding Equipment Cost = $4720

17.185 Total material handling equipment cost -

Containers	$26,611
Pallets	9,880
Pallet tracks	1,012
Seeding equipment	4,720

Total Material Handling Equipment Cost = $42,223

17.19 Total cost of facilities and equipment -

Site preparation	$ 2,500
Water well	5,500
Greenhouses	45,328
Headhouse	12,019
Lathhouse	6,932
Material handling equipment	42,223
Contingent items (5% of total)	5,725

Total Cost Facilities & Equipment = $120,230

17.2 Annual fixed costs -

The factors contributing to fixed costs are:

1) Depreciation
2) Taxes
3) Insurance
4) Interest on average investment
5) Land cost

17.21 Depreciation -

Depreciation is determined by dividing the total cost of the facility or equipment by its expected life (see table 6). The assumption is made that all items will have no salvage value.

Certain items have been grouped together for the purpose of depreciation.

Lumped costs -

Greenhouse structure, steel pallets & tracks -

Quonset structure		$10,480
less plastic film	-	460
less equipment installation cost	-	4,000
Fiberglass corridor		1,896
Pallets & track		10,892
Total		$18,808

Environmental control equipment -

Heating equipment	$ 9,600
Cooling equipment	5,412
Control equipment	508
Heating & cooling installation	4,000
Greenhouse watering system	8,035
Cyclic lighting	2,159
Telephone monitor	850
Lath house watering sys.	749
CO_2 generator	400
Total	$31,713

Well and standby generator -

Standby generator	$ 5,128
Well	5,500
Total	$10,628

Lath house -

Lath house structure	$ 6,423
less fabric	- 2,747
less fabric installation	- 90
Total	$ 3,586

6. Depreciation Schedule

	Initial Cost	Depreciation Period (yrs)	Annual Depreciation Cost
›reparation	4,800	30	160
: standby generator	10,628	20	531
ıouse cover	460	1	460
ıouse structure steel			
Llets and track	18,808	12	1,567
›nment control equipment	31,713	7	4,530
-foam containers	26,610	5	5,322
›use	12,019	25	481
›use material handling	4,700	10	470
quipment			
house structure	3,346	20	167
house cover	2,837	7	405
ngent items	5,725	10	573

Total Annual Depreciation Cost = $14,666

17.22 Insurance -

The annual cost of insurance is estimated to be 2% of the average investment.

$$\text{Average investment} = \frac{\$116,000}{2}$$

Annual Insurance Cost = $1,160

17.23 Taxes -

The tax is determined by use of a sliding scale. 27% is the average of rates in the sliding scale over the first 15 years. After 15 years the percentage stays constant at 15%. 27% of the initial cost is taken as the true value. 20% of the true value is assigned as taxable value.

Initial cost = $116,000

$116,000 x 0.27 = $ 31,320

$31,320 x 0.20 = $ 6,260

Tax levy = 193.37

Tax = 6.26 x 193.37

Tax = $1,210

17.24 Interest -

Interest cost is determined by computing annual interest on the average investment.

Average investment = $58,000

Interest rate is assumed to be 9.25%

Annual interest = $58,000 x 0.0925

Annual Interest = $5,365

17.25 Annual land cost -

Land area = 2.5 acres

Lease rate = $100/acre

Annual Land Cost = $ 250

17.26 Total annual fixed cost -

Depreciation	$14,666
Insurance	1,160
Taxes	1,210
Interest	5,365
Annual land cost	250

Annual Fixed Cost = $22,650

17.3 Annual operating costs -

The factors which contribute to the operating costs are:

1) Fuel consumption for heat.
2) Electric power consumption.
3) Fuel consumption for generating CO_2
4) Growing media
5) Fertilizer
6) Maintenance
7) Labor

17.31 Fuel cost -

Headhouse -

Heating Cost = $150

Greenhouses -

A heating cost estimate was made based on the heating cost incurred in a local greenhouse operation. This greenhouse is a fiberglass-covered quonset with approximately the same size as the greenhouses in the sample design. Average yearly fuel cost rate is $.88/mcf.

Heating Cost = $2800

Total Heating Cost = $2,950

17.32 Electric power consumption cost -

Power consumption cost is based on an estimate made by a greenhouse manufacture/supplier. (17)

This supplier made an estimate of the cost of operating heating and cooling equipment. The estimate was based on a rate of 3¢/kw-hr.

