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GREENHOUSE STRUCTURES

AND

SYSTEMS

Some Greenhouse Considerations*

T. C. Skinner [1]

GREENHOUSE LOCATION AND ORIENTATION

Most greenhouses are erected to produce plants during the off-season; therefore, they must provide a desirable plant environment. Correct location and orientation of the house are of paramount importance in providing ideal environmental conditions. Since location can also influence the heating cost, labor utilization, and disease factors, economic success may also depend on the site selection.

Recommendations for locating and orientating your greenhouse are given in this publication. The following specifications are the ideal ones; however, some builders may not be able to follow each suggestion given, depending on individual limitations of his greenhouse. For example, houses used for display and sales purposes are often connected to existing buildings; therefore, they may have to sacrifice some of those factors described for production-type greenhouses. Bench culture or similar production practices may also justify deviation from some of the standard requirements.

Location Of The Greenhouse

Sunlight

Sunlight provides energy for plant growth, and is generally the limiting factor in greenhouses. When planning the construction, give primary consideration to obtaining maximum sunlight exposure during those "short" days of mid-winter when the sun is lowest in the sky. Maximum sun altitude (angle of sun above earth's horizon) occurs at noon and varies from a high on June 21 to a low on December 21. At solar noon, the sun is located due south. This means that the building site should preferably have an open southern exposure. If the land slopes, it should ideally slope to the south.

Do not build near large trees, buildings, or other obstructions which will shade the building. Figure 1 gives the ratio of shadow length and height obstructions for selected solar altitudes. To determine how far away an obstruction must be to prevent a shadow on the greenhouse, multiply these ratios by the obstruction height. As a general rule, no objects taller than 10 feet should be within 27 feet of the greenhouse in either the east, west, or south direction. Even objects this tall will cast long shadows in the early morning when the sun is particularly low in the sky.

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* Based on published information by J. N. Walker and G. A. Duncan, Department of Agricultural Engineering, University of Kentucky, Lexington, Kentucky.

[1] Extension Agricultural Engineer, Department of Agricultural Engineering, IFAS, University of Florida, Gainesville, Florida.

Angle β	Ratio L/H
20	2.75
30	1.73

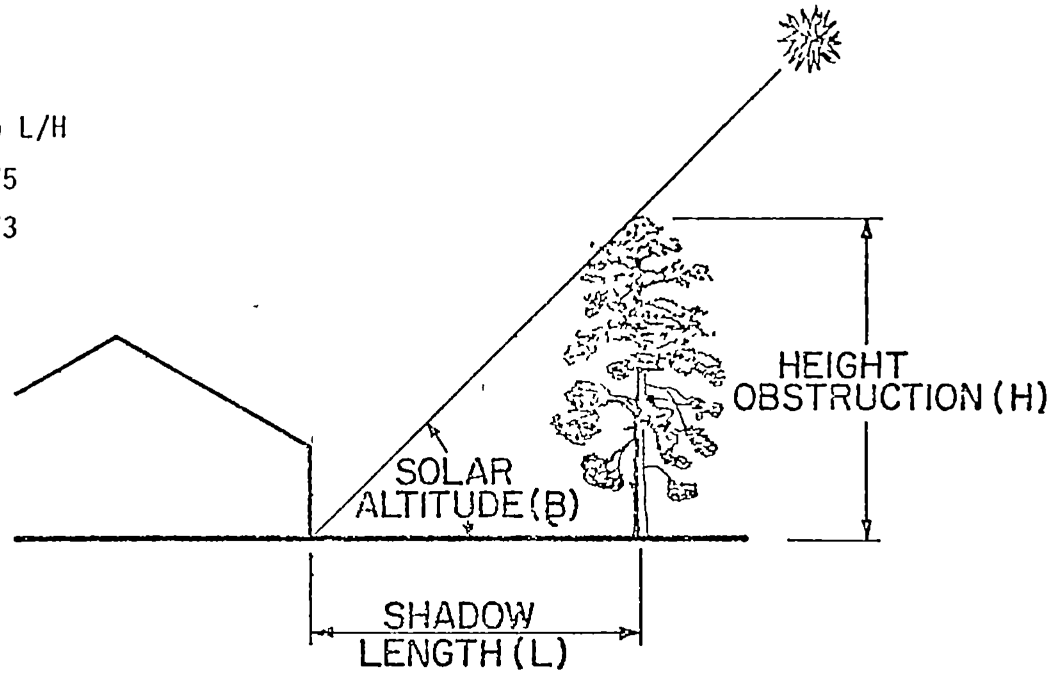


Figure 1. Ratio of shadow length and obstruction height for selected solar altitudes.

Soil

When plants are to be grown in the soil covered by the greenhouse, select a site where a deep, good draining soil is available. Avoid top soil below which a tight hardpan is present. Although organic matter and artificial types of conditioners can be added, problems are reduced if a site with good natural soil is selected. Grading often produces uneven soil conditions within the greenhouse. Careful soil analysis and preparation are necessary if even plant growth is to be achieved. Before any organic matter or additives are mixed with the soil, make a complete soil analysis and carefully follow the resulting recommendations.

Avoid areas where chemical residues which would injure greenhouse crops may persist, including places heavily sprayed with damaging weed killers and herbicides. If you question the degree of danger, grow selected plants in samples of the soil to determine if any detectable injury occurs. Noxious weed seeds can also be a problem, but generally proper sterilization methods will kill most weed seeds.

Drainage

Select a site that is level and well drained to reduce problems with salt build-up and insufficient soil aeration. A high water table may result in saturation of the soil and prohibit effective use of the greenhouse. Ground water which flows into the house may carry soil diseases. If necessary, tile drain the area enclosed by the greenhouse.

Ground beds should be nearly level. If they slope in any direction, water will tend to concentrate in the low areas, accentuating any problems of poor drainage. Slopes within the greenhouse also allow hot air to rise and cold air to settle, creating environmental problems. A greenhouse in a low, damp area could be subject to higher humidities and dampness which accentuate leaf mold, diseases, etc.

Sheltered Area

Although obtaining maximum sunlight should have first considertion, placing the greenhouse in a sheltered area will reduce wind-induced heat losses. For example, a wind barrier north of the greenhouse may materially reduce heating costs; yet it would have little effect on the light received. Trees are helpful in preventing heat loss, but deciduous trees which lose their leaves in the winter are not effective when the heat loss potential is greatest.

Utilities

A greenhouse requires a number of utilities, notably electricity, water, and an energy source for heat.

Electricity: The electric service for ventilation alone will require approximately 4 to 6 kilowatts for a 1/4-acre range. For a small hobby-sized house, connected loads of up to 1 to 2 kilowatts are not unusual. If lights are used for photoperiod control or supplemental lighting, the electric load will increase significantly. Normally the electric power companies will willingly supply the necessary service; however, the grower should attempt to anticipate his intended electric usage and provide sufficient entrance capacity to allow for full electric utilization.

Water: A reliable supply of clean water is mandatory. A water requirement of up to 1/3 gallon per square foot per day may be needed. Depending upon the soil type, up to 1 gallon of water per square foot may be put on the soil at one time.

Energy Source: The availability of an inexpensive energy source is often one of the most important factors in determining where to build a greenhouse range. Natural gas is a widely preferred fuel because of its clean performance, low maintenance, and relatively low cost. Not only is it one of the lower cost fuels, but gas heating equipment is generally among the least expensive for initial cost, annual maintenance, and operating costs. LP Gas and fuel oil are alternate sources of fuel and can be transported to greenhouse locations that are not close to gas lines. Since heating costs can be a substantial part of the production cost, select a location carefully for its fuel availability and economy.

Emergency Power

Standby emergency power equipment sized for electrical support of heating equipment, air circulation, and minimum ventilation is vital when storms disrupt local service for long periods (2 hours or more).

Alarm System

The consequences of a heating system failure during freezing temperatures can be catastrophic. An alarm system which is independent of the electrical service should, therefore, be provided. Place the alarm bell in a residence of location where people are normally present.

Convenience

Locate the greenhouse near your place of residence, if possible. This will prove convenient for you and will facilitate care during weekends or holiday periods. If the ventilation and watering systems are not fully automatic, operator care will also be mandatory during sunny periods. Should a heating failure occur, corrective action must be prompt.

Orientation Of The Greenhouse

Light Availability and Shading Effects

Orientation of the greenhouse for maximum light availability is also an important consideration. For the southern regions, a north-south orientation of the ridge is preferable. With east-west orientation, however, a problem is encountered with ridge and furrow houses as shown in Fig. 2. A definite shadow line develops within the houses due to the north sloping roof sections and the gutter between sections of the house. This shadow effect is usually sufficient to result in reduced plant growth in the region of the house affected. Depending upon the width of span, the shadow area can be 10 percent or more of the house space. Although shadows occur within north-south oriented ridge and furrow houses, the shadows move across the floor of the house as the day progresses and noticeable reduction in growth in one region of the greenhouse is not normally apparent.

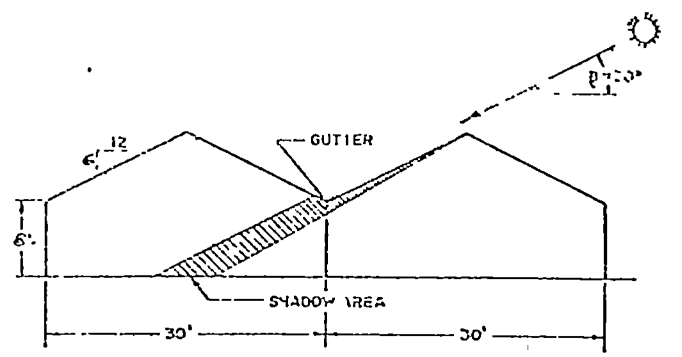


Figure 2. Shadow effect of north slope and gutter of east-west oriented greenhouses when solar altitude is 30°.

Environmental Equipment

Ventilation, cooling and heating systems are noticeably affected by the way the greenhouse is oriented and the equipment installed.

Ventilation: Ventilation air should not have to move more than 120 to 150 feet across the house between entrance and exit. Design and install fan ventilation systems so that air moves with prevailing summer winds rather than against them. This procedure will eliminate opposing air forces which decrease the air flow rate by 10 percent or more. Usually, you should install exhaust fans in the leeward end of the greenhouse and fresh air inlet shutters in the windward end. However, sometimes a sidewall fan location in the leeward side and fresh air inlets on each end are best for certain houses.

Cooling System: When pad cooling is used, locate pads on the north wall (end or side) of the greenhouse(s) to prevent shading. For best cooling effectiveness, air should not travel over 150 feet between pads and the exhaust fans

(200 feet absolute maximum). For long houses, over 150 feet in length, locate the bank of pads in a sidewall at the center of the house with fans in each end. (NOTE: A water supply of approximately 1 to 2 gallons per minute per 100 square feet of pads is generally required. Also, 100 square feet of pad areas per 1,200 to 1,500 square feet of greenhouse floor area is typical. Obtain more detailed information on pad cooling before making a decision to purchase.)

Heating System: The greenhouse heating system should provide adequate heat supply and distribution throughout the house for environmental uniformity. Consistent heat supply is especially important toward the northwest portion of glass houses or those with sizeable cold air leakage and infiltration.

Site Layout

Grade and Fill

Prior to erecting the greenhouse, grade and fill those areas where changes are needed to level the site, establish drainage, roads, parking, etc. If you plan to practice soil culture, remember that poor existing soil must be removed and replaced by 12 inches or more of good topsoil. Grade and fill to requirements, then replace the top soil without compaction. Any subsurface tiling or urility lines can be placed during these operations.

Transportation and Parking

When selecting the site, try to locate near a good road so that materials can be conveniently moved to and from the greenhouse. Sufficient room for turning and parking vehicles is desirable for greenhouses of commercial size, especially when bedding plants and flowers are sold on the premises.

Headhouses

Place headhouses on the north side of the greenhouse to avoid shading a portion of the house. Attachment to the greenhouse or a connecting passageway makes work, handling, and greenhouse operations more convenient. Processing facilities, cold storage rooms, and other such facilities should be adequately incorporated into the ultimate layout.

Expansion

When building, always keep future expansion in mind. Most successful ranges are expanded several times after the first house or small range area is constructed.

Figure 3 illustrates many of the factors of location, orientation, and layout for one greenhouse or a range.

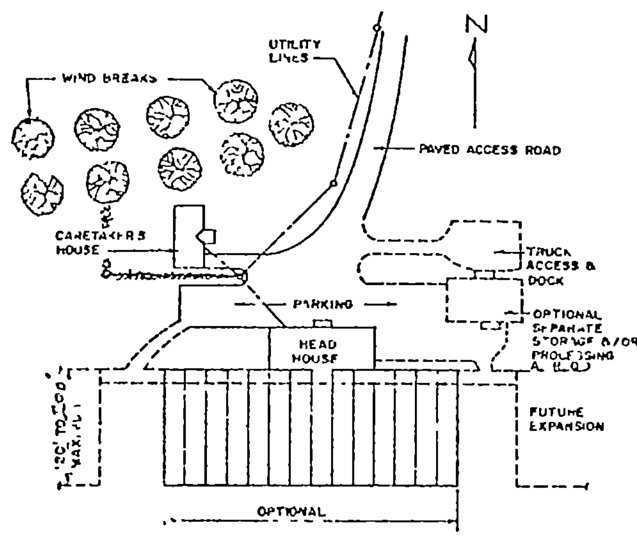


Figure 3. Typical greenhouse range layout on a level but well drained, southerly exposed site.

Summary

Important points to remember are:

-- Orient and locate the house for maximum sunlight. In southern latitudes, the ridge should run north-south.

-- Avoid placing the house near objects east, west, or south which will shade the house.

-- Place in an area sheltered from northerly and north-westerly high winds if possible.

-- Locate on a deep good soil which is well drained and where surface water does not run into the house.

-- Avoid sloping beds or floors in the greenhouse. Locate the greenhouse near adequate and reliable sources of utilities--electricity, water and fuel.

-- Provide good access roads, parking, and turn-around area.

-- Position headhouses or supporting facilities on the north side.

-- Arrange initial construction so that the range can be expanded.

GREENHOUSE STRUCTURES

Greenhouses vary from small hobby types to ranges which cover several acres in one enclosure. All of them have one thing in common, they are built to permit the off-season production of plants. The basic purpose of the greenhouse structure is to provide a reliable enclosure within which an environment favorable to plant growth can be created.

In commercial greenhouses, operations are generally permanent and long depreciation schedules are acceptable. Annual cost is generally more important than the initial cost; however, if capital is limited, the initial cost may still govern the type of construction used. In determining the annual costs, depreciation, interest, maintenance, insurance, taxes and operating costs must all be considered.

Functional Features

Regardless of its use, every greenhouse must meet certain functional requirements. For those planning to build, an understanding of these requirements will help in selecting a design. In the discussion that follows, the remarks are largely directed towards commercial greenhouses.

Strength

Every greenhouse must be designed to withstand the loads which will be imposed upon it without failure or significant deformation. The primary load which must be considered is wind.

Wind Loads

For most sections of the United States, the major load which must be considered is wind. The wind speeds used in design of crop production buildings should be the winds predicted for a 25-year recurrence interval. This means that you would expect winds of the given intensity to occur once every 25 years. For the majority of the United States, except for the two regions shown in Figure 4, the maximum expected wind speed would be 80 mph. In the two shaded regions, special consideration should be given to design, and the advice of engineers who are aware of the local wind conditions should be sought.

A wind blowing at 80 mph develops a maximum possible pressure of 16.4 lbs. per sq. ft. on a flat surface perpendicular to the wind. However, the actual wind loads on buildings are not this severe because of a height adjustment factor.

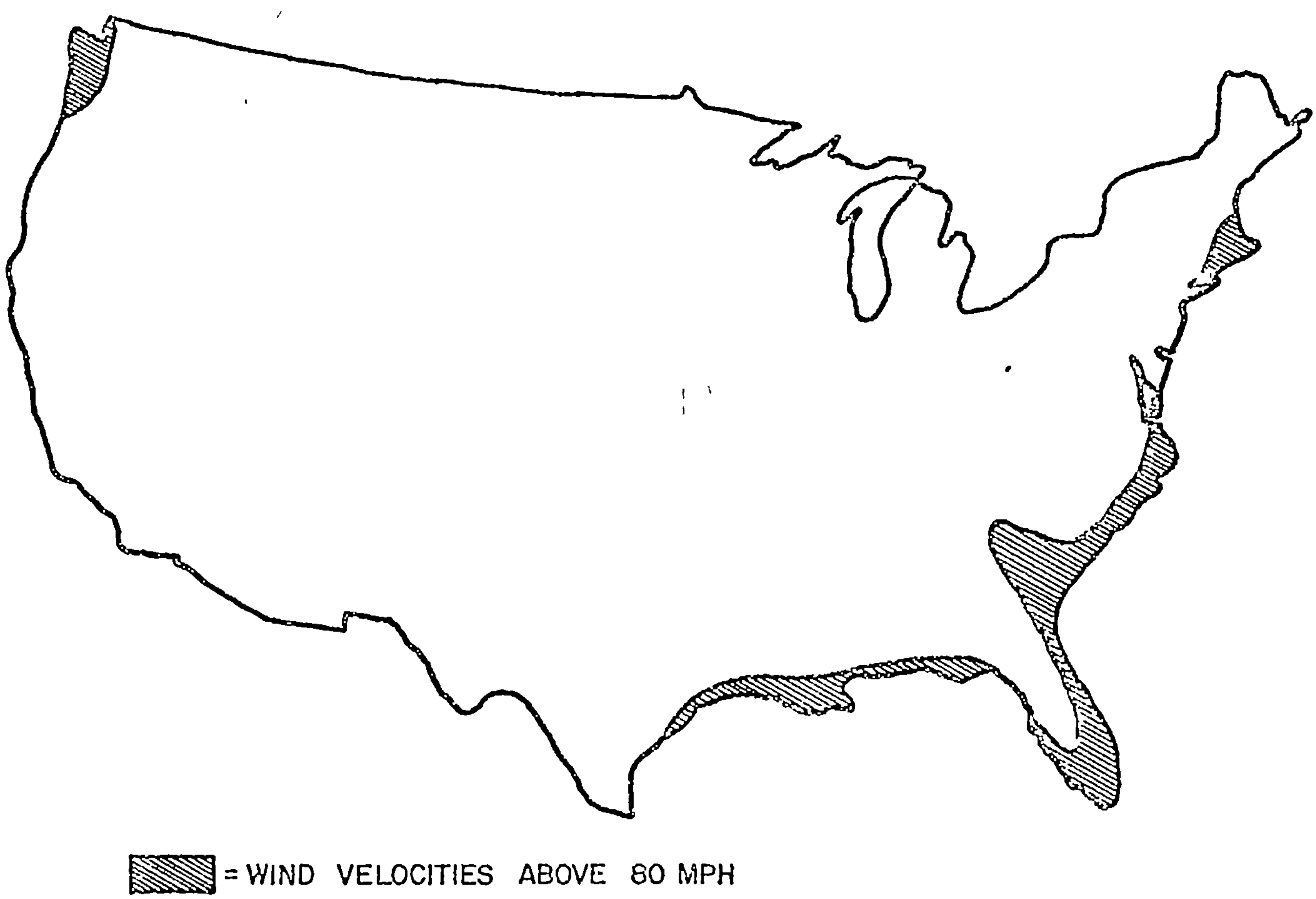


FIG.4: WIND MAP FOR A 25 YEAR RECURRENCE INTERVAL.

Wind speeds are measured and reported by the U.S. Weather Bureau for a height of 30 feet above the ground. The wind is less intense closer to the ground. The wind velocity reduction from 30 feet above ground to the ground surface is shown in Figure 5. The pressure developed by the wind is related to the square of the wind velocity. Therefore, the wind pressure reduces more rapidly than the wind velocity as the ground surface is approached. As shown in Figure 5, the pressure and wind velocity at 15 feet height are approximately 85% and 90%, respectively, of that at 30 feet. At 10 feet the values are 73% and 85%, respectively. The height of the building will, therefore, affect the wind load.

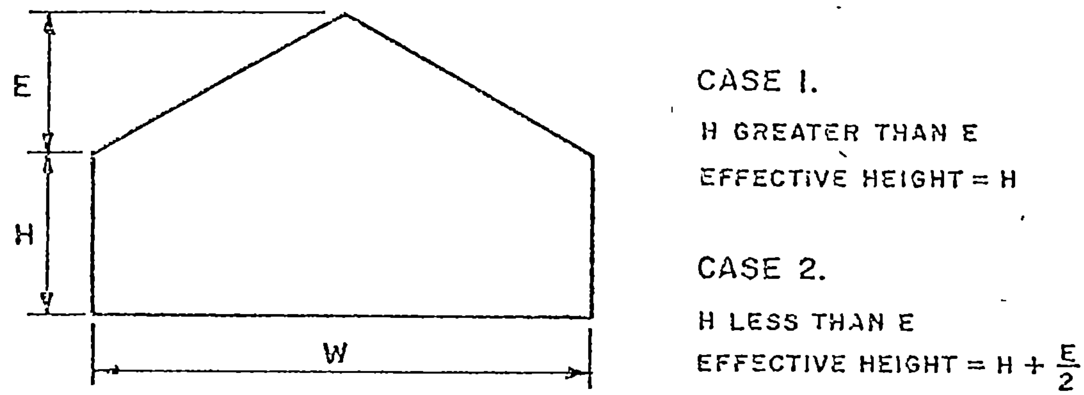


Figure 5 Effective height of a building for wind loading

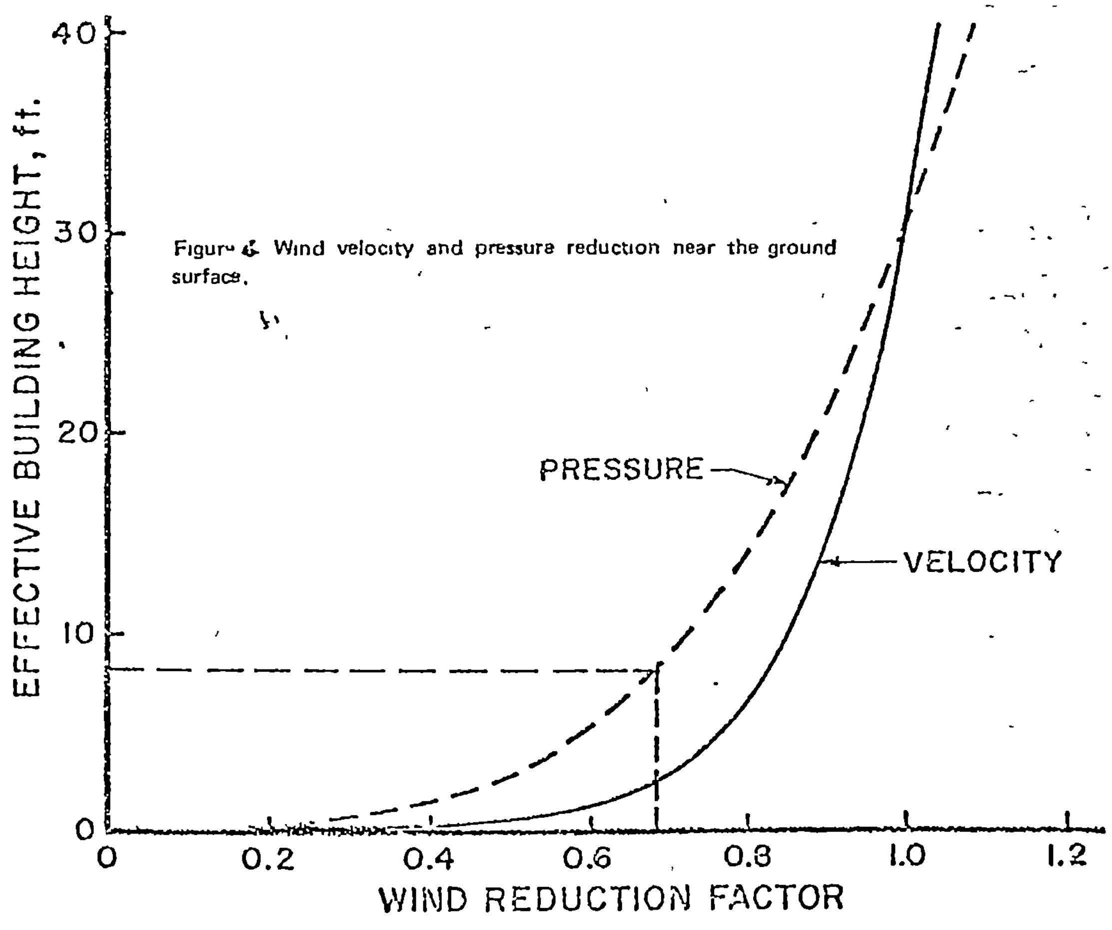


Figure 6 Wind velocity and pressure reduction near the ground surface.

The effective height of a building is defined as the distance above the ground at which the wind force acts. This is illustrated in Figure 6. For many buildings, it is the eave height (H). However, for wide buildings or steep-roofed buildings where the height from the eaves to the peak is greater than the eave height, the effective height is the distance from the ground to midroof (H + E/2). The eave plus mid-roof distance can become fairly large and result in large effective wind pressures that are important in building designs. For example, if an 80 mph wind speed, as reported by the U.S. Weather Bureau, occurs and effective building height is 8 feet, the maximum potential wind pressure would be reduced by a factor of .68 (see Figure 6) which results in the wind pressure being reduced from 16.4 to 11.1 lbs. per sq. ft. For a building 100 ft. long, the forces against the building could possibly total 8,880 lbs. However, one more factor in wind forces must be considered.

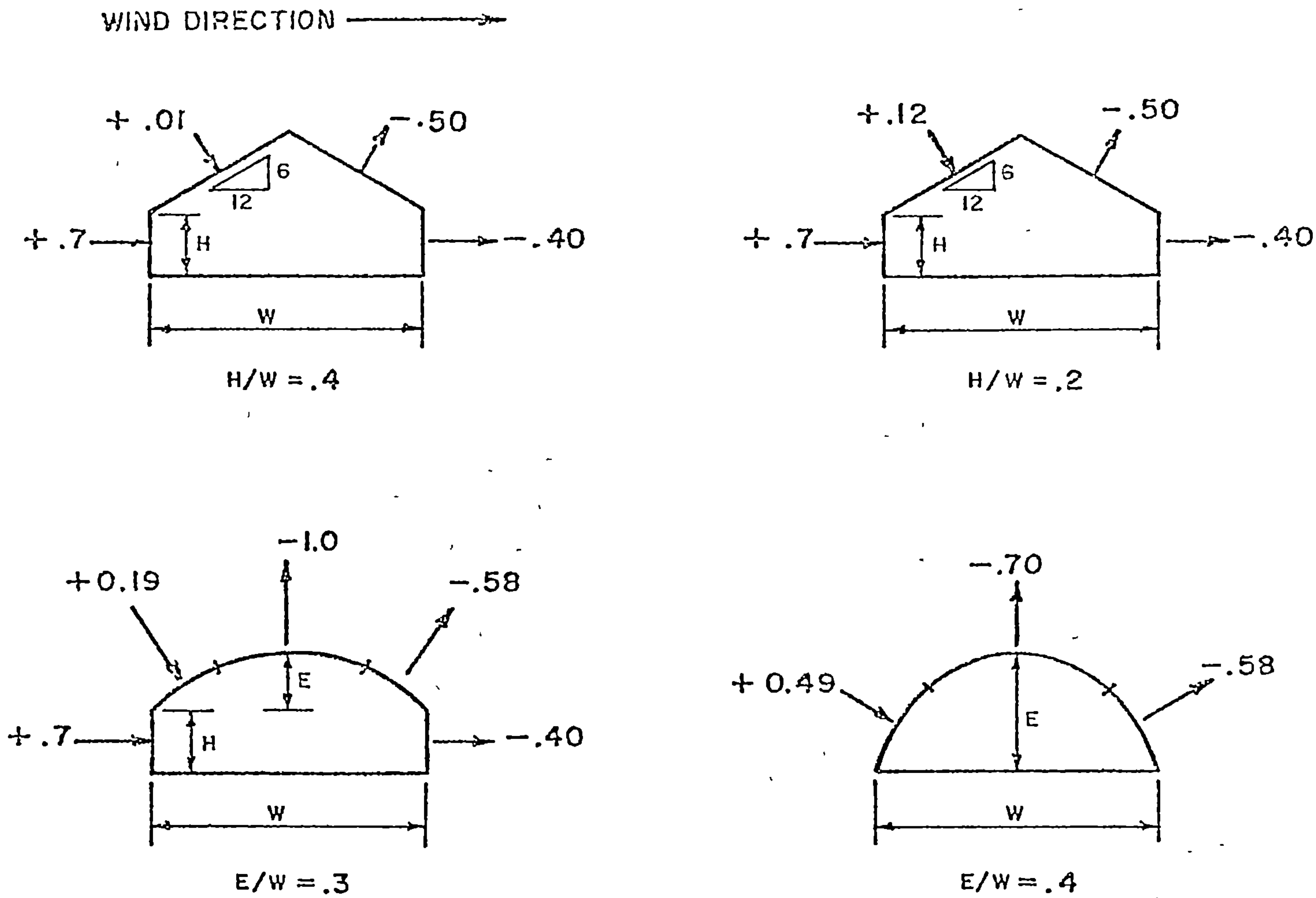


Figure 7: Typical wind force coefficients for various roof slopes.

The full wind pressure is not normally developed on the surface of the building because of shape and orientation. The wind generally hits the surfaces at some angle, depending upon the building profile, and an aerodynamic effect develops. This is similar to the forces which are created over the surface of an airplane wing. Due to the aerodynamic action, an uplifting or suction force develops on many building surfaces. To describe the forces, wind force coefficients are used. These coefficients are multiplied by the wind pressure to determine the design wind forces. A negative coefficient represents a suction or uplifting force and a positive coefficient, a pressure or inward acting force. Typical coefficients are shown in Figure 7. For each roof shape, the windward roof section coefficient varies considerably with the height to width ratio and roof slope. The other coefficients are affected only slightly by changes in these values. For the upper roof sections and for the roof and wall sections on the side away from the wind, uplift or suction occurs, the magnitude of uplift being 0.50 to 1.0 of the potential wind pressure force. For example, for a semicircular greenhouse with an effective height of 8 feet and $E/_W$ equal to 0.4 (Figure 7), the lower 1/4 roof section on the windward side would have an inward acting pressure of 5.4 lbs. per sq. ft. (11.1 lbs./sq. ft. times 0.49). For the same greenhouse, an uplift of 7.8 lbs lbs. per sq. ft. would occur in the center section; and on the downwind side, an outward acting force of 6.4 lbs. per sq. ft. would be expected. Interestingly, the uplift force is the largest force and is of a magnitude comparable to snow loads in most areas of the United States. This means that anchorage of the building and covering to prevent wind uplift and overturning of the building is just as important as providing adequate supports for snow loading!

The problem can become even more critical if a large door is left open on the windward side of the building during high winds. If this happens, a positive pressure builds up inside the greenhouse so that not only is there an uplift suction force due to the aerodynamic effect, there is also a pressure on the inside equal in magnitude to about 0.7 of the potential wind force acting in the same direction. These two combined forces, when they occur, are generally greater than the full potential wind force!

Crop Loads

If the greenhouse roof frame is also to support a crop load, such as hanging baskets, additional strength may be required.

Foundations

For any given wind condition, the loads imposed upon the structure must be carried to the ground by the foundation and footings. The foundation and footings must, therefore, resist uplift, overturning and downward acting loads. The downward load includes not only possibly the crop weight, but also the dead weight of the structure itself.

Though the size of foundations and footings would depend upon the size and type of the greenhouse and the loads which occur, all foundations for permanent greenhouses should be of a durable material and should extend to a minimum depth of 18 inches. Little support can be expected from the loose topsoil and earth within the top 6 to 12 inches. If post construction is used, where the main side-wall members are set directly into the ground and where the soil around the post is intended to prevent overturning, depths deeper than 18 inches are required. The most common failure of greenhouses constructed in this manner is the tipping of sidewalls with a subsequent dropping of the ridge line and a weakening of the rafter-to-eave plate joint. Though the filling of post holes with concrete is helpful this is not a substitute for placing the posts to an adequate depth.

For permanent greenhouses, concrete is the most suitable foundation material. A 2,500 PSI or better mix should be ordered if ready-mix concrete is used. If a continuous foundation is used along the full length of the house, it is recommended that 3/8" diameter reinforcing rods be placed horizontally in the foundation approximately 1 1/2" from the bottom and top and 1 1/2" from the edges of the foundation. This is particularly desirable in areas where high soil moisture exists, where rock outcroppings occur, or where some fill has been used and the foundation is near the surface of the original soil. Where fill has been used, the foundation or footings should always be placed sufficiently deep so that they bear on the undisturbed soil on which the fill was placed.

Special precaution must be taken with foundations if rigid-frame construction is used. As loads occur on rigid frames, there is a tendency for the base legs of the frame to spread, and horizontal forces as large as the vertical loads can be developed. This spreading tendency must be resisted if the frames are to carry the loads without failure. This means that foundations such as masonry block, which have low resistance to horizontal loads, should not be used for supporting rigid-frames unless proper reinforcement is done.

Maximum Light Transmission

In most greenhouses light becomes the limiting factor in growth during much of the off-season production period. Consequently, everything which can be done to obtain maximum light intensity within the greenhouse should be accomplished. Orientation is important and is discussed elsewhere. As a general rule, the greenhouse ridge should run north and south in the southern parts of the United States. The roof slope should also be about 28° (6:12 slope) or more whenever possible.

The most important features in obtaining maximum light transmission are to minimize the number and size of structural members in the roof area and to use a highly transparent glazing material. It is for these reasons that wide span glass and certain plastics are used. The use of stronger, wide-span covering material reduces the number of supporting members required, and thereby reduces shading. Wooden truss houses, though providing clear span unobstructed interiors, have the disadvantage that there are more members to cause interference with light and thus are not recommended. Only properly designed and fabricated steel or aluminum trusses should be used. Overhead heating, irrigating, and electrical lines should also be kept to a minimum to prevent light blockage.

Structural Influence on Heating and Ventilation

The final success of a greenhouse will generally depend upon the ability of the operator to control the environmental conditions within the greenhouse. Though any shape structure can be successfully heated or ventilated, some designs greatly increase the difficulty or cost in providing an adequate system. In these cases, a less than optimum system is often installed, which then creates problems in management.

In greenhouses used the year around, the solar intensity during the winter will often become sufficiently intense to require ventilation even when outside temperatures are near freezing. If this air is brought into the house and directed on the crop without first intermixing with the air within the greenhouse, growth will be hurt. Similarly, if hot air from heating units is allowed to come in direct contact with the plants, rapid drying and poor growth will also occur. In most greenhouses, attempts are made to mix ventilation or heating air with the greenhouse air in the greenhouse space above the crop. In bedding plant and other low crop production, adequate space exists within even low profile houses to effectively achieve this mixing above the crop. However, with tall crop production on benches, adequate space may not be available. This is particularly true in narrow houses where the rise from the eaves to the peak is small. Some growers argue that they want low houses to minimize the volume of air they must heat, but this volume is not a truly important factor. The important factor in the cost of heating is the amount of exposed wall or ceiling area, since any heat added to a greenhouse remains in the house until it passes through the covering material. Though an increase in height does increase the wall area, this is usually a very small increase in the total amount of exposed area. As a general rule, at least 1/3 of the total house volume should be unoccupied if it is intended to use this space for the introduction and intermixing of ventilation or heating air with the greenhouse air.

Ventilation and evaporative cooling both require the introduction of large quantities of outside air during bright warm days. A common method of doing this is to place fans in one sidewall or end and introduce the air through baffles, pads, or louvers in the opposite wall or end. When this is done, the air picks up the solar heat in the house as it moves across the house, resulting in the air gradually increasing in temperature as it nears the fan. If this temperature rise and air velocity are to be kept within reasonable limits, the distance across the house from the fans to the air inlet openings should not be more than 100 to 150 feet (200 feet absolute maximum). The house length or width in the other direction can be any desired dimension depending on the size of greenhouse range desired.

Working Height

The height of the house in the walk areas should never be less than 6'6". This allows a working man to move conveniently through the house. For tall crops such as tomatoes, 6 feet should also be the minimum height at the eaves, and 7 feet is commonly considered as being the minimum desirable height. For low crops, the eave height can be as low as 4 feet, as long as greenhouse workers do not have to regularly move back and forth in this area of the house. Some quonset type houses severely restrict plant growth around the outer walls due to the low curvature.

Roof Slope

One other important factor is the roof slope of the greenhouse. The roof slope affects the run-off of condensed water from the ceiling. Slopes of 28° (6:12 slope) are generally considered as minimal if run-off without severe dripping is to occur. With lower slopes, run-off is restricted, and dripping is a serious problem. With some of the plastic covering materials where drops occur more readily than they do on glass, even greater slopes would be desirable.

Access

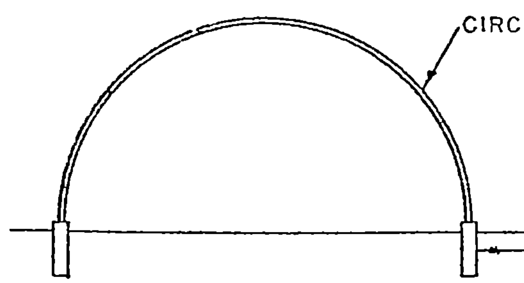
In most greenhouses it is necessary on occasion to remove large amounts of plants, and in some instances, to remove the soil or rooting media. On these occasions, large doors in the end of the greenhouse will prove useful. This permits the use of tractors or large wheeled carts or wagons. Such doors also facilitate the use of large equipment for tillage operations within the greenhouse. If walking tractors are to be used, 4-foot wide doors are adequate, but 6 to 8 foot doors are desirable if standard-size, four wheel tractors and wagons are to be used within the greenhouse.

Types of Greenhouse Structures

Greenhouse structures come in a variety of shapes and styles. All are acceptable if properly designed and erected. The features discussed in the previous section should be considered in selecting a specific type of greenhouse. In addition, cost, aesthetic appearance, flexibility and availability should be considered.

The various common shapes and advantages or special features of each type are listed below:

Quonset:



--Simple and efficient construction using thin-wall electrical conduit for houses up to 10 to 12 feet wide (build yourself) or galvanized steel pipe commercially formed for wider houses up to 36 or 40 feet.

--Primarily used with plastic covering which is applied externally. Strong fastening at the ends and edges (and ridge sometimes) is very important. Various types of extruded metal bars with rod inserts and screw-down clamps are available. Wider spans with larger curvatures bendable can be used with the rigid-plastic panels.

--Internal layer of plastic is difficult to apply and therefore external double-layer with the air inflation technique is recommended.

--Provides clear-span interior with minimum shading but has some side-wall height restriction on tall crops unless higher foundation supports are used. Higher foundations increase significantly the strength required and the potential for wind damage.

--Not suited for ridge and furrow designs. Each house should be separate from another.

--Usually have to use extra wooden construction for ends, doors, fan-shutter-louver framing, etc. End-wall covering may be the same as rest of structure. Sometimes solid material is used on a north end-wall.

--Several commercial pre-fab packages are available for this type of greenhouse.

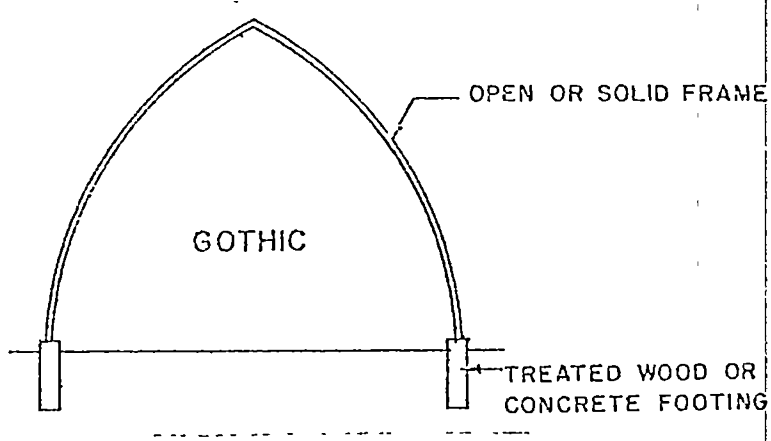
Gothic:

--Fabricated by bending pipe or laminating wood strips in a gothic shape.

--Has pleasing aesthetic appearance.

--Construction and covering features similar to quonset above.

--Good height near side-walls but has greater exposed-surface-to-ground-area-ratio which allows more heat loss than other designs. Good air circulation is required to prevent air and heat stratification in the gable. The extra volume allows adequate space for mixing ventilation or heated air with the greenhouse air.

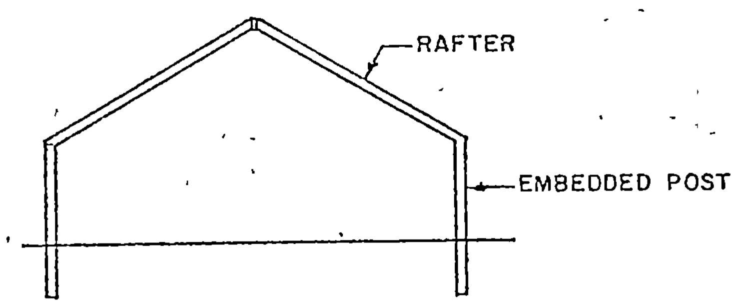


--Usually built of wood from blueprints. Commercial pre-fab packages are limited in availability.

Post-Rafter:

--Simplest construction, but requires more wood or metal than some other designs.

--Clear-span interior, but limited in width to approximately 20 or 24 feet with wood due to rafter size and strength. Wider houses can be built with steel or aluminum, depending on design.



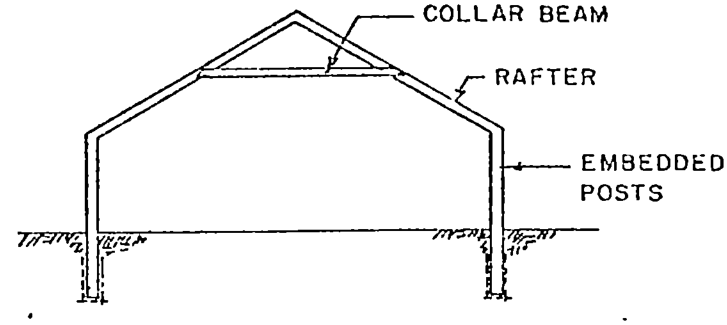
--Wood construction is primarily used with low-cost film plastic coverings.

--Requires strong widewall posts and deep post embedment to withstand outward rafter forces and wind pressures.

--Smooth interior and exterior for easy covering.

A-Frame:

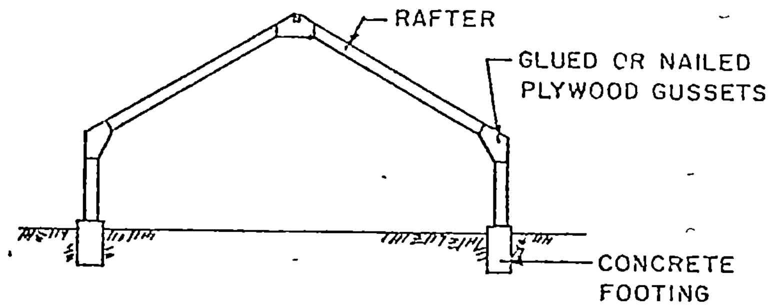
--Comparable to the wooden post-rafter construction above except the collar beam strengthens the rafter construction for wider houses but hinders placement of an inner liner.



Rigid-Frame:

--Provides high strength per unit of wood used and is suitable for self construction with proper materials and blueprints in widths of 10 to 40 feet.

--Used in many commercial designs of steel or aluminum structures, expecially glass covered houses.



--Unobstructed clear-span interior.

--Smooth interior and exterior for ease of covering with film or rigid plastic materials for most build-your-own designs.

--Excellent strength permits a relatively small number and size of wood or metal members to be used, resulting in minimum shading.

--Proper foundation piers or concrete wall required for adequate support of large lateral loads developed with such frames.

--Suitable for ridge and furrow type construction.

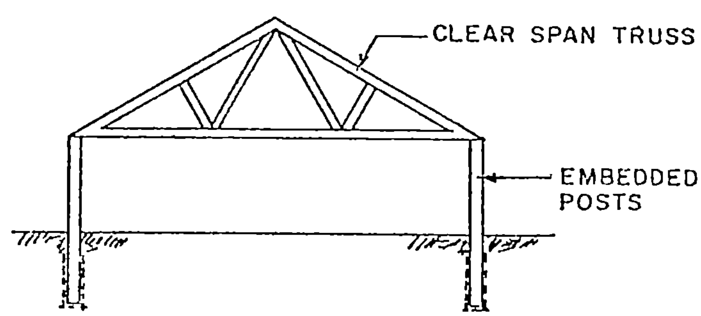
Post-Truss:

--Wood trusses not recommended due to excessive shading. Use only steel or aluminum designs having adequate strength and minimum shading.

--Clear-span floor area, but truss members obstruct gable space.

--Commercial designs available in widths up to 60 feet or more.

--Well suited to covering with rigid plastic panels or glass panes, depending on sash bars used. Not often covered with film plastics.



TRUSS

--Sidewalls must resist lateral wind loads which require strong posts and adequate embedment, and, normally, concrete backfill around posts.

--Suitable for ridge-and-furrow construction.

Structural Materials

The most common structural materials are wood, galvanized steel, and aluminum.

Wood

The most commonly used material with home- or local contractor-constructed greenhouses is wood. It is also used to a limited extent by some commercial greenhouse manufacturers for the gothic shaped structure and for glass supporting bars. Regardless of where wood is to be used in a greenhouse, the high moisture environment which exists within a greenhouse makes it mandatory that only treated lumber be used if reasonably long life is desired.

When wood is used for the main structural frame, care should be taken to use only high grade wood. Many of the designs are based upon select structural quality, which is the highest grade normally used in construction. Some of the designs further specify that any defects in the lumber be placed out of the high stress areas. With the rigid-frame designs, this high stress area is the stud and rafter closest to the eave joint.

When plywood is used for gussets with trusses or rigid-frames, it should be exterior grade, and one of the faces should be a smooth face at least "C" grade or better. Also, the plywood should be preservative treated for long life comparable to the treated wood. The edges of plywood should be well painted to prevent moisture from entering into the edges and causing delamination.

Glue

Gluing of wooden joints is frequently specified and used because of the superior strength obtained per unit of wood used. Though casein or "white" glue is commonly used for structural gluing, the high moisture condition in greenhouses requires an adhesive highly resistant to moisture. Thus, the casein or "white" glues should never be used for greenhouse construction. The adhesive which has the moisture resistance capabilities desired and which can yet be used under noraml conditions is resorcinol resin. This adhesive will cure at temperatures at 70°F or above and is marine-rated for use in "humid" environments. It is a reasonably good gap filler and is tolerant of some minor surface irregularities. This adhesive is actually stronger and more durable than wood. Resorcinol adhesive is not available in all localities; but, due to its exceptional performance regardless of the exposure condition and its ease of use, no other adhesive should be substituted without an engineer's approval. Tests on the gluing of plywood to treated lumber indicate that adequate joint strength can be obtained with resorcinol adhesive with penta-chlorophenol or the salt-type preservative treated lumber if visible oil and preservative crystals are removed by sanding or wire brushing prior to gluing.

Steel

Steel is commonly used for commercially manufactured houses. Occasionally growers bend steel pipe to form small quonset or gothic shaped houses. The high moisture within a greenhouse can result in excessive rust. All steel should be painted or galvanized. If galvanizing is done, it should preferably be done after all cutting and welding has been performed. Those areas where bare metal is exposed by cutting or welding should be painted. If steel is kept painted, it is a highly durable material and should last indefinitely. Care must be taken when cleaning dirty glass with acid, due to the corrosiveness of the acid on galvanized coatings and paint. Acid should be kept away from the steel as much as possible. After completion of the cleaning, the metal affected should be repainted.

Aluminum

Aluminum is being used more extensively by commerical manufacturers due to its light weight and excellent durability. Aluminum generally requires no maintenance and is very attractive. Its high strength makes it possible to use small roof support members, minimizing shading problems. Aluminum has not yet been used to any extent in owner-fabricated, build-your-own type greenhouses.

Coverings

The type of structure used must be compatible with the covering desired. All the quonset and wooden structures can utilize film plastic; some can use corrugated fiberglass. Most all the commercial steel and aluminum designs use fiberglass or glass materials for covering.

Summary

The type of greenhouse one builds should depend upon its use, location, size, and the grower's preference. The grower should consider both the initial and annual costs. If capital is limited, initial cost is very important. Possibly one of the designs which would permit an initial covering with low cost film but a later covering with a rigid plastic would be preferable. As a general rule, the increased durability of well constructed glass houses and the reduced annual maintenance costs due to the elimination of recovering results in glass greenhouses and many of the plastic greenhouses having comparable annual costs. In determining what type of greenhouse to build, a grower will need to consider these factors:

Initial cost--Is capital limiting or is the long term future unclear?

Annual cost--How much are the actual annual costs which must be borne by the production income?

Insurance--Can the house be insured against fire, and is the insurance high? Some of the plastic houses cannot be insured for fire and the poorer plastic house designs cannot be insured for structural failure.

Taxes--Are plastic houses not taxed or taxed at a low rate as temporary structures in the community in which the house is to be built?

Heating costs--The use of a double layer of film can reduce heating costs by 30 to 40%. Double covering reduces light and requires some extra labor for annual or every-other-year installation.

Environmental control--Does the design lend itself to easy installation of heating and ventilating equipment and provide an environment suitable for the crop being grown?

Flexibility--Can the crop being grown be changed if the economic picture changes and can the structure be easily expanded for a larger range?

Structural strength--Is hail a problem in the area in which the house is to be built? Are there other physical hazards or unusual circumstances?

Labor simplification--Does the design permit the use of mechanical equipment? Will it allow future installation of mechanization?

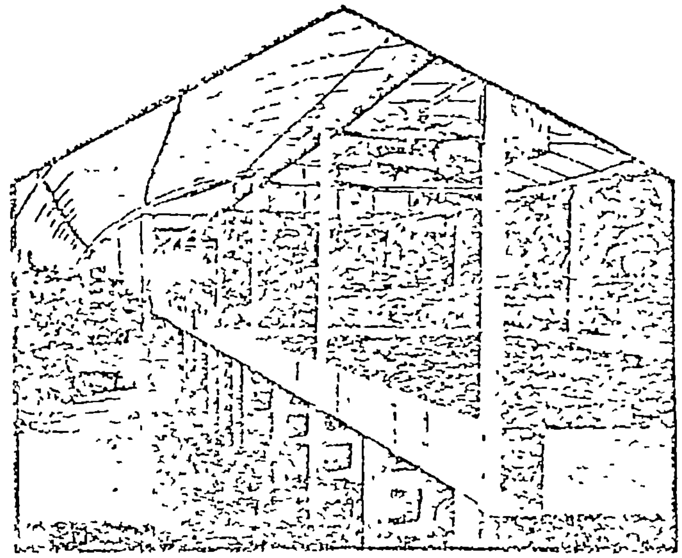
There are not simple, clear-cut answers to the above questions, and the grower must select the type of house he feels will best meet his needs. Still, he should select a sound design which can withstand the wind and snow loads in the area the house will be built. The failure of a greenhouse structure can have catastrophic consequences, and a poorly-designed house will almost always end up being the most expensive.

GREENHOUSE BENCHES

The use of greenhouse benches has several advantages over planting directly in the greenhouse soil or setting pots in the soil: 1) plants are at a more convenient height to work comfortably; 2) benches permit a more effective display of plants; 3) benches provide improved air circulation and environmental control around the plants; and 4) benches permit better disease and growth control.

Greenhouse benches elevate plants and flowers closer to eye level where they can be better observed and tended without the inconvenience of stooping or bending. This is especially important for many flower crops where plant height is not too great.

Air circulation is very important for good plant growth. Though plants might dry more rapidly when grown on benches than when placed on or in the ground, this is often an advantage due to the better control over watering which it permits. With control over watering, fertilizers can be properly applied with regard to both time and amount. Increased air circulation also helps to minimize root and foliar diseases since it causes the plant surfaces to dry more rapidly after watering instead of allowing moist areas where spores can germinate. Also due to air circulation under benches and around pots, the roots of plants on benches are warmer than the roots of those in the cooler soil of ground beds, resulting in a greater growth for the benched plants.



Plants grown in pots placed on the floor of a greenhouse also have a tendency to root through into the greenhouse floor soil unless a barrier is provided. And problems with diseases and insect pests are greater with such culture than when using benches.

Bench Size

Greenhouse benches should be customized for the individual operation. The best size depends on several factors, such as the height and reach of persons working around the benches, the type of plants grown on the benches, and aisle access to one or both sides of the benches. A tall person with correspondingly long reach could comfortably work with higher and wider benches than a short person. In commercial or other houses where several people are to be working with the plants, the benches should obviously be of a height and width suitable to an "average-sized" worker. This means, approximately, a 32- to 36-inch bench height.

As for width, benches generally should be 42- to 48-inches wide if they are to be worked from both sides, and 30- to 36-inches if they are accessable only from one side. Many establishments use benches wider than this, but difficulty may be encountered when plants are handled frequently.

Some exceptions do occur. For example, tall flowering plants should be grown in lower bench-beds so the stems and flowers will not be out of the reach of workers. Also, temporary benches for growing, bedding, or other small potted plants could be lower and wider where once-on and once-off handling is practiced. For example, temporary benches as wide as 5- to 6-feet and only 18- to 24-inches high are used successfully for bedding plants.

In instances where shade plants are to grow under the benches, bench heights as high as 48 inches have been used. With these high benches, however, some difficulty in inspecting and handling plants on the bench is encountered and therefore such height should normally be avoided.

Bench Arrangement

The arrangement of benches within a greenhouse should depend on several factors, including 1) the dimensions of the house, and walk-way location; 2) heating and air circulation patterns; and 3) materials handling into and out of the greenhouse.

In any arrangement, the bench-to-aisle space ratio should be considered. For efficient production houses, the aisles should be less than 1/4 to 1/3 the total house area.

The types of equipment used will cause some exceptions.

In commercial houses the standard arrangement is to run benches the length of the house, as shown in Figure 8. This permits long continuous runs of watering lines, heating pipes, and/or plant support techniques. This arrangement often uses more floor space for aisles than shown.

Normally, benches should not be placed directly against exterior walls, since this interferes with maintenance of the house. Also, such benches will likely be cooler than benches elsewhere in the house and uneven plant growth will occur. Allowing a sidewall space of 6 to 12 inches permits better air circulation around and under the benches.

In hobby houses, where a great number of different plants having different temperature requirements are grown, the cooler outside bench may be utilized to obtain a desirable difference in environmental conditions for particular plants.

The "peninsular" type bench arrangement shown in Figure 9 gives the greatest amount of bench area per unit of aisle space and yet permits convenient access to all areas. In this arrangement there is a single, wide center aisle with narrow aisles branching from it. The center side is made wide enough for all greenhouse

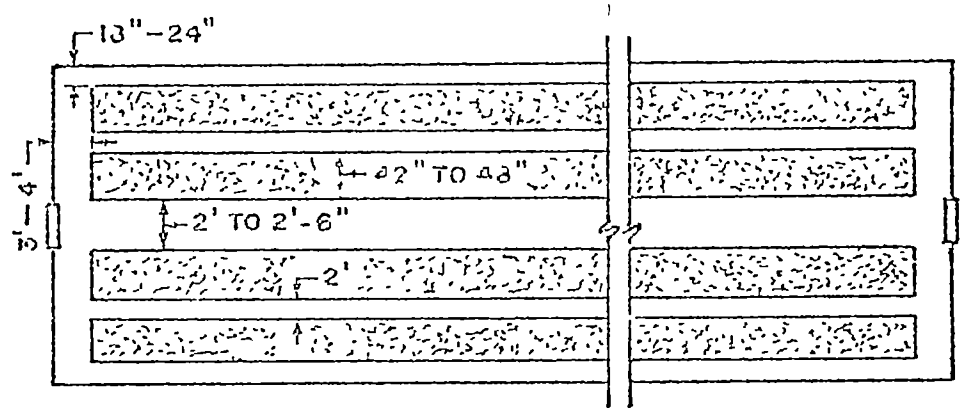


Figure 8: Longitudinal bench arrangement for houses to permit long continuous water lines, heating pipes, and/or plant support techniques.

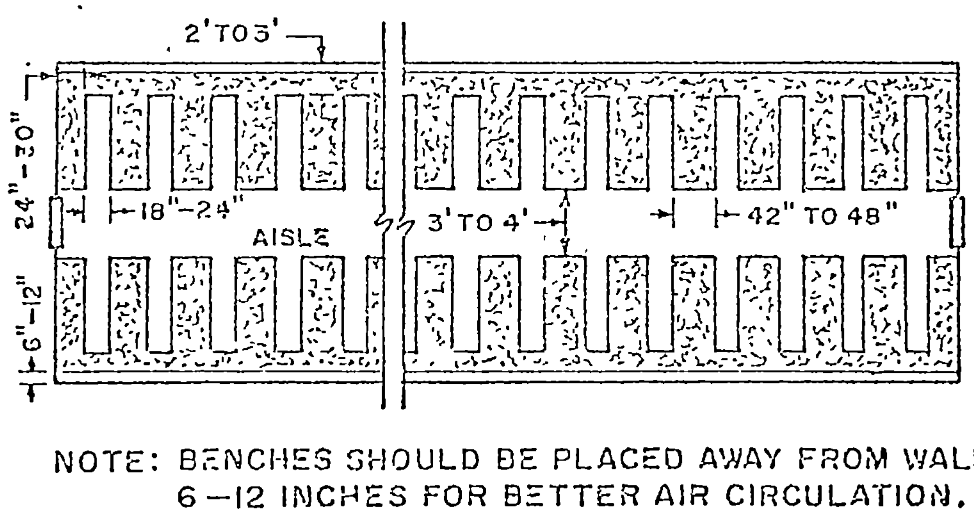


Figure 9: Cross or "peninsular" bench arrangement for greater bench-to-aisle ratio and easy access to all plants from center aisle.

equipment, while the side aisles are only wide enough to permit a person to enter. The center aisles would normally be 3 to 4 feet wide and the side aisles only 1 1/2 feet wide. With this arrangement it is allowable to have a considerable amount of bench area adjacent to the outside walls of the house. Where it is desired to have better air circulation, the benches would have to be moved in 6-12 inches from the walls to permit free movement of air between the walls and the benches as described above.

Bench Design

Both the commercial and peninsular bench arrangements may be either flat or stepped. Flat benches are simply "tables" upon which plants are placed. Step benches are just what the name implies--"stair-steps." The stepped arrangement permits a better display of plants for in-house sale and marketing. With wide or high-stepped benches, it will be necessary to work from one side. The step bench may be quite light in construction and can be built as a part of the greenhouse. It is possible with step benches to get a few more mature plants in the same bench area than with "tables." One disadvantage of step benches is that plants on them get more light from one direction. This results in uneven plant growth unless they are rotated occasionally. Step benches can be built quite tall and, when so constructed, provide considerable area underneath for shade-cultured plants.

With stepped and flat benches, either a solid or open bottom can be provided. Slat and wire benches are two types of open benches. Open benches provide the maximum amount of air circulation among the plants. Insect and disease problems are also reduced. For example, with some wire benches it is almost impossible for slugs to travel from one pot to another. If wood is used, slat construction is generally more resistant to rotting than closed or solid-bottom construction due to better aeration and drying.

Open benches may or may not have sides. Where sides are used, they serve primarily to keep plants from being brushed off the benches. This is particularly necessary in commercial walk-in greenhouses.

Closed benches are used whenever a crop is to be planted directly in the soil contained on the bench. This system has been successfully used with a number of cut flower crops. Many growers also use flat benches containing a few inches of sand or gravel for pot plants. Since the sand or gravel provides a solid base in which the pot can be set, problems with tipping are minimized. The sides and solid bottom of such benchesreduce air circulation to a large extent and thereby slow the drying of pots placed on them. Though this may be advantageous in some instances, disease organisms and insects harbored in this moist layer of gravel or sand generally are more serious than any drying problem. Solid-bottom benches in which a layer of sand or gravel is to be placed must be strongly constructed in order to carry the weight of these materials. Closed-bottom benches with sides are not particularly suited to the step-type construction.

Types of Bench Construction

Corrugated Asbestos-Cement Bench:

The major advantage of the corrugated asbestos-cement ("Transite") bench is its excellent durability. It comes close to solid concrete in its permanence. The material is strong, though it will crack or break if abused. However, corrugated asbestos-cement will not rot or deteriorate. These benches are easily installed, with no special tools or skill required for fabrication. The material comes with corrugations every 4.2 or every 2 1/2 inches. The 2 1/2 inch material should be used when available since it is somewhat easier to work with.

For small pots it may be necessary to lay wire mesh over the corrugations before setting the pots. The wire mesh provides a reasonably flat surface upon which to set the plants yet permits good air circulation around the pots.

In some cases gravel is placed on corrugated benches to support the small pots, but this has the disadvantage of reducing air circulation and increasing the problem with disease and insects.

When sides are used, they are usually 6" to 8" high and normally made from flat cement-asbestos material. When this material is used, the sides have the same permanence as the bottoms. It is important that the sides be fastened to the bottom in such a way that a gap is left between the corrugated bottom and the sides. This gap is necessary to allow excess water to drain freely from the benches. Glavanized bolts and straps are normally used for attaching the sides. The bench is then filled with a stuiable growth media, as required by the plants being grown. A gravel or coarse sand bottom layer is necessary to provide good drainage.

The major disadvantage of benches of this type is their comparatively high cost.

Other Corrugated Materials:

Other types of corrugated materials are sometimes used but generally do not prove as satisfactory. The corrugated plastics lack the strength of the cement-asbestos materials. Problems with deterioration of some materials are also experienced. Aluminum would have reasonably good permanence, but the normal roofing forms would be comparatively weak. If aluminum is used, one should choose the 0.024 inch thick aluminum in preference to the more commonly available 0.019 or 0.0215 inch thick material. Galvanized steel, though available in sufficiently strong thicknesses, would be a poor choice for benches due to the rusting problem which will be encountered. The zinc-galvanized coating may also be toxic to plants in many situations.

Flat Cement-Asbestos Board:

Flat cement-asbestos board can also be used for constructing a bench. As with the corrugated form, the material should be 3/8" thick. Such benches do not have the strength of corrugated benches, but have the advantage that small pots will set on such benches without tipping. Flat cement-asbestos boards should not be used for benches which will be filled with soil.

Several different types of supporting frames can be used, as shown in Figures 10 and 11. For each type, the leg supports should be spaced four feet apart.

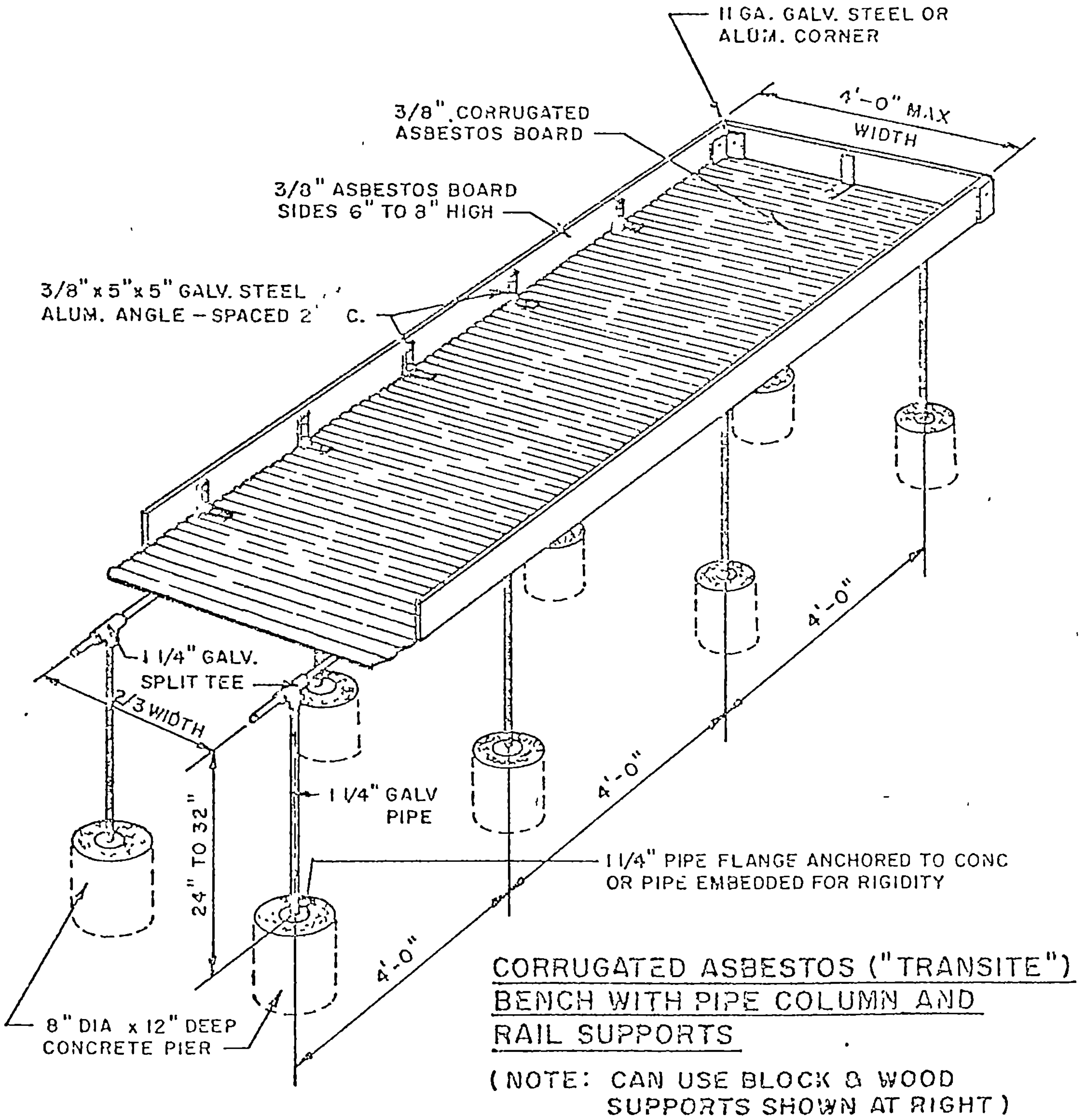


Figure 10: Corrugated asbestos ("transite") bench with pipe column and rail supports.

Wood Benches:

Wood can be used for flat or step benches, but unless the wood is treated or is a very durable species, such benches can deteriorate rapidly and lack permanence. Some preservatives can damage the roots of plants that grow in contact with the wood. Thus, for good performance and permanence, use wood treated with water-borne, salt-type preservatives.

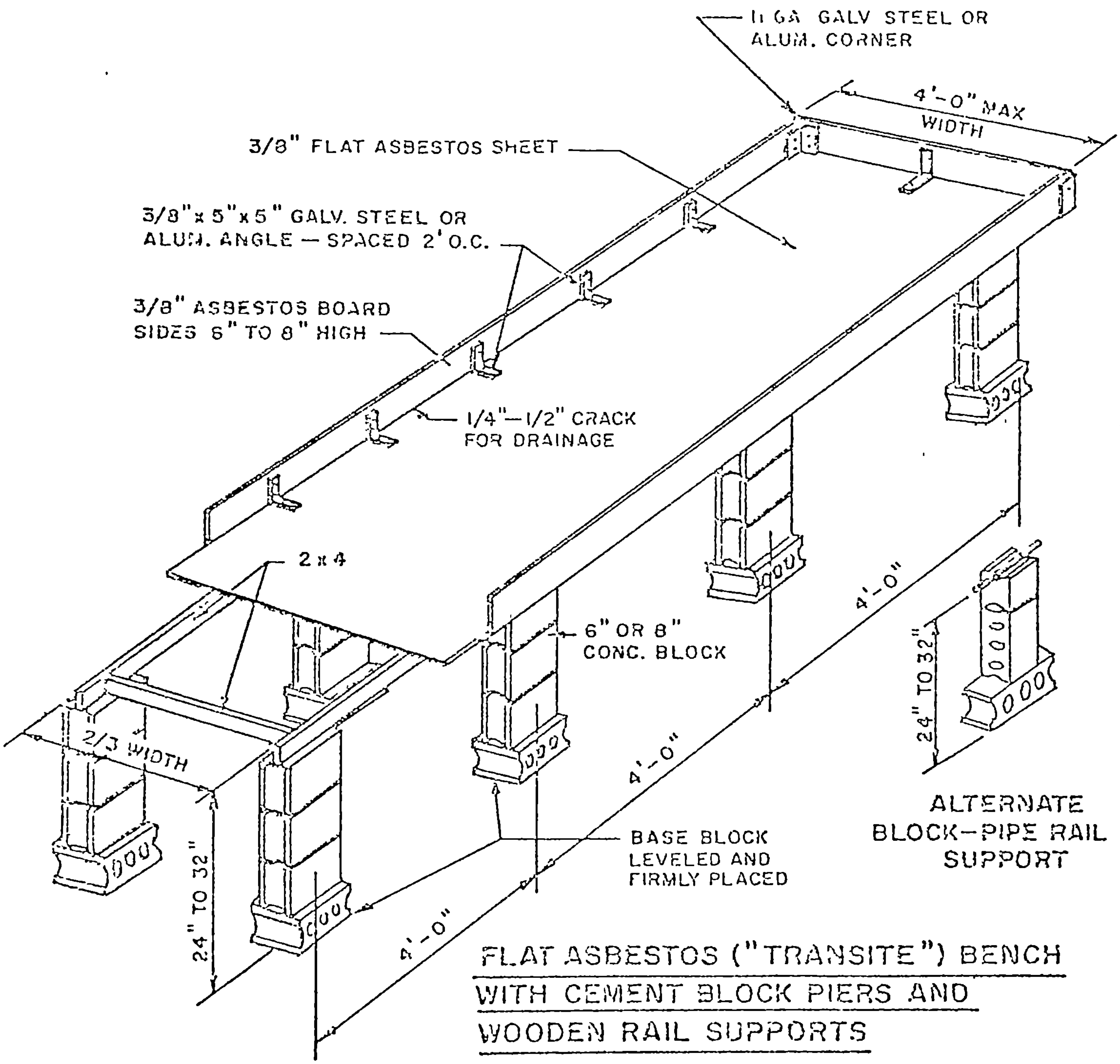


Figure 11: Flat asbestos ("transite") bench with cement block piers and wooden rail supports.

For greenhouse use, the treatment should be one of the commercial, water-borne, salt-type preservatives such as Chromated Copper Arsenate ("Osmose K-33", or "Green Salts"), Ammonical Copper Arsenite ("Chemonite"), or Fluro Chrome Arsenate Phenol ("Tantalith", "Wolman Salt", or "Osmosalts"). Wood properly treated with such material will last for 20-30 years or more in greenhouse use. (NOTE: Some of the above treatments are not rated for "ground contact" use.) Since fumes and vapors from wood treated with the more toxic oil-borne materials like penta or creosote can be damaging to plants, these preservatives are not recommended for greenhouse benches.

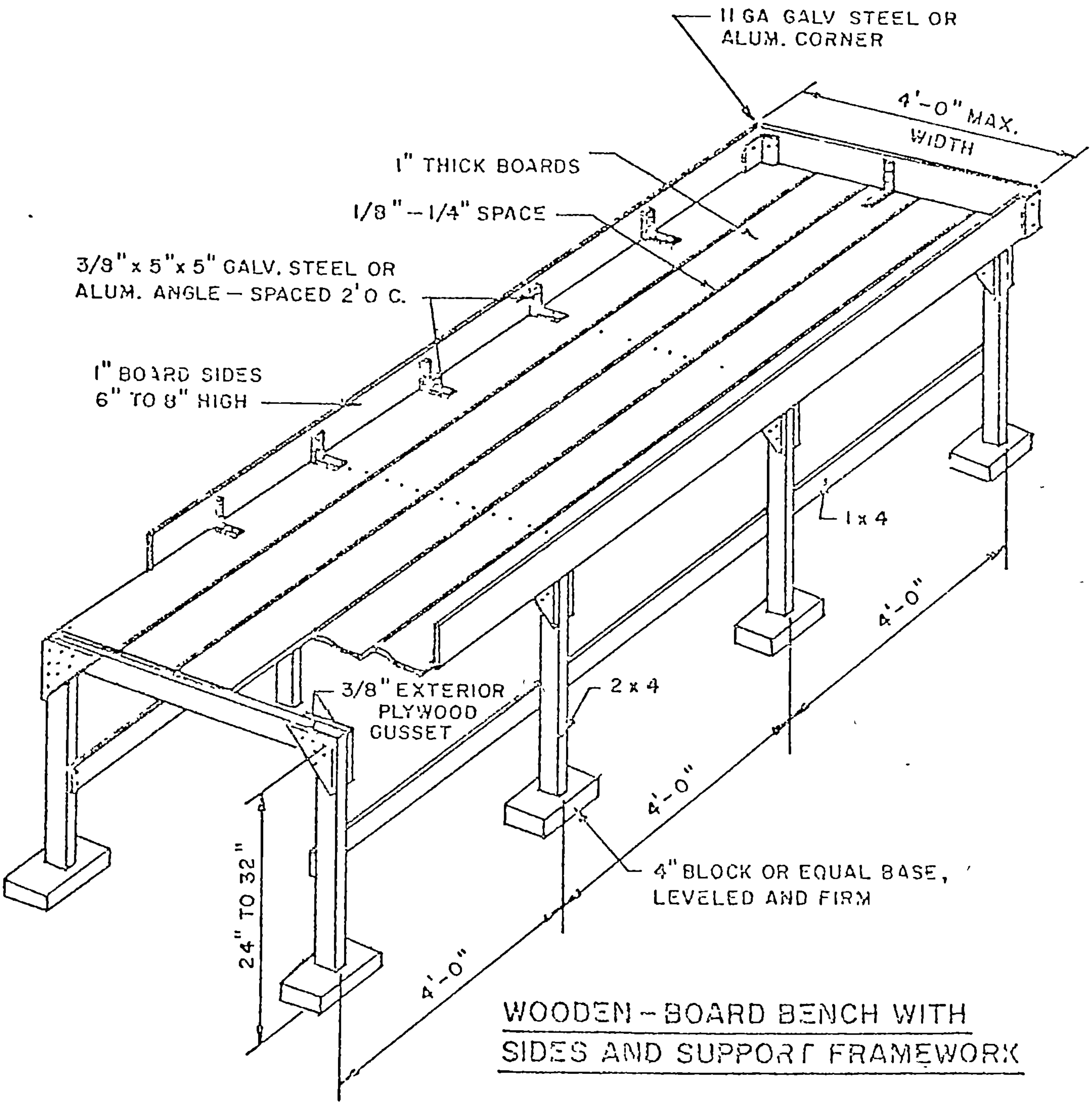


Figure 12: Wooden-board bench with sides and support framework.

Wood treated with all of the water-borne, salt-type preservatives can be effectively painted once the wood has been redried. If possible, 6 months to 1 year weathering is recommended, since tests have indicated this period will eliminate any toxicity of these materials to plant roots.

Figure 12 shows a wooden bench with side boards. For flat-topped wood benches, a 1/8-inch to 1/4-inch crack should be left between the bottom and side boards to allow water to drain from the bench and to prevent damage to the bench if the wood swells due to moisture absorption. Cross supports should be spaced not more than 4 feet apart.

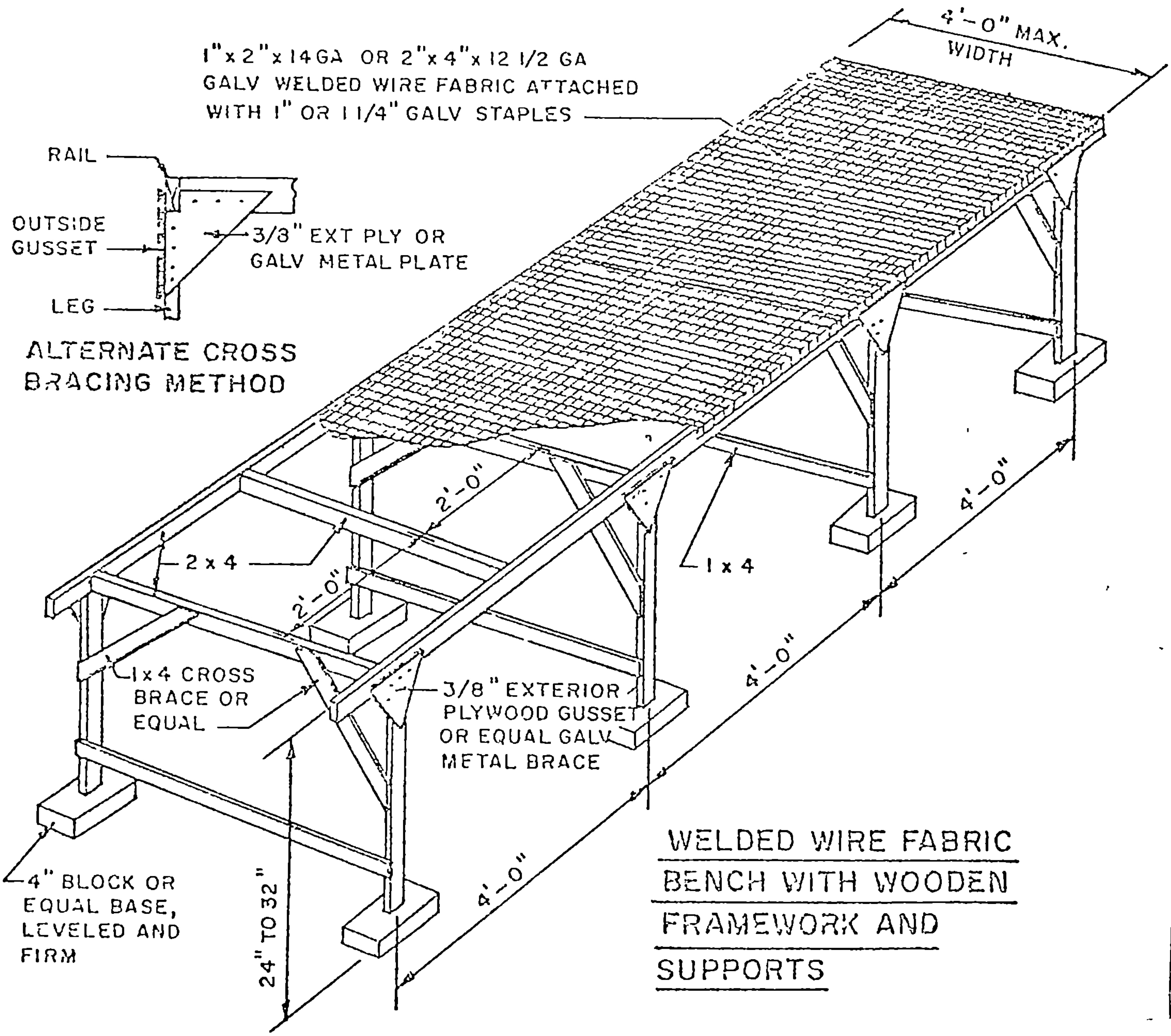


Figure 13: Welded wire fabric bench with wooden framework and supports.

Welded-Wire-Mesh Bench:

Benches of the wire-mesh type shown in Figure 13 are widely used in pot-plant culture. They give excellent air drainage and simplify insect control problems. The construction is simple. The framework can be made of 2" x 4" wood, species rot resistant or treated. Welded wire fabric is then stapled to this framework. The mesh should be one of the heavy wire types, since sagging is a problem with even the best materials. A 1" x 2" welded mesh, 12 1/2 or 14-gauge, has been used with good results. Staples should be 1 1/4 to 1 1/2-inch long. The use of galvanized wire and staples will delay the rusting problem and thus lengthen the life of the bench.

To minimize sagging, cross supports should be spaced 2 feet apart, though some sagging will eventually occur and the pots will not set evenly. However, the cost of such benches is generally low when compared to other types.

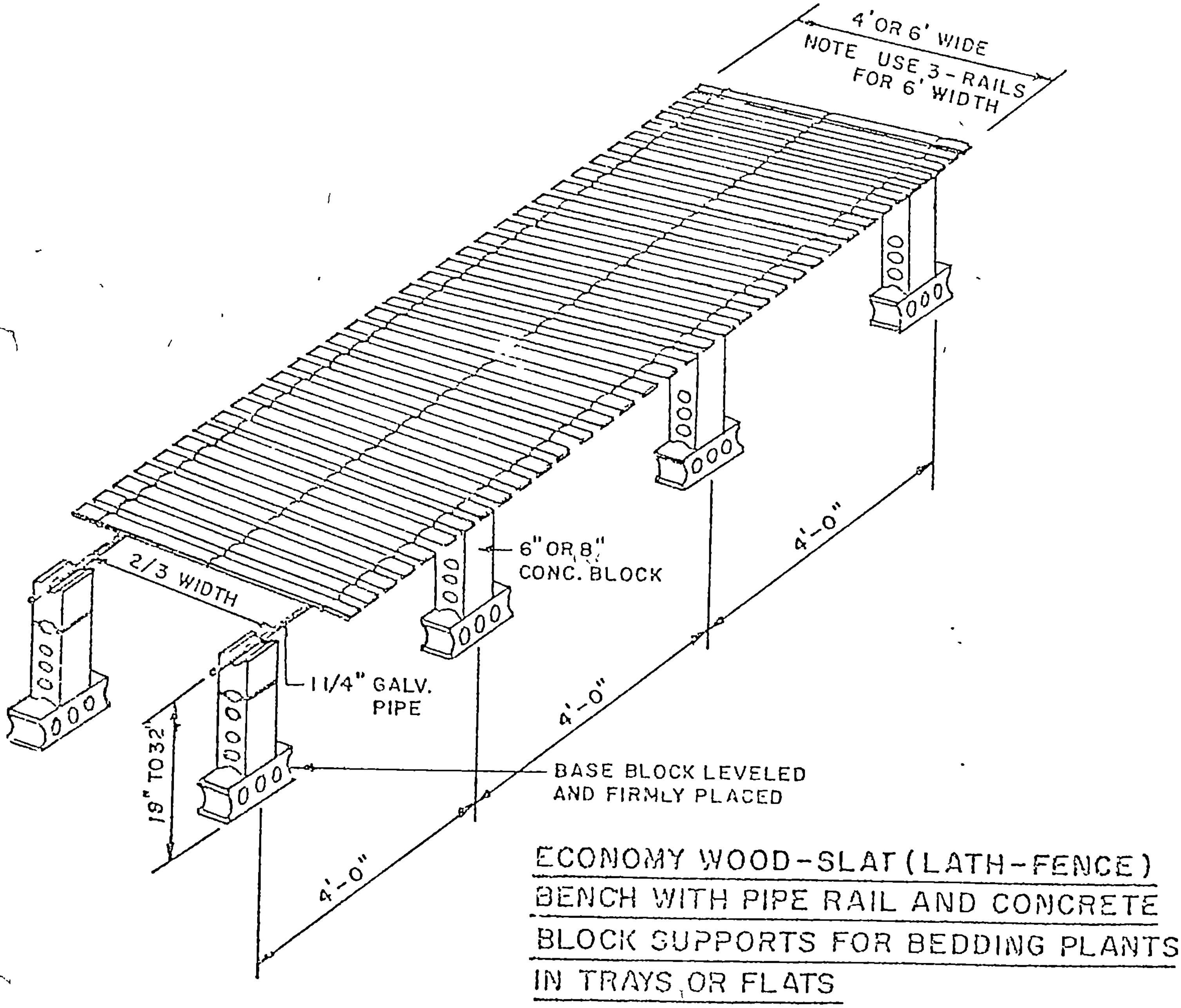


Figure 14: Economy lath-fence bench with pipe rail and concrete block supports for bedding plants in trays or flats.

Wood-Slat (Lathe-Fence) Bench:

When using small plants in pots and these pots in trays or flats, an economy bench top as shown in Figure 14 can be made of lathe-fencing placed on treated 2" x 4" supporting rails or pipe rails. The lathe-fence allows good air circulation around the pots. A problem would be encountered with pot tipping if small bedding-plant size pots were used alone on the fence. Wire mesh of 1" x 2" size should then be used over the slats to prevent pot tipping. Since the lathe-fencing is not generally preservative treated, the permanence of the bench top is not good in comparison to benches made completely with treated wood. The lathe fence is, however, easily replaced when deterioration requires its replacement. No practical method of providing side walls for lathe-fence benches now exists.

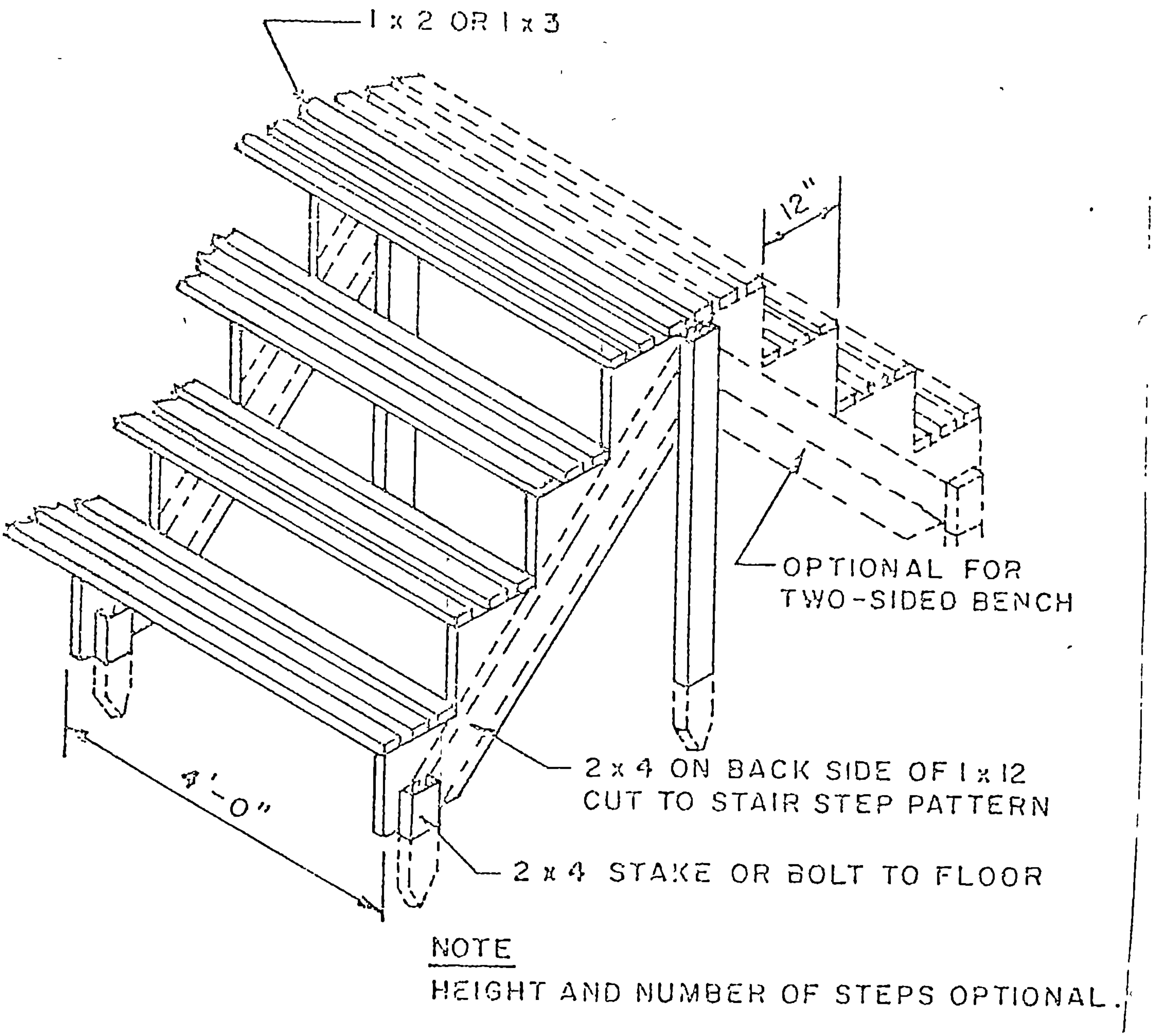


Figure 15: Wooden step-bench.

Wooden Step Benches

Wooden step benches like the one shown in Figure 15 can be made any size, width, angle or height. The size of plants to be placed on the bench and the greenhouse size will largely dictate the specific dimensions of the bench. Slats are most commonly used and they should be treated with a wood preservative. Painting the slats will reduce toxicity problems and will also increase the light reflected below the bench. Step benches are usually built to face south so that they will receive maximum sunlight. If two-sided step benches are used, plants on the northern side will receive considerably less sun than those on the southern side. Thus, orientate the benches north-south so the morning and afternoon sun will shine on each side equally.

Step benches require more labor for construction than some of the other bench types, but this seldom is a factor in determining what type of bench to build. Shading problems, work efficiency, and space utilization should be the primary considerations. Remember, if you want to have uniform plants, pots on step benches will need to be turned occasionally when light intensity is higher on one side of the bench than the other.

Evaporative Cooling Of Greenhouses In Florida

T. C. Skinner and D. E. Buffington*

Evaporative cooling may be defined as a process of reducing the air dry bulb temperature by the evaporation of water into the airstream. The means of evaporating water, moving the cooled air through the greenhouse, and exhausting the warmed air comprises the cooling system. In greenhouses this is usually accomplished by installing at one end or side of the greenhouse a porous pad over, through and around which water is circulated in a fine mist or film so that all exposed surfaces of the pad are wet (Fig. 1). Exhaust fans are located on the opposite end or side of the building from the pads (Fig. 2). If all vents and doors are closed when the fans operate, air is pulled through the wetted pads and water evaporates. The air, being warmer than the water with which it comes into contact, gives up a part of its heat to the water, thus cooling the air being introduced into the building. As each gallon of water is evaporated, 8,100 BTUs of heat energy is absorbed in the change from liquid to vapor. It is important to recognize that with this type cooling system the air will be at its lowest temperature immediately after passing through the pads. As the air moves across the house to the fans, the air picks up heat from plants, soil, etc. and the temperature of the air gradually increases. Thus a temperature gradient results, with the pad side being coolest and the fan side warmest.

The distance between the pads and exhaust fans is influenced by a number of factors including the following:

1. Optimum dimensions of the house from an efficient, functional and operational standpoint.

2. Effective tolerance of plants produced in the house to temperature

* Professor and Associate Professor, respectively. Department of Agricultural Engineering, IFAS, University of Florida, Gainesville, Florida.

differences. The greater the tolerance to temperature differences, the greater the distance between pad and fans can be. It is not practical to separate the pad and exhaust fans by more than 200 feet (Fig. 1). A distance of 150 feet or less is preferred.

There are other factors which will influence how effectively the system will operate (and these are very often the cause of system failures). Some of the more common and significant of these are:

1. Type of construction and condition of the house. Managing the house to make sure that it is as tight as possible, and that all doors and other openings are always kept closed except when in use, will have a dramatic effect on the success or failure of the system (Fig. 3). It is very important to keep the building as tight as possible so that entering air will be forced to come through the pads. If a door is left open, a vent unclosed or uncovered, or excessive cracks uncaulked, you can be sure it will be easier for the air to take these routes into the building rather than through the pads and an ineffective system is the result.

2. Condition of the pads is very important. We know that under our Florida conditions we have severe problems with the pads. They are often subjected to many undesirable factors such as clogging due to impurities in the water, algae and decay. As the pad material is clogged or decomposed by any of the above or other causes, its ability to function as designed is impaired. Air being exhausted by the fans will enter the building at the point(s) of least resistance. If a pad area is totally or partially clogged, very little if any air will pass through that portion of the pad. If the pad has decayed, has bare areas or tends to slump and compact the air again will take the path of least resistance. This means less air-water contact, thus much less cooling (Fig. 4). When a pad has decayed and slumped, the

only alternative is to install a new pad.

Up to this point, discussion has been directed primarily at potential problems of which a person using or contemplating the use of an evaporative pad cooling system should be aware. It is now time to discuss some specifics of the system and its component parts. Perhaps a good approach would be to pose a series of questions and see what answer(s) we come up with.

1. What type pad material should be used?
2. How much pad area is needed?
3. What capacity water supply will be needed?
4. What fan capacity will be required?
5. Where should the pads and fans be located?
6. What temperature differential can be expected between air entering the pad (outside air) and the air entering the greenhouse, and is it possible to predict within reasonable limits what the air temperature entering the greenhouse will be?
7. What about the temperature gradient across the greenhouse - is it alwyas uniform and predictable?
8. Does orientation of the building in relation to other structures and/or prevailing winds influence efficiency of operation?
9. What about controls needed?
10. If I know the answer to all of the above questions, will I have all the information I need to be assured of a good operating system, or is there more?

Let's examine the several questions posed concerning an evaporative cooling system on a question by question basis.

1. The first question dealt with types of pad materials. Until recent

years aspen pads were almost universally used and are still popular in many areas of the country. Many evaporative cooling systems in Florida use aspen pads. Under our Florida conditions the life of an aspen pad is usually quite short. It is very susceptible to algae infestation which leads to rotting and compaction. This makes it very difficult to maintain an efficiently operating system without frequent and costly pad replacements.

Other pad materials are available, and it appears that some may be more resistant to algae growth and physical deterioration than aspen pads. One such pad is made from a special cellulose paper (Fig. 5) which has been impregnated with insoluble salts to resist rot, rigidifying saturants and wetting agents. Another pad material being used is made of cement impregnated fibers (Fig. 6) while another is made of rubberized hog hair* ~~(Fig. 7)~~.

Some of these newer pad materials are looking real good under our Florida conditions, but more time and data are needed before it can be said with a high degree of confidence that one has a decided advantage over the others. An operator planning to replace an old pad system or install a new one should check out all the pad material options available to him and get all the information possible about each. Then compare costs, life expectancy claims, cooling efficiencies, probability of maintenance problems and then select the one that appears best for his operation.

2. The amount of pad area needed depends upon several factors, including the type of pad material used. If aspen pads are used it is normally recommended that 1 square foot of pad be provided for each 150 cubic feet per minute (CFM) of air moved by the fans. The fan capacity should be based on

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* Rubberized hog hair has not held up well. It becomes brittle in about 2 years and small pieces sift into the return water and damage impellers and pumps by abrasion or clogging. The remedy is a filter on the return line just before the pump.

total CFM delivered at 1/8 inch static water pressure. On the other hand, the manufacturers of the cellulose paper pads claim that much higher face velocities are possible without drifting (movement of free water into the house). With the higher permissible velocities, it would follow that fewer square feet of pad area would be needed. In a well designed and operated system, efficiencies of up to 85% cooling can be achieved (Fig. 8). Regardless of the type pad material used, the fans should have the capacity to provide a minimum of one air change per minute.

3. The amount of water needed will vary with the type system used, but normally, to assure complete pad surface wetting, about 1/3 gallon of water per foot of pad length is recirculated. However, a valve should be placed in the line from the pump so that the flow to the distribution pipe can be adjusted. The water collected by the bottom gutter is returned to a sump from which the water is pumped to the upper distribution pipe or gutter. For houses more than 75' in length, it is usually more efficient to locate the sump near the center of the house. The sump should have a capacity of 1 to 1 1/4 gallons for each linear foot of pad in order to hold the water which drains back to the sump when the system is stopped.

4. It has been determined that fans should have the capacity to provide at least one air change per minute. Heat enters the greenhouse through the greenhouse covering. Most types of coverings allow solar radiation to enter the enclosure, but alters the wave length of the light rays so they cannot leave. This phenomena, known as the "greenhouse effect," accounts for the high temperature inside uncooled greenhouses. Light energy absorbed is converted to heat energy and is necessary for photosynthesis. The portion radiated by the structure, soil, plants, etc., causes the temperature of the air to rise as it passes by. (Refer to discussion of temperature gradient.)

Solar heat loads on greehnouses will vary according to latitude location, as well as time of year and day. In this area (central Florida) it will vary from a maximum direct normal solar irradiation in BTU/hr. Sq. Ft. of about 280 in June to 300 in September (Fig. 9).

5. Location of pads and fans will be influenced by a number of factors including:

a. When possible locate the pads on the prevailing summer wind side and the fans on the down wind side of the greenhouse (Fig. 2). Should the pads be protected by another house within 25 feet, the wind effect is negligible and can be ignored.

b. If it is necessary to face fans into the prevailing winds, increase fan CFM capacity ten to fifteen percent and correspondingly increase fan motor horse power and add shutters or back draft dampers.

c. The exhaust fans should not discharge toward the pad of another house unless the houses are separated by at least 50 feet.

d. When fans from two adjacent houses within a close distance to each other exhaust into a common area between the houses, they should be offset from each other to avoid the air from one blowing directly against the other (Fig. 20). If fans do not have at least 1 1/2 fan diameter clearance between their discharge opening and the nearest obstruction, roof mounted fans should be used.

e. The maximum practical distance from pad to fan should never exceed 200 feet. Distances of 150 feet or less are more effective (see temperature gradient). For most houses about one foot of pad height is required for every 20 feet of pad to fan distance.

f. In very long houses it may be more efficient to locate a pad at each end with the exhaust fans at the center of the house using side wall or roof mounted fans. The cooled air then flows in from each end and is exhausted at the midpoint of the house. All fans should be equipped with automatic shutters for weather protection and to prevent backdrafts when fans are not in use.

g. Special motorized roof housings are used for mounting fans on the roof.

h. The fans should be properly screened and guarded to safeguard personnel from coming in contact with any moving parts (fan blades, pulleys, belts, etc.).

i. A correctly designed pad system is essential to achieve maximum cooling performance. It must be a continuous section along the entire side or end of the greenhouse, be the correct size and thickness. A blank space in the pad, such as a doorway, will cause a hot spot through the house for a distance of 6 to 8 times the width of the blank. Exhaust fans should not be spaced more than 20-30 feet apart (Fig. 2).

j. Pads may be built inside the house or in the walls, or they may be built outside the house (Fig. 11).

6. A well designed, properly installed and operated evaporative cooling system may have an operating efficiency of up to 85% (Fig. 8). The difference between dry bulb temperature and wet bulb temperature is referred to as the wet bulb depression. By referring to the psychrometric chart (Fig. 12), if you know the outdoor temperature and relative humidity, you can calculate the wet bulb temperature which theoretically would be the temperature of the

entering air. However, no system is 100% efficient. If the efficiency of your system is 85% (and this would really be outstanding) then the entering air temperature would be the wet bulb temperature plus 15% of the wet bulb depression.

7. The <u>temperature gradient</u> across the greenhouse is important and hard to predict because there are so many variables in a greenhouse which affect the gradient such as bench arrangements, physical obstructions to the movement of air across the house, percentage of floor area covered by plants, or if the floor is bare soil, or covered with concrete, etc. The configuration of the roof can also have an influence on temperature gradient. Experience has shown that air may heat up as rapidly as 1^{0}F. for every ten feet of movement on sunny summer days. The slower the air movement, the faster the air heats up, and the greater the gradient.

Actually, what is of most importance is the temperature gradient across the house at plant level. In most systems the air tends to diverge at an angle of about 7^{0} or roughly 1 foot in 8 feet. Consequently, the upper layer of cooled air tends to rise toward the peak of the building above the crop zone and thus does little cooling of the plants. In cross flow arrangement of gutter connected houses, the gutters serve as baffles and tend to keep the cool air at crop level. In longitudinal flow arrangements where the air flow is lengthwise the house, triangular shaped baffles need to be placed extending from the roof, tapering down to just above the top of the crop level. The baffles should be transparent and spaced about 30 feet apart. These baffles should be in a fixed position (Fig. 13).

Where plants are grown on raised benches, baffles about 2/3 the way down the sides of the bench will tend to force most of the cooling air to crop level for more effective cooling.

8. Orientation of the building in relation to other buildings or structures and in relation to prevailing summer winds do have an influence on efficiency of operation and may affect fan arrangements or whether the pad and fan will be located on the side or end walls and whether ceiling fans will be used.

9. Equipment controls - It is important that the evaporative pad cooling system have adequate controls for the operator to be able to adjust the house environment to provide maximum growing conditions for the plants and a comfortable environment for workers. Fans should be controlled by thermostats and/or humidistats. Thermostats are used to turn fans and pumps on and off, as required to meet changes in outdoor climate conditions and thereby maintain more uniform greenhouse temperatures with lower operating costs. A humidistat can be used to control the pump of the cooling pad system to help prevent an excessive greenhouse humidity. A humidistat can be used to operate exhaust fans to help prevent excessive greenhouse humidities. Thermostats and humidistats should be checked thoroughly at the beginning of each season and several times during the season to make sure they are functioning accurately.

As stated earlier, exhaust fans should be uniformly spaced not more than 20-30 feet apart. The fans may be wired so that the thermostats will turn on alternate banks of fans in sequence as the temperature demands. Some greenhouses are equipped with 2-speed fans which should be controlled with 2-stage thermostats. This arrangement will permit the first stage to turn the fan on low speed and off as required while the second stage will run the fan on high speed according to demand.

It is important that during the time of year when a thermostat controls the heating system, that the cooling thermostat which controls the first stage fans should be set 5^{O}-10^{O}F. above the setting of the heating thermostate to avoid having the heating and cooling systems on at the same time.

If evaporative cooling water pumps are controlled by humidistats and thermostats, they should be wired in series. This will help maintain more uniform temperatures and avoid excessive humidities. It will also help conserve power and water. In all cases, however, a thermostat should be used as the main pump control. The thermostat should be set to stop the pump before all the fans go off so that the pad can dry out.

Each thermostat and humidistat should have a manual control switch wired in parallel with it so that manual control can be used when desired. A safety disconnect switch should be located near each fan and pump.

All controls and instruments including thermostats, humidistats and thermometers should be shielded from the direct rays of the sun to avoid being influenced by solar radiation and to provide more correct readings and control settings. They should also be mounted so that air can circulate freely around the sensing elements and be located where they represent the average greenhouse condition at plant level. Aspirated thermostats at plant level are the best choice. Do not locate near heating lines or near an air inlet opening. This will distort the readings as far as indicating what the true environmental conditions are for the plants in the greenhouse.

10. There is more to learn about pad and fan systems. An understanding of how an evaporative pad cooling system operates and managing the total greenhouse operation to maximize the contribution which the system can make to provide the best possible environment for the production of plants and worker comfort is important. Let's review some things dicussed previously.

We learned that it is the wet bulb temperature and not the relative humidity that determines to what temperature air can be cooled by evaporation of water. Wet bulb temperatures can be determined in several ways such as (1) checking with your local weather station or (2) invest in a simple sling psychrometer. Weather data collected by the weather bureau for many years indicates that the average summer wet bulb temperatures for central Florida are about 79-80^{O}F. The most critical time to check wet bulb temperatures is in the afternoon when solar radiation and outside temperatures are highest (Fig. 14). With an efficient, well managed system, you should be able to reduce the temperature of the air entering the house to within 3-4^{O}F. of the wet bulb temperature. Remember, this will not be the temperature in all areas of the house. Recall we talked about the house's temperature gradient and as the air moves across the house to the exhaust fans, it will pick up heat so that the exhausted air will likely be some 7-8^{O}F. higher than the entering air. In a poorly managed system the exhausted air could have a much greater differential than this.

In summary, the following should be observed if the pad cooling system is to be successful.

1. You must have adequate pad surface area and an adequate water supply and distribution system. You do not want a sheet of water flowing down the pad surface. This would increase resistance to air flow and cause transfer of free water into the house. You do want the pad surfaces covered with a water film. Check with manufacturers' recommendations as to quantity of water per linear foot of pad.

2. The pad should be continuous along the entire wall.

3. Face velocity of the air will depend upon the pad material. Follow manufacturers' suggestions. This velocity will determine the number of square feet of pad area needed for a house of a given configuration.

4. It is during the heat of the afternoon when the dry bulb temperature is normally at its peak, that the difference between the dry bulb and wet bulb

temperature is the greatest. Thus the greatest potential for cooling is obtained during the heat of the day when it is needed most.

5. Have automatic shutters on the fans so there will not be back drafts when a fan is not operating (Fig. 15).

6. Construct a tight house and keep it tight. Do not leave doors or vents open when the system is operating. Remember it is easier for air to move through an open door than through the pad.

7. Construct the pad, whether outside the wall, in the wall or inside the house so that all air entering the house will have to pass through the pad.

8. Provide for closing off the pads during the winter when heating, not cooling, is required.

9. The use of overhead high pressure mist cooling systems has been used by a few greenhouse operators, but has some serious disadvantages which we will not attempt to go into at this time. Package unit evaporative coolers are available (Fig. 16); however, these too have some very severe limitations as far as practical applications are concerned, especially in large commercial houses.

10. Watch the pad condition carefully. If you notice bare spots or thin areas in the pad, you can be sure that a large portion of air entering the house is through these areas, and you are going to have hot spots in the house. To operate efficiently, the pad, pump system, fan system and control systems must be designed to operate as a unit. They must be checked frequently to be sure all parts are functioning properly. Manage the house operations so that doors are never left open and are opened only when necessary to move people or plants and equipment in and out. An open door can reduce the effectiveness of a pad cooling system significantly.

The best house equipped with the best possible equipment and sophisticated controls can be a big loser without good management.

FANS FOR GREENHOUSES

D. E. Buffington and T. C. Skinner*

Fans are used in processing applications involved with drying, ventilating, heating, cooling, aspirating, elevating and conveying. Processing and other agricultural activities requiring fans are greatly increasing. Costs are becoming more and more important, and it is necessary that a person be able to select and apply the best fan for any installation taking economic factors into consideration.

Fan Definition

A fan is an air pump -- a machine that creates a pressure difference and causes air to flow. The impeller does work on the air in giving it both static and kinetic energy that varies in proportion depending on the fan type. Fans have generally been classified as either centrifugal or axial flow, based on the direction of air flow through the impeller. Axial flow fans are generally classified as propeller fans, duct fans, vane axial fans, and disc fans. The propeller fan, essentially an air screw, is used for moving large quantities of air against low static pressures and is most commonly used for general ventilation applications. Centrifugal fans are generally used for moving air against high static pressure, such as experienced in grain drying applications. The propeller fan is the most common fan used for ventilation in greenhouses; however, other types of axial flow fans are also used.

Fan Testing

Fans are tested in accordance with strict requirements of AMCA (Air Moving and Conditioning Association) Standard 210. This standard specifies

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*Associate Professor and Extension Agricultural Engineering, respectively, Department of Agricultural Engineering, IFAS, University of Florida, Gainesville, Florida

in detail the procedures and setups to be used in testing the various types of fans. Fans are tested under these standard test conditions so that all fans are rated on an equal basis. Thus, fans of different manufacturers and of different types can be rated and compared using the same basis of testing and obtaining performance data.

Fan Laws

Fan laws relate the performance characteristics of any geometrically similar series of fans. Variables generally involved are fan size, rotational speed, volume flow rate, static pressure, horsepower, and mechanical efficiency. The laws governing fan operation provide a useful tool for determining requirements where changing the volume capacity of a fan is required for a given system. At a new fan rotational speed, the new operating point for a given fan can be determined from the fan laws as follows: Volume flow rate (CFM) varies directly as fan speed (N). Static pressure (SP) varies as the square of fan speed. Horsepower (HP) varies as the cube of the fan speed.

In equation form, the laws are:

$$CFM_2 = CFM_1 \times \frac{N_2}{N_1}$$

$$SP_2 = SP_1 \times \left(\frac{N_2}{N_1}\right)^2$$

$$HP_2 = HP_1 \times \left(\frac{N_2}{N_1}\right)^3$$

Subscript 2 refers to the new operating point at the new rotational speed N_2, while subscript 1 refers to the operating point at the present rotational speed N_1.

These laws apply only when <u>all</u> flow conditions are similar. Increasing the speed of a fan causes changes in several important parameters, which may invalidate the fan laws.

Fan Noise

Fan noise is a function of fan design, volume flow rate of air, total pressure, and efficiency. After making a decision on the proper type of fan for a given application, the best selection of a specific fan must be based on efficiency. The most efficiently operating fan will also be the quietest fan. Low outlet air velocity does not necessarily assure quiet operation.

Noise comparisons of different types of fans on the basis of rotational speed is erroneous. The only valid basis for comparison of different fan types is the actual sound power levels generated by the fans when the fans are all producing the required volume flow rate of air at the specified static pressure. Actual fan sound power levels for rated conditions can be obtained from the fan manufacturer as part of the normal fan data.

Fan Selection

When selecting a fan, the following information must be known. These factors will govern the type of fan to be selected and its size.

(1) Volume of air to be moved per unit time.

(2) Static pressure -- the estimated system resistance and expected variations.

(3) Space available for installing fans.

(4) Amount of noise permitted.

(5) Efficiency -- select fan that will deliver required volume at the expected static pressure with the minimum horsepower.

(6) Economic considerations.

Fan selection is based on the static pressure for a given volume of air that needs to be moved. Although the volume of air desired can be calculated accurately, the static pressure requirement can only be estimated.

For most greenhouse applications, the static pressure resistance will be no higher than 0.10 - 0.15 in. of water. However, when using fans as part of an evaporative cooling system, be sure to obtain the static pressure drop across the cooling pad from the manufacturer. Some of the new types of cooling pads may have higher static pressure requirements than the conventional aspen pad.

If the actual system pressure requirement for a given volume flow is known, the characteristic curve of a system can be calculated. For most normal systems, this curve is a parabola as shown in Figure 1 with its origin at zero volume, zero pressure, with the pressure varying as the square of the volume. Thus, if the volume flow through a given system is doubled, then the pressure required will be four times greater.

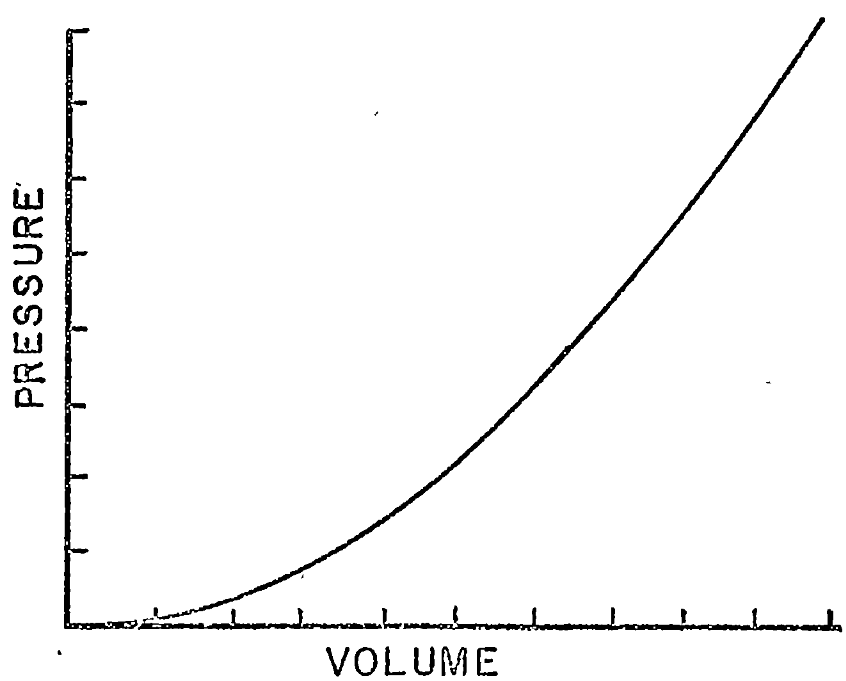

Figure 1. Ventilation system characteristic curve

A fan at a given rotational speed has a characteristic pressure-volume curve from wide open volume with no static pressure resistance to block tight with no air movement. A typical fan characteristic curve is shown in Figure 2.

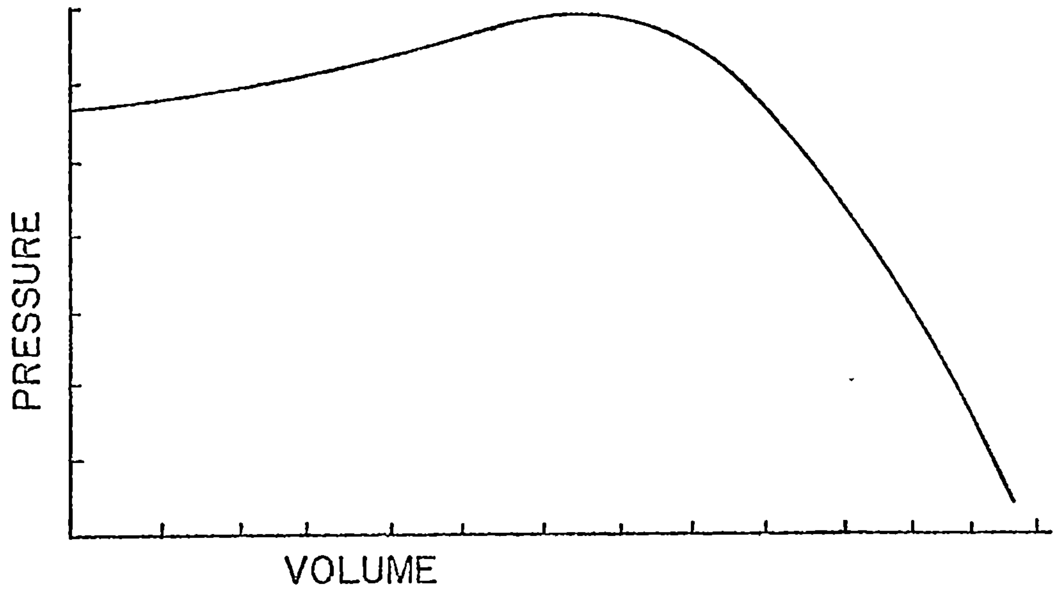

Figure 2. Representative fan characteristic curve

When the fan characteristic curve is superimposed on the ventilation system characteristic curve as shown in Figure 3, the intersection of these two curves is the point of operation and is the only point on the system at which the fan can operate. Selecting a drive that will allow fan speed to be easily changed within recommended limits is important because system pressure requirements are never exactly known.

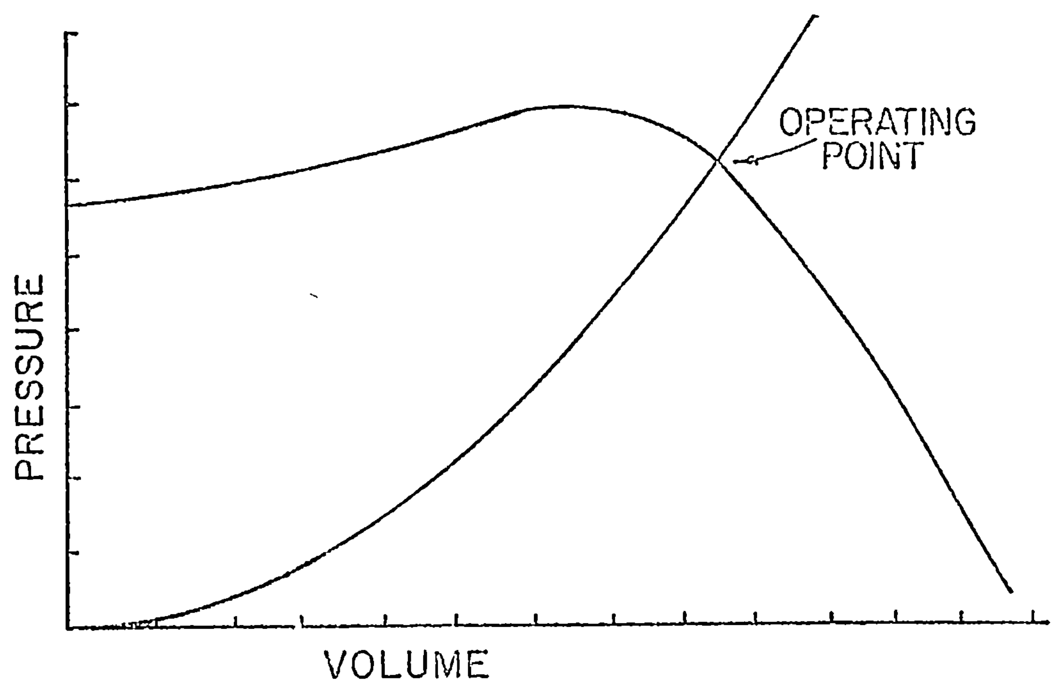

Figure 3. Operating point defined by intersection of system characteristics and fan characteristic curves.

Typical fan characteristic curves are shown in Figure 4 for a centrifugal blower (1), vane-axial fan (2), and propeller fan (3). The curves indicate that as static pressures increase, the volume flow rates decrease when operating to the right of the maximum points (denoted as A in Figure 4). The peak pressure of a fan characteristic curve corresponds to the conditions under which a specified fan will operate most efficiently. Furthermore, this point also corresponds to the operating conditions where the given fan will be the quietest. A fan should never be operated to the left of the peak pressure because the air flow across the fan blades usually becomes unsteady and may produce undesirable pressure fluctuations and noise.

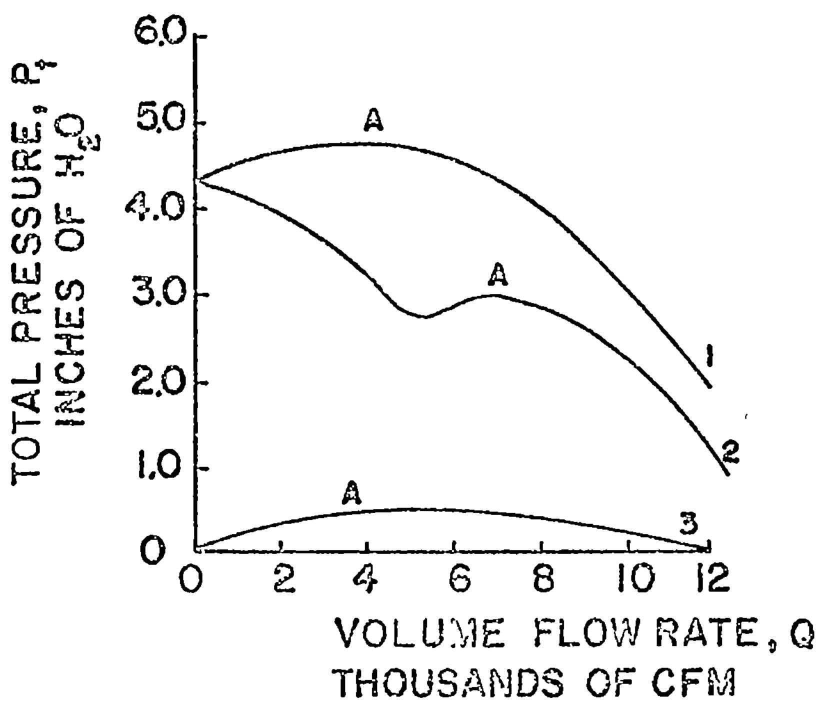

Figure 4. Characteristic curves for : centrifugal blower (1), vane-axial fan (2) and propeller fan (3). Point A corresponds to peak pressure point.

Most fan manufacturers do not supply fan characteristic curves for the fans in their sales literature. However, they do supply fan rating tables that supply the static pressure-volume relationships to the right of the peak pressure. A fan rating table is presented in Table 1 for three different fans that are capable of supplying about 10,000 cfm (cubic feet per minute) of air.

TABLE 1. Fan rating table for three fans

	Blade Dia.	Free Air	1/8" SP	1/4" SP	3/8" SP	FAN RPM	Motor HP
Fan 1	30"	10200	9200	7400	4300	640	3/4
Fan 2	36"	11700	10220	8690	7560	650	1
Fan 3	54"	29100	22300	14100	10400	385	2

Fan 1 delivers 10,200 cfm at conditions of free air. Free air means there is no static pressure. However, at 1/8 in. static pressure, the air flow rate drops to 9200 cfm and finally to 4300 cfm at 3/8 in. static pressure. Fan 2 supplies 10,200 cfm at 1/8 in. static pressure and drops to 7560 cfm at 3/8 in. static pressure. Fan 3 delivers much more than 10,000 cfm at all static pressures below 3/8 in. Only at 3/8 in. static pressure does Fan 3 deliver 10,400 cfm. If you are selecting a fan to deliver 10,000 cfm for greenhouse ventilation and the expected static pressure in the greenhouse is 1/8 in. of water, then the proper choice would be Fan 2. Fan 1 could not deliver enough air at 1/8 in. static pressure and Fan 3 would deliver too much air.

Table 2 presents fan rating data for two fans capable of delivering approximately 10,000 cfm at 1/8 in. static pressure. For ventilation in a greenhouse, Fan 2 would definitely be superior to Fan 1 in all respects. Fan 2 would be much more efficient because it operates close to its peak pressure whereas Fan 1 would be operating far to the right of its peak pressure. Consequently, Fan 2 would be quieter than Fan 1. Furthermore, Fan 1 would be more expensive than Fan 2 because of its inherent capabilities that are not being utilized in this application.

TABLE 2. Fan rating table for two fans

	Free Air	1/8" SP	1/4" SP	3/8" SP	3/4" SP	1" SP	2" SP	3" SP	FAN RPM	MOTOR HP
Fan 1	----	10380	10230	10080	9570	9210	7620	5520	1048	3
Fan 2	11700	10220	8690	7560	--	--	--	--	650	1

Whenever selecting a specific brand of fans, make sure the fan manufacturer tests and rates the fans according to AMCA standards. Otherwise, the performance characteristics supplied with a fan may not be dependable. All reputable fan manufacturers rate their fans in accordance with AMCA standards.

Fan Inspection and Maintenance

Scheduled inspection of fans is recommended. Items checked should include:

(1) bearings for over heating (lubricate or replace as required).

(2) belt drives for proper tension to prevent slipping.

(3) fan wheel for proper rotation,

(4) dust accumulations on fan blades, housings, and shutters,

(5) weeds and shrubs growing outside the greenhouse that block the fans.

Accumulations on a fan will cause vibrations that can normally be detected when bearings are checked. Dust accumulations must be removed from fans, housings, and shutters on a regular basis to maintain balance of the impeller to prevent excessive vibrations and to move air efficiently. When an impeller is unbalanced, the volume of air moved by the fan can easily be reduced by thirty or forty percent.

Fan rotation is often reversed with repair or alterations to wiring circuits or starters. Since fans do move a fraction of their rated capacity when running backwards, such incorrect operation often goes unnoticed in spite of the much less effective performance of the ventilation system.

Fan Motor Selection

Generally when a fan is selected for a given application according to the guidelines presented earlier, the recommended motor size is supplied by the equipment supplier. For most greenhouse applications where humidities are extremely high at times and where the air can be quite dusty at other times, it is absolutely essential that the specified motor be totally enclosed and have sealed bearings. A totally enclosed motor is required to protect the motor windings from the corrosive effects of the high humidities and dust accumulations that would shorten the service life of the motor.

It is important that the motor be properly matched to the fan. A relatively small motor will not be capable of accelerating the impeller to its intended speed, or the motor may heat up to a point where a circuit breaker will trip out or damage to the motor may occur. Too large a motor will be inefficient because of both higher initial and operating costs.

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HEATING GREENHOUSES

T. C. Skinner
D. E. Buffington*

A greenhouse has one purpose: to provide and maintain the environment that will result in optimum crop production or maximum profit. This includes an environment for work efficiency as well as for crop growth.

This publication will be limited to equipment and methods used to control or maintain desirable temperature and other environmental conditions in a greenhouse during those periods when supplemental heat is required. Obviously there are many ways this can be accomplished both from the standpoint of equipment used, types of fuel used, type of construction and management practices followed. Because each operation usually has some unique characteristics such as types of plants produced, level of quality of production strived for, type(s) of house(s) used and management procedures followed, it is important that all of these factors be considered when selecting and installing a heating system.

Greenhouse heating systems will be discussed based on the following methods of distributing the heat, heat source and fuel used. They might be described as follows:

1. Unit space heaters, either floor mounted or suspended and normally fueled with natural or bottled gas or fuel oil and using fans for heat distribution. This system requires a relatively moderate capital investment, is easy to install and provides for easy expansion of facilities. If unit air heaters are used they should be spaced and directed to blanket the entire area with heated air. (See Fig. 1)

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* Extension Agricultural Engineer and Associate Professor, respectively; Department of Agricultural Engineering, IFAS, University of Florida, Gainesville, Florida.

Something else to consider that is often ignored, either purposely or from a lack of understanding of what consequences might occur, is the use of unvented or improperly vented gas or oil fired units. These units produce CO_2 gás which is necessary for improved plant growth (check with an expert horticulturist for best levels in your house). However, other gases which are harmful to humans (carbon monoxide) and many plants (ethylene, sulphur dioxide and unburned hydrocarbons) are also a by-product of combustion. These can cause serious problems if the unit heaters' exhaust is not properly vented to the outside (Fig. 2) and if adequate intake air is not available for combustion. Normal air contains about 300 parts/million (PPM) of CO_2 while concentrations up to 2000 PPM have been used in greenhouses. This additional CO_2 should come from a commercial CO_2 generator (normally using either solid or liquid carbon dioxide), not from combustion. Also, heaters normally operate at night when the plants cannot use the CO_2 produced. Another by-product of combustion is water vapor. High nighttime concentrations of CO_2 and water vapor in a closed house with a lowered oxygen supply (combustion uses oxygen) is generally considered undesirable from the standpoint of disease control. Test kits are available to measure the levels of CO_2 in greenhouses.

To assure good air movement to the outside through the vent stack, make sure the vent pipe is of adequate size (check heating unit manufacturers' recommendations) and that it extends at least four feet above the highest point of the building (Fig. 2). Fresh air intakes sized to accomodate the burner of unit heaters (normally

6 to 8 inches in diameter) is a necessity in tight greenhouses. Also, the proximity of taller buildings or trees which might cause a down draft to greenhouse ventilation stacks or intakes should be avoided.

2. Hot water systems utilizing piping that can be perimeter, under benches, or overhead fan-forced unit heaters can be used. These require a boiler, valves and other necessary controls. However, a hot water system is simpler to install and normally requires less maintenance than a steam system. There is slower heating and cooling of pipes, but temperatures are normally more uniform. Hot water systems are mainly used in smaller ranges.

3. A steam heating system needs a boiler, valves, traps and other controls depending upon the size and type boiler used. Steam provides rapid heating and cooling of the steam lines and usually less pipe is needed. Lines may be smooth or finned, and about 1/2 of the heat should be overhead and about 2/3 along the side walls. Lines can also be arranged under benches or with overhead fan forced unit heaters. Also, a steam system allows the use of steam for soil pasteurization. A steam system requires a high initial investment; however, it has a long life expectancy. Steam heating systems are most often used in large ranges as steam can be transported long distances efficiently.

4. Unit radiant heaters using gas of the "Salamander" grove heater (return stack) and which use fuel oil may be used for frost protection (Fig. 3). These are not recommended for routine greenhouse heating because they are not thermostatically controlled; therefore, control of temperature and combustion products is difficult. They are economical for providing minimum levels of environment control

in Southern portions of Florida but demand close attention when in operation.

5. Solar energy research for heating greenhouses is currently going on by university researchers, but at present the initial cost of a quality system is very high compared to other systems described (Fig. 4).

6. Poly-tube or fan-jet systems are frequently used to provide more uniform heat distribution, air movement and ventilation in greenhouses using any of the above heat source systems. However, they are most frequently installed in conjunction with unit heaters. (Fig. 5) The velocity of air discharged from openings in the tube should not exceed 1200 to 1800 feet per minute (fpm). The volume of the openings (total) should be 15-20 times the cross-sectional area of the tube.

As indicated earlier, a dependable source of heat is necessary for temperature control. The best type of system will depend on many factors, many of which have already been mentioned. These factors should be carefully considered before investing in the heating equipment, and -- what is best for one operator may not be best for another.

Before determining the type system to use, it is necessary to calculate the amount of heat that will be required. Remember this should be based on the most adverse conditions that you reasonably expect to encounter. Normally in the central part of Florida an outside low is 25 to 30°F, about 15-20°F in North Florida, and around 35°F in South Florida. The minimum inside temperature will depend upon the type or types of plants being grown. Some tropicals cease to grow at 55-60°F, and the plants are killed at about 45°F. Decide whether you just want to save the plants from severe injury or if you want normal or near normal growth to continue. Then determine the temperature needed to achieve your objective, subtract the expected minimum adverse temperature for your location, and obtain the differential in °F for which you need to be prepared.

An easy and fairly accurate method for estimating the amount of heat required can be obtained by multiplying the surface area of the greenhouse by the maximum temperature difference to be maintained, and this product times a heat transmission factor that depends on the covering of the greenhouse and is also influenced by quality of construction. A factor of 1.0 to 1.2 is used if the house is covered by a single layer of polyethylene film (PE) or rigid plastic. 1.0 would assume a well built, tight greenhouse while 1.2 would assume a little less quality construction and more air leakage. The same analogy will be true for the transmission factors used for other materials. Also, wind velocity affects the transmission factor; the higher the wind velocity, the greater the heat loss. Use a factor of 0.75 to 0.8 if the house is covered with a double layer of PE film with an air space of at least 3/4" but not more than 4". Use a factor of between 1.1 to 1.4 if the house is glass glazed. Add 10% to the values obtained if the house is located in a windy location and there are many leaks for air infiltration.

For example, a 30' x 120' gable greenhouse with 6' side walls will have about 5750 square feet of surface area through which heat can move. If this house were covered with rigid plastic and a 40°F temperature difference were to be maintained (65°F at an outside low of 25°F), the heating system would have to supply 5750 x 40 x 1.2 - 276,000 BTU per hour. Now, if this house were very tightly constructed and fairly large panels were used, and the house were protected by a wind break of some kind, then you might be able to use a lower heat transmission factor of about 1.0. Then the heating input required would be 5750 x 40 x 1.0 = 230,000 BTU/hr. (It should be noted that the "heat transmission factors" used take into consideration factors such as air infiltration and wind effects, which means that the term as defined herein does not conform to the strict definition of heat transfer coefficient.) This BTU/hr. figure can be used to determine pipe length in steam and hot water systems or the size of unit heaters. If a central boiler is used, add at least 25 percent to determine boiler size to allow for heat losses in the distribution system. One boiler horsepower equals a heat output of about 33,500 BTU/hr.

Another factor to consider is the efficiency of the heating unit. Most manufacturers of heating equipment show both input and output BTU/hr. Calculations on equipment size should be based on output capacity.

The choice of fuel for heating is often a problem of economics, but in the future availability may be equally or more of a consideration. At the present time, however, the fuel that will provide a dependable source of heat at the lowest cost is generally the one to use (Fig. 6).

In conclusion, the successful heating of greenhouses is dependent upon correct sizing and installation of the heating system, proper controls and methods of obtaining uniform heat distribution. The type of greenhouse construction, crops to be grown, temperature levels to be maintained are all important factors to consider in the selection and design of any greenhouse heating system. For these and other reasons only persons thoroughly familiar with greenhouse heating systems and their application to your specific requirements should be allowed to design and supervise the installation of your heating system.

In general the following recommendations should be observed:

1. The heating system should allow for easy expansion of the range in the future, and the system should have sufficient capacity to offset the heat loss from the greenhouse under the most severe conditions. Normally, design

for temperatures slightly above minimum 15 to 25 year lows as shown by local weather records.

2. Provide an adequate system of automatic controls or be prepared for extensive manual control during severe weather. The most important control in most heating systems is the thermostat which is used to control the operation of the heating system. For this reason the thermostat should be placed at plant level, shielded from direct rays of the sun, and sense "line air". Sensing "line air" is accomplished by placing the thermostat in a small box or enclosure ventilated by a very small capacity fan. Thermostats for greenhouses should be sensitive to within at least 2 - 3°F. To be sure of this degree of accuracy, they must be calibrated against a dependable thermostat several times a year. An inexpensive maximum-minimum recording thermometer can easily provide a check on the accuracy of the thermostatic control and is well worth the investment. It is not enough to have good control over the heating system. An operator must know what degree of temperature control is necessary for the type of plants being produced. If flowering crops, for example, are being grown, <u>their</u> flowering is usually timed for a certain holiday season. Temperature control can be essential to the success or failure in this kind of operation.

3. If possible, select a heating system that will allow you to convert from one fuel source to another.

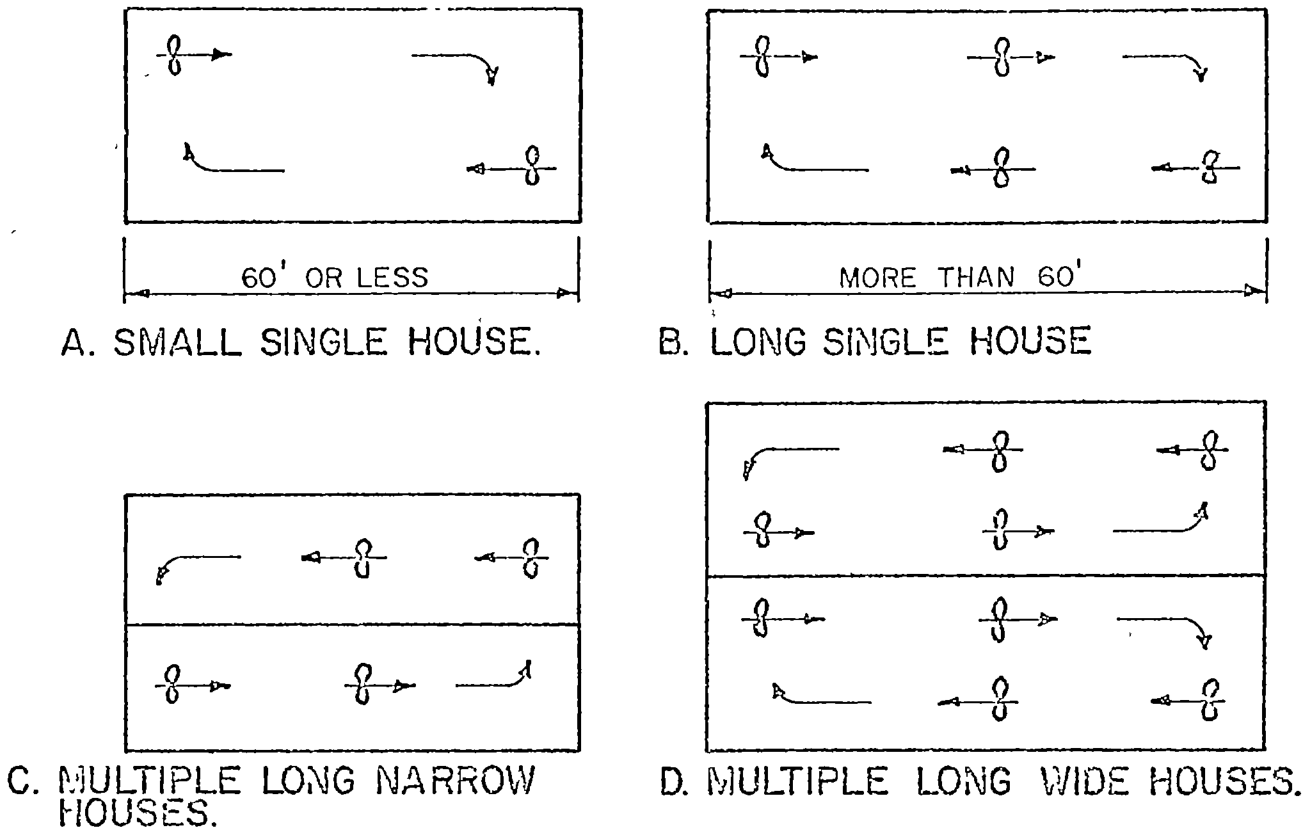


FIG. I TYPICAL ARRANGEMENTS FOR FANS FOR HORIZONTAL CONVECTION AIR CIRCULATION SYSTEMS.

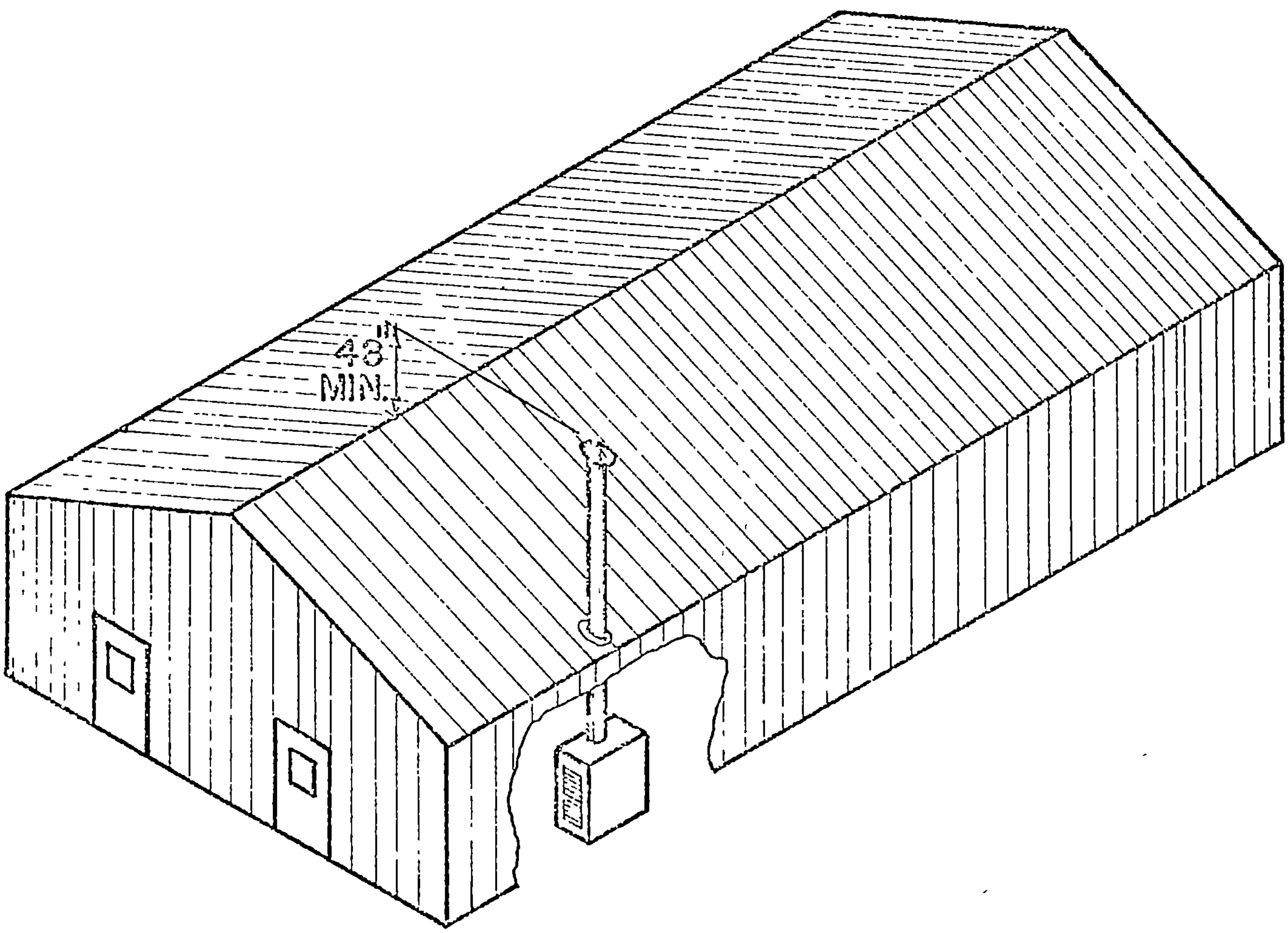


FIG. 2 ALL GREENHOUSE HEATING UNITS SHOULD BE VENTED TO THE OUTSIDE. TOP OF VENT STACK SHOULD BE AT LEAST 48" ABOVE THE ROOF PEAK.

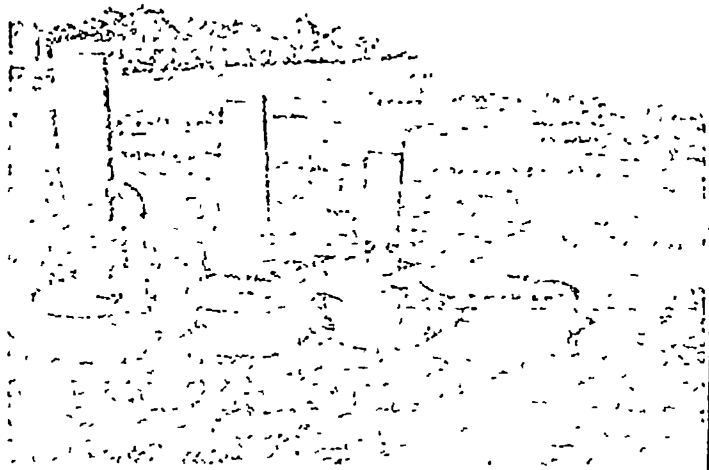


FIG. 3 - THE TYPE RADIANT HEATERS SHOWN ABOVE ARE NOT RECOMMENDED FOR GREENHOUSE HEATING.

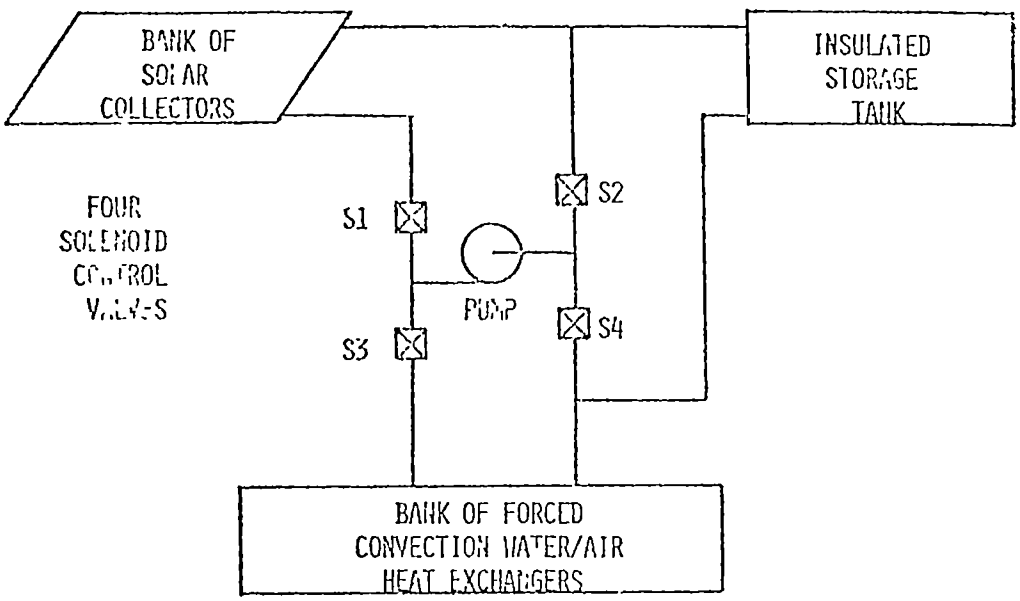
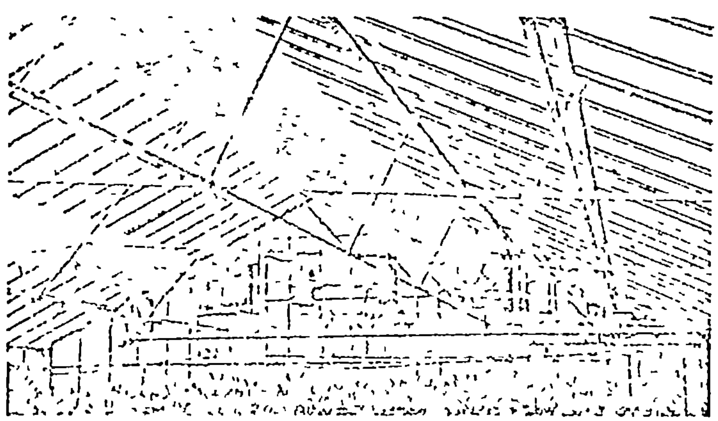
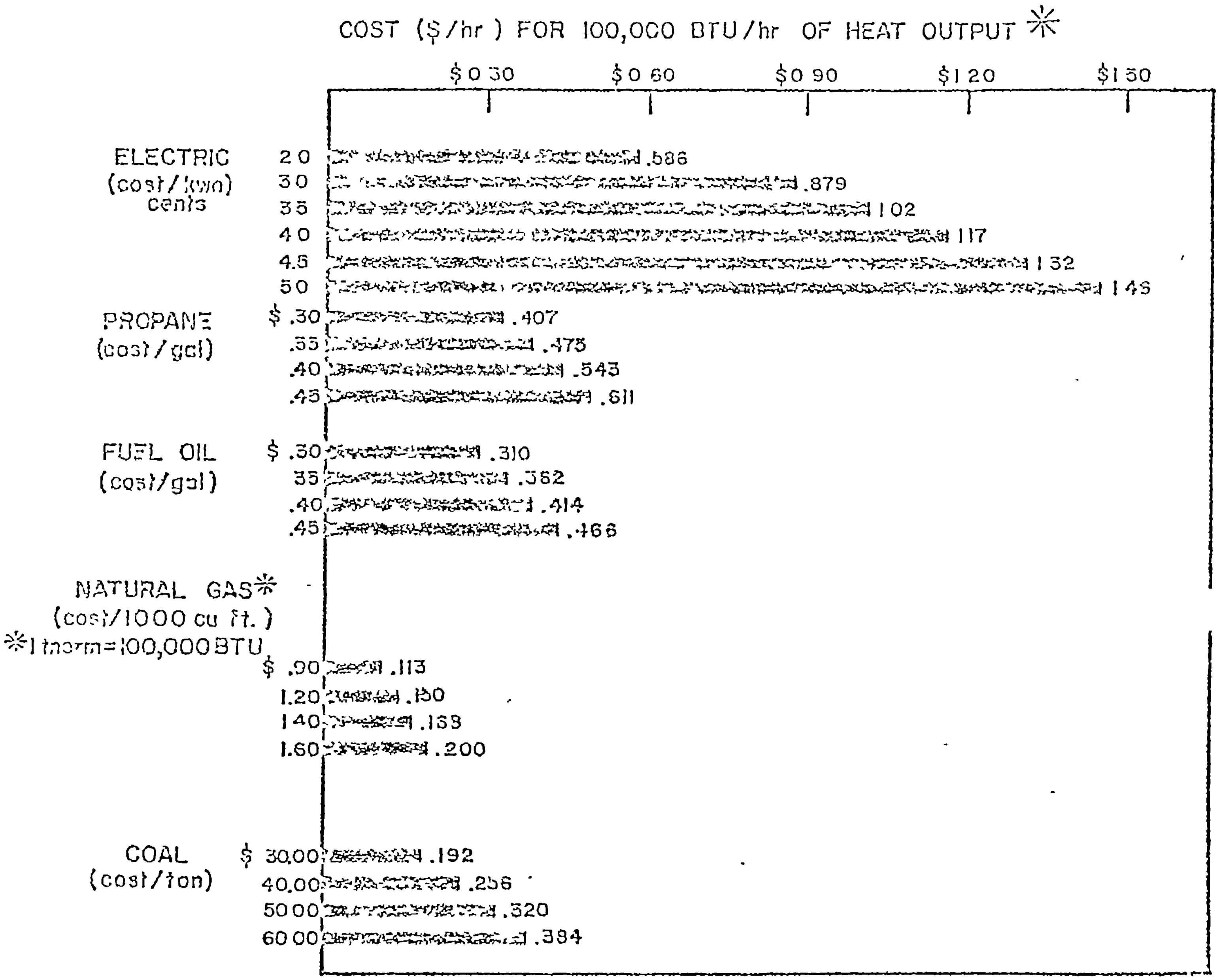


FIGURE 4 SCHEMATIC DIAGRAM OF BRADENTON GREENHOUSE SOLAR HEATING SYSTEM



VIEWS OF FAN JET SYSTEMS WITH HEAT-KITS AND UNIT HEATERS

FIG. 5



*FUEL HEAT VALUES AND COMBUSTION EFFICIENCIES ARE AS FOLLOWS:

FUEL	ESTIMATED EFFICIENCY PERCENT	HEAT VALUE (BTU PER UNIT)
COAL (BITUMINOUS)	60	13,000 BTU/lb.
NATURAL GAS	80	1,000 BTU/cu. ft.
PROPANE	80	92,000 BTU/gal.
FUEL OIL, NO. 2	70	138,000 BTU/gal.
ELECTRICITY	100	3,413 BTU/kw. hr.

COMPARISON OF FUEL COSTS FOR EQUIVALENT HEAT PRODUCTION

FIG. 6

WINTER VENTILATION AND HEATING REQUIREMENTS OF GREENHOUSES FOR CONDENSATION CONTROL[1]

D.E. Buffington and T.C. Skinner

University of Florida, Agricultural Engineering Department
Gainesville, Florida 32611

and

B.A. Barmby

Orange County Extension Agent III
Orlando, Florida

Introduction

Condensation forming on the inside surfaces of greenhouses is of considerable economic significance. Economic problems associated with condensation in greenhouses are fungus diseases; difficulty in maintaining a clean greenhouse; more rapid deterioration of structural components; and damp, uncomfortable environmental conditions for the workers. Furthermore, the presence of condensation is considered to be unsightly and a nuisance to some greenhouse managers.

Condensation occurs when warm, moist air in a greenhouse comes in contact with a cold surface such as glass, fiberglass, plastic, or structural members. The air in contact with the cold surface is cooled to the temperature of the surface. If the surface temperature is below the dew point temperature of the air, then the water vapor in the air will condense onto the surface. For example, condensation will occur if air in a greenhouse at 70^{o}F and 70% relative humidity comes in contact with a surface that is 60^{o}F or colder.

Most of the condensation problems in greenhouses occur when the minimum outside temperatures drop below 50^{o}F. This occurs between the months of November and March, except for unusual environmental circumstances. Condensation will form the heaviest in greenhouses during the period from sundown to several hours after sunrise. During the daylight hours, there is sufficient heating in the greenhouses from solar radiation to minimize or eliminate condensation from occurring except on very cold, cloudy days. The time when greenhouses are most likely to experience heavy condensation is sunrise or shortly before. At this time, the outdoor air temperature is usually at a minimum.

[1]Authors gratefully acknowledge the cooperation and assistance of Mr. Lamont Marchman, Evergreen Gardens of Apopka, Inc., Apopka, Florida.

Four general methods exist for controlling condensation: 1) exhausting moist air and replacing it with heated, outside air; 2) providing continuous air movement; 3) applying double layer covering; and 4) using a wetting agent. Of these four methods, only exhausting moist air and replacing it with heated outside air is really effective in eliminating condensation. The other methods reduce and minimize the amount of condensation that may occur, but are not solutions in themselves to eliminating condensation formation. This publication deals with ventilation and heating requirements of greenhouses to prevent condensation formation.

Materials and Methods

Environmental conditions were recorded inside and outside a large, double-vaulted commercial greenhouse in Apopka, Florida, during two consecutive cold seasons in 1973 and 1974. Inside surface temperatures, bed temperatures, and air temperatures were measured with copper-constantan thermocouples at 16 locations. These measurements were recorded on a thermocouple recorder. Inside and outside air temperatures and relative humidities were measured and recorded with hygrothermographs.

Results and Discussion

The nine inside surface temperatures that were recorded at the time of the minimum temperature of the day were averaged to obtain the mean inside surface temperature. Based on the measured data points obtained during the two cold seasons, the mean inside surface temperature was found to be simply the average of the inside and outside air temperatures, within $2^{o}F$. This result appears to be reasonable when one considers that the fiberglass material, about 1/32 in. thick, has essentially no thermal resistance. The only resistance to heat flow is that offered by the inside and outside air films. These two air films would have approximately the same thermal resistance at the time of the minimum temperature of the day, because then the outdoor air is usually very still.

Having established the relationship between inside surface temperature and inside and outside air temperatures, the minimum ventilation requirement to prevent condensation can be calculated. The calculated ventilation rates for the stated inside and outside air temperatures in columns 1 and 2 are presented in column 3 of Table 1. To greatly increase the application of the calculated values for ventilation and heating to maintain desired conditions, the rates are expressed per unit of greenhouse bed area. Ventilation is expressed in units of cfm (cubic feet of air per minute) per square foot of actual bed area of the greenhouse.

The ventilation rate was calculated by analyzing a conservation of mass equation; that is, the moisture entering the greenhouse in the ventilation air plus the moisture produced within the greenhouse equals the moisture leaving the greenhouse in the ventilation air. In equation form, the moisture conservation balance becomes:

$$MW_o + W_{prod} = MW_i \qquad (1)$$

where:

M = mass flow rate of ventilation air, lb/(hr ft^2 bed area)

W_o = humidity ratio of outside air, grains H_2O/lb dry air

W_{prod} = moisture production rate within the greenhouse, grains H_2O/(hr ft^2 bed area)

W_i = humidity ratio of inside air, grains H_2O/lb dry air

The ventilation rate was calculated from equation (1) by first solving for M, the mass flow rate of the ventilation air. The mass flow rate or air was then converted to ventilation rate, with units of cfm per square foot of bed area, by multiplying air mass flow rate and specific volume of 13.33 ft^3/lb and dividing by 60 min/hr. The conversion factor obtained was 0.222. In order to solve equation (1) for M, the value of W_i was determined from a psychrometric chart such that the dew point temperature of the inside air mixture was 4^{o}F below the predicted inside surface temperature. By choosing W_i in such a manner incorporated a modest safety factor into the values presented in Table 1. The 4^{o}F margin also take into consideration that the surfaces of the greenhouse with an unobstructed view of the sky will be cooler than other surfaces of the greenhouse due to the radiation losses. The values of W_o and W_i can be obtained most conveniently from a psychrometric chart. The rate of moisture production by the plants and soil was estimated to be 0.00275 in. of water per hr based on calculations involving data collected in the greenhouse and on results published by Stewart and Mills (1). The resulting relative humidity for the recommended ventilation rate is presented in column 5 of Table 1. This value was also obtained from a psychrometric chart.

The heating required to prevent condensation was calculated by analyzing a conservation of energy equation; namely, the heat content (enthalpy) of the ventilation air entering the greenhouse plus the heat added by the heating equipment equals the heat content of the ventilation air leaving plus the heat lost by conduction through the exposed surface area of the greenhouse. In equation form, the total heat balance equation is:

$$Mh_o + Q_{htr} = Mh_i + Q_{cond} \qquad (2)$$

where:

M = mass flow rate of ventilation air, lb/(hr ft^2 bed area)

h_o = enthalpy of outside air, Btu/lb dry air

Table 1. Minimum ventialtion and heating rates required to prevent condensation inside fiberglass greenhouses

Outside temperature F	Inside temperature F	Ventilation[z] rate cfm	Heating[z] required Btu/hr	Resulting inside relative humidity %
10	50	1.76	92.0 + 40 S[y]	38
	55	1.48	87.8 + 45 S	36
	60	1.23	81.8 + 50 S	34
	65	1.11	82.3 + 55 S	30
20	55	1.38	68.1 + 35 S	43
	60	1.11	62.8 + 40 S	41
	65	0.97	62.7 + 45 S	38
	70	0.85	61.5 + 50 S	35
30	55	1.39	52.2 + 25 S	54
	60	1.17	53.5 + 30 S	50
	65	0.97	52.2 + 35 S	46
	70	0.85	51.1 + 40 S	43
40	55	1.71	43.3 + 15 S	65
	60	1.31	44.3 + 20 S	60
	65	1.01	42.8 + 25 S	56
	70	0.82	42.2 + 30 S	52
	75	0.67	40.8 + 35 S	48
50	60	1.71	34.7 + 10 S	73
	65	1.17	34.3 + 15 S	67
	70	0.89	34.9 + 20 S	62
	75	0.72	35.4 + 25 S	57
60	65	2.02	27.5 + 5 S	80
	70	1.23	30.1 + 10 S	74
	75	0.89	31.4 + 15 S	68
	80	0.65	30.2 + 20 S	63
70	70	2.47	11.1	88
	75	1.31	23.0 + 5 S	80
	80	0.82	24.7 + 10 S	74

[z] Ventilation rate and heating required are expressed per ft^2 of greenhouse bed area.

[y] S = exposed surface area of greenhouse, ft^2/bed area of greenhouse, ft^2.

Q_{htr} = heating rate within greenhouse, Btu/(hr ft^2 bed area)

h_i = enthalpy of inside air, Btu/lb dry air

Q_{cond} = heat lost by conduction, Btu/(hr ft^2 bed area)

The values of h_o and h_i in equation (2) can also be obtained from a psychrometric chart.

The rate of heat conduction through the exposed surface areas of the greenhouse was calculated according to:

$$Q_{cond} = S \cdot \Delta T / R \qquad (3)$$

where:

S = ratio of exposed surface area of the greenhouse to the bed area of the greenhouse

ΔT = temperature difference between inside and outside air temperatures, ^{o}F.

R = overall resistance to heat flow, hr ft^2 ^{o}F/Btu. A constant value of 1.0 (hr ft^2 ^{o}F)/Btu was used throughout this study.

Having determined the mass flow rate from equation (1), the heat loss by conduction from equation (3), and h_o and h_i from a psychrometric chart, the heating rate required to prevent condensation within the greenhouse was calculated from equation (2). The results, in terms of S, are presented in column 4 of Table 1.

The value of S generally ranges from 1.5 to 3.0 depending on the configuration of a greenhouse. A large multi-vaulted greenhouse will have a S-value closer to 1.5 or 2.0. The value of S <u>must</u> be calculated for each particular greenhouse in order to determine the total heating required to prevent condensation from Table 1.

The greenhouse that was monitored for this study was used for propagating cuttings. Consequently, most of the water produced inside the greenhouse during the early morning hours was evaporation from the bed media. In greenhouses used for growing larger plants, transpiration from the plants would produce more water within the greenhouse. Under such circumstances, the ventilation and/or heating rates may need to be increased to prevent condensation. Only experience with a particular greenhouse operation can dictate whether an increase would be necessary.

An alternative to increasing the ventilation and/or heating rates presented in Table 1 would be to add air mixing devices, such as turbulators, inside the greenhouse. A turbulator is effective in reducing thermal stratification, thereby insuring a more uniform air temperature throughout the entire greenhouse (2). Turbulators, or similar air mixing devices, would be most needed in those greenhouses having a large portion of their surface areas exposed to an unobstructed view of the sky. When a surface has an unobstructed view of the sky, its temperature will drop several degrees below ambient temperature on clear nights because of radiative cooling.

In any greenhouse, some ventilation will occur because of natural infiltration. The magnitude of the rate of natural infiltration depends on the openness of the greenhouse. The more open the greenhouse, the more infiltration will take place. However, it is most difficult to try to effectively eliminate condensation by manipulating the openness of the greenhouse, especially when desiring to control temperature and to minimize amount of heating fuel required.

To illustrate the use of the data presented in Table 1, consider the following example.

Example

The cross-section dimensions of a large, double-vaulted greenhouse are shown in Fig. 1. The greenhouse is 372 feet long. By using basic arithmetic methods, the exposed surface area is calculated for the different structural components, and then totaled as shown in Fig. 1. Note that the floor is not considered as part of the exposed surface area.

The bed area, assumed to be 75% of the total floor area, is 21,204 ft^2 (.75 x 372 x 76). Therefore, the S-value equals 1.67 (35,480 ft^2/21,204 ft^2).

Consider the case when the outside temperature is forecast to reach a low of 30^oF. Assume you desire to maintain an inside temperature of 65^oF and that you want no condensation to occur. Referring to the values presented in Table 1, the ventilation rate is 0.97 cfm per ft^2 bed area, or 20,600 cfm (0.97 x 21,204); the required heating rate is 110.65 Btu/hr ft^2 bed area (52.2 + 35 x 1.67); the total heating required is 2,345,000 Btu/hr (21,204 x 110.65); and the resulting inside relative humidity would be about 46%.

Summary

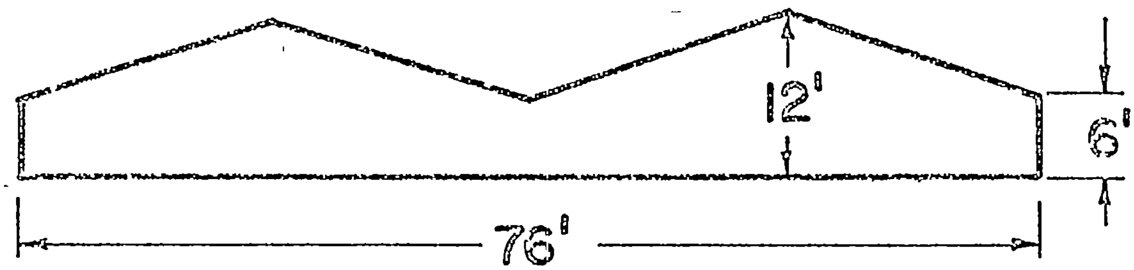
Temperature and humidity measurements were recorded inside and outside a commercial greenhouse in Apopka, Florida, during two consecutive cold seasons in 1973 and 1974.

Predictive equations were developed to determine the minimum ventilating and heating requirements to prevent condensation from forming inside the greenhouse. The equations were formulated based on the environmental conditions, ventilation rates, physical characteristics of greenhouses, and principles of heat and mass transfer. Calculations from the predictive equations are tabulated to present the ventilating and heating requirements for a wide range of inside and outside environmental conditions.

Literature Cited

1. Stewart, E. H. and W. C. Mills. 1967. Effect of depth to water table and plant density on evapo-transpiration rate in Southern Florida. Trans. of the ASAE 10(6): 746-747.

2. Walker, J. N. and G. A. Duncan. 1974. Effectiveness of recommended greenhouse air circulation systems. Trans. of the ASAE 17(2): 371-374.



SURFACE	AREA
ROOF	29,648 ft^2
SIDE WALLS	4,464 ft^2
END WALLS	1,368 ft^2

TOTAL EXPOSED SURFACE AREA=35,480 ft^2

Figure 1. Cross-section view of double-vaulted greenhouse used in the example.

GREENHOUSE VENTILATION

Dennis E. Buffington*

Greenhouse ventilation involves removing air from inside the greenhouse and replacing it with outside air. The ventilation may be: (1) natural - caused by wind and temperature forces, or (2) mechanical ventilation - ventilation accomplished by using fans. The purposes for ventilation are to control high temperatures during the summer caused by the influx of solar radiation, to maintain relative humidity at acceptable levels during winter, and to provide uniform air flow throughout the entire greenhouse.

Ventilation systems for greenhouses must be considered for three different periods of the year--winter, spring-fall, and summer.

Winter Ventilation

A heating system with adequate capacity is needed in the winter to maintain environmental conditions inside the greenhouse conducive for plant growth and development. Even during the coldest part of the winter, when the heating system is running at full capacity, some ventilation is still required in the greenhouse. Fresh, outside air must be ventilated into the greenhouse in order to remove the warm, moisture-laden air from within the greenhouse. If the moist air within the greenhouse is not removed, high humidities and excessive condensations will occur. Studies have shown that humidities over 90% foster rapid development of leaf mold and fruit and stem rot. Infection of leaf mold on tomatoes actually occurs at humidities above 80%, but below 70%, problems with infection are slight. Economic problems associated with condensation in greenhouses are fungus diseases, difficulty in maintaining a clean greenhouse, more rapid deterioration of structural components, and damp, uncomfortable environmental conditions for the workers.

Condensation occurs when warm, high humidity air in the greenhouse comes into contact with a cold surface, such as glass, fiberglass, plastic or structural members. The air in contact with the cold surface is cooled to the temperature of the surface. If the surface temperature is below the dew point temperature of the air, then the water vapor in the air will condense onto the surface.

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*Associate Professor, Department of Agricultural Engineering, IFAS, University of Florida, Gainesville, Florida.

For example, condensation will occur if air in a greenhouse at 70°F and 70% relative humidity comes in contact with a surface that is 60°F or colder.

Exhausting moist air and replacing it with heated, outside air is effective in eliminating condensation and other problems resulting from high humidities. Whenever ventilation rates are increased in the winter, the heating requirements also increase. Consequently, it is necessary to determine a ventilation rate to maintain humidities below the damaging level and, at the same time, to keep the heating requirements as low as possible.

Ventilation requirements of greenhouses in winter are generally on the order of two to three air changes per hour. The higher the inside temperature is maintained in the greenhouse, the lower the air exchange rate that is required to maintain humidities below the damaging level. However, in no circumstances should a ventilation rate of less than two air changes per hour be used. In addition to humidity control, this minimum ventilation rate is required to remove any gases of combustion that may be present as a result of leakages around the heating and ducting system. Figure 2 presents the heating requirements of a greenhouse as shown schematically in Figure 1 for two different temperatures. The heating requirement when the greenhouse is maintained at 60°F is about 20% less than the heating required to maintain 70°F. At 60°F, however, the ventilation rate necessary to maintain humidities at a reasonable level is three air changes per hour. Figures 3 and 4, respectively, show the inside relative humidities that would result as a function of the different winter rates for 60°F and 70°F. Obviously, there is no benefit whatsoever in ventilating above four air changes per hour in the winter. The result will be excessive heating requirements and perhaps some damage to the plants because of low relative humidity.

Summer Ventilation

The only purpose of a ventilation system in a greenhouse in the summer is to prevent the air temperature inside the greenhouse from rising too high above the outside air temperature. The reason for the higher air temperature inside the greenhouse is because of the large influx of solar radiation through the greenhouse glazing material. The ventilation system must effectively move air directly through the crop and over the soil in order to prevent excessive temperature buildups around the plants. A generally accepted minimum ventilation rate for temperature control in the summer is one air change per minute. The resulting temperature rises (inside temperature-outside temperature) for the greenhouse shown in Figure 1 are presented in Figure 5 for ventilation rates ranging from one air change every three minutes to three air changes per minute. As ventilation rates increase, the temperature difference between inside and outside air decreases. The disadvantage of an increased ventilation rate is, however, the increased cost for the fans and accessories as well as increased operating costs. Regardless of how high the ventilation rate in a greenhouse is in the summer, the inside air temperature will never be as low as the outside air temperature. If one is interested in maintaining an inside air temperature below outside air temperature, then evaporative cooling or some other means of conditioning the air must be used.

Spring-Fall Ventilation Rates

The recommended ventilation rates for the spring-fall seasonal period will be somewhere between the ventilation rates required for temperature control during the summer and the ventilation rates required for humidity control during winter. The spring-fall period is characterized by some periods that are relatively cool while other periods may have great intensities of solar radiation. No special provisions are necessary for maintaining ventilation rates during this period except for the thermostatic controls which will determine the amount of ventilation necessary.

Determining Ventilation Volume Rates

In the preceding discussion, ventilation rates were expressed as a minimum ventilation rate of two air changes per hour during the wintertime, and a minimum summertime ventilation rate of one air change per minute. In order to select fans as part of a ventilation system, one must know the total volume of air to be moved by the ventilation system. Volume of air to be moved is calculated from air changes per hour or minute. An air change (ac) is equivalent to the volume of the greenhouse. For example, the greenhouse indicated in Figure 1 has a volume of 254,448 ft^3. Therefore, one air change per minute would correspond to a ventilation flow rate of 254,448 cfm (cubic feet per minute). For the winter situation, when the minimum ventilation rate is stated as two air changes per hour, the volume flow rate of air would then be 508,896 cfh. (254,448 ft^3/ac X 2 ac/hr.) Dividing the previous answer by 60 then yields an air flow rate of 8,481 cfm.

The volume of a specific greenhouse is calculated as the product of the area of one end wall times the length of the greenhouse. In the example in Figure 1, one end wall area of the greenhouse is 684 ft^2. The length is 372 ft. The product, 684 ft^2 times 372 ft, equals 254,448 ft^3. To calculate the area of an end wall of a greenhouse, the following relationships may be helpful:

1. Area of a rectangle is base times height.
2. Area of a triangle is base times height, divided by 2.

When selecting fans, only those fans rated in accordance with AMCA (Air Moving and Conditioning Association) standards should be used. This rating specifies the volume fan capacity against static pressure resistance to air flow measured in inches of water pressure. For most greenhouse ventilation, the fans should move the desired air volume rate against a static pressure of 1/8 inch water. In applications involving some of the newer pad materials in evaporative cooling systems, be sure to check with the manufacturer for the static resistances to be expected in such systems.

Topics on fan selection, testing, noise, maintenance and care are presented in the handout entitled "Fans for Greenhouses."

Natural Ventilation

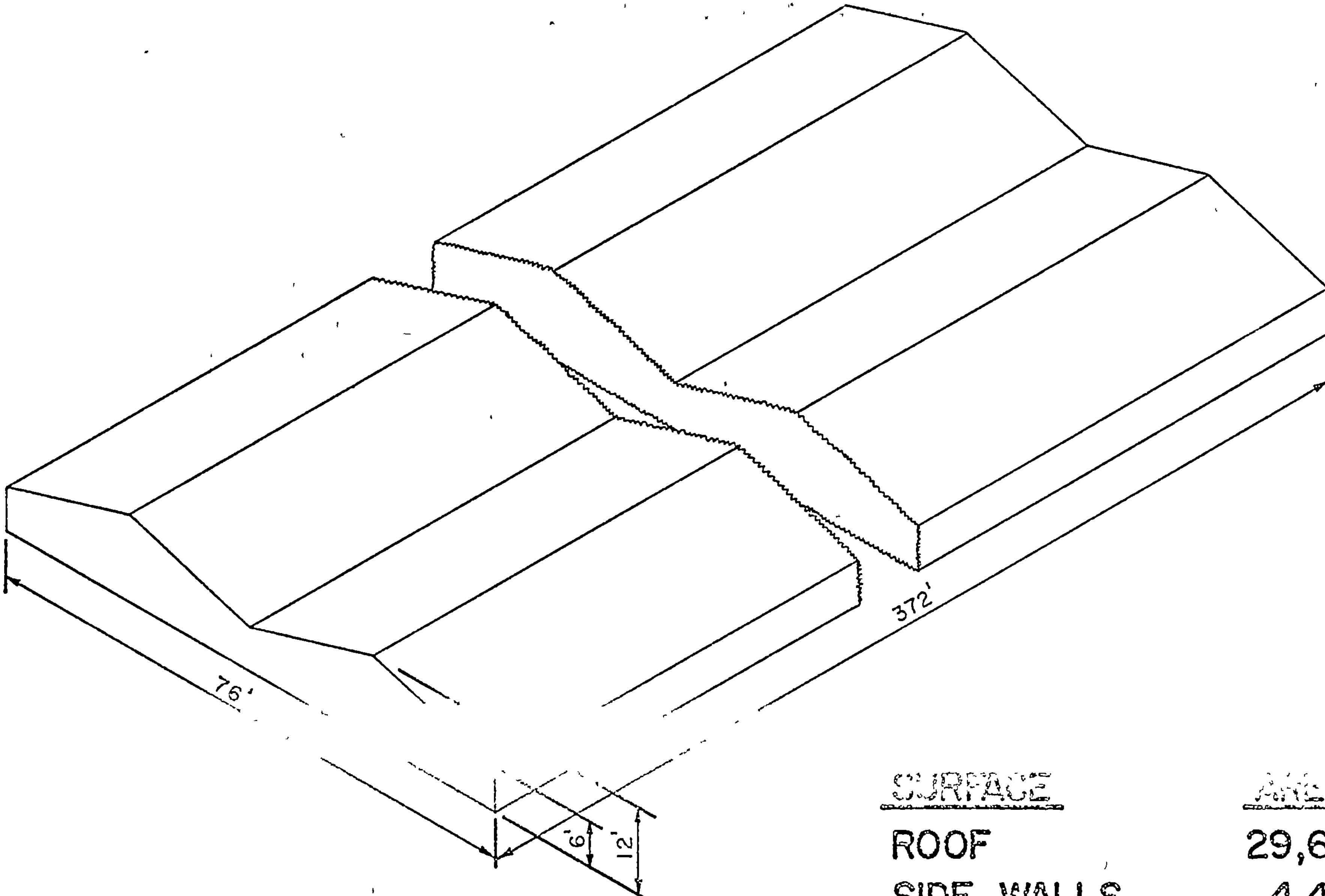
Many older greenhouses depend upon natural ventilation for the movement of air. However, with increased concern about the high cost of energy required to operate greenhouses today, increased emphasis is again being placed on natural ventilation systems for greenhouses. In greenhouses employing natural ventilation systems, sidewall vents and ridge vents continuous for the full length of the building can be opened to whatever amount is desired to allow air to move through the house. In order to vent a house satisfactorily, the house must have both sidewall and ridge vents. If a house has only side vents, than it can only be vented during periods of wind movement outside. Using ridge vents and side vents permits the greenhouse to be vented by both wind pressure and themal gradients. Thermal gradients generally are created within the greenhouse by the solar energy heating the materials inside, which in turn, heat the air. As air is heated, it becomes lighter and rises through the ridge vents, with the makeup air coming from outside through the sidewall vents. If sidewall and ridge vents are adequately sized, quite satisfactory ventilation rates can be achieved with some temperature control.

A natural ventilation system will not be nearly as dependable or satisfactory as one equipped with a mechanical ventilation system. Also, there will be problems of uneven air distribution in even the best designed natural ventilation system in a greenhouse. The only real advantage of a natural ventilation system is that it does not have any electrical operating expenses as would be encountered with mechanical ventilation systems