Power Cost (heating and cooling) - $660/year.

Power consumption of heating and cooling equipment is estimated to be about 80% of the total.

Total Power Cost (heating, cooling and all other electric equipment) = $\frac{\$660}{.80}$

Total Power Cost = $825

17.33 Fuel cost for generating CO_2 -

Generator operates 10 months.
Estimated daily operation is 3.25 hours.
Estimated gas consumption is 700,000 ft^3.
Rate assumed is $0.88/mcf

Fuel Cost = $615

17.34 Growing media cost -

Vermiculite -

1200 ft^3 required per year

Vermiculite Cost = $700

Peat -

480 ft^3 required per year

Peat Cost = $480

Perlite -

220 ft^3 required per year

Perlite Cost = $154

Total Growing Material Cost = $1,334

17.35 Fertilizer cost - (13)

Fertilizer cost estimate is based on the cost incurred in growing Ponderosa pine in a forest research laboratory. The annual amount of fertilizer required per tree is assumed to be the same in the sample design.

The required amount is calculated for 2 crops plus 1/3 crop held for 6 months.

The nutrient material costs are based on prices at Chemistry Stores at Montana State University.

Fertilizer cost per tree - $.00148/yr

910,000 trees per crop

Fertilizer for 6 months on each crop

(910,000 x $.00148 x ½) 2 = $1347

910,000 x 1/3 x $.00148 x ½ = $ 224

Fertilizer Cost = $1571

17.36 Maintenance cost -

Maintenance cost is assumed to be 0.5% of the total investment.

Maintenance cost = 0.005 x $116,000

Maintenance Cost = $ 580

17.37 Labor cost -

Full time greenhouse operator - $14,000

Part time help for the following:

1) Plastic cover replacement
2) Thinning
3) Moving pallets
4) Relief time for full-time man

Part-time labor $7,000

Labor Cost = $21,000

17.38 Total annual operating cost -

Fuel (heating)	$2,950
Electric power	820
Fuel (CO_2 gen.)	615
Growing material	1,334
Fertilizer	1,571
Maintenance	580
Labor	21,000

Total Annual Operating Cost = $28,870

17.4 Total annual cost -

Annual fixed costs	$22,650
Annual operating costs	28,870

Total Annual Cost = $51,520

17.5 Cost per seedling -

1,820,000 seedlings per year (assuming 100% survival)

Annual cost = $51,520

$$\text{Cost} = \frac{51{,}520}{1{,}820{,}000 \text{ seedlings}}$$

Cost Per Seedling = 2.8¢

1,640,000 seedlings per year (assuming 90% survival)

$$\text{Cost} = \frac{51{,}520}{1{,}640{,}000 \text{ seedlings}}$$

Cost Per Seedling = 3.1¢

CONCLUSION

Growing pine seedlings by this greenhouse method appears to be feasible, since the cost is comparable to that incurred in growing seedlings in outdoor nurseries.

An important factor in this type of operation is the method of outplanting the seedlings. Since the cost of styro-foam containers is a major cost item, handling them in a manner which will minimize container damage becomes very important.

Some of the cost estimates in this analysis have a fair degree of accuracy. However, it is apparent in the report that some estimates are rather rough. The accuracy of these estimates could be significantly improved with further studies and additional investigations of actual greenhouse operations.

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Brighton By-Products Co. Inc. P.O. Box 23
New Brighton, Pennsylvania 15006

Chicopee Manufacturing Company, Cornelia, Georgia 30531

Geo. J. Ball, Inc., West Chicago, Illinois 60185

H. E. Anderson Company, 2100 Anderson Drive
Muskogee, Oklahoma 74401

Ickes-Braun Glasshouses, Box 147, Deerfield, Illinois 60015

Interstate Alarm Company, 127 E. Main, Missoula, Montana 59801

Johnson Gas Appliance Company, Cedar Rapids, Iowa 52405

Master Growers Systems, Division of the Hatcher Sales Company,
3596 Oakcliff Road, N.E., Atlanta, Georgia 30340

Modine Manufacturing Company, 1500 De Kovan Avenue
Racine, Wisconsin 53401

Monsanto Company, P.O. Box 120, 2710 Lafayette
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Stuppy Greenhouse Supply, 120 East 12th Avenue
North Kansas City, Missouri 64116

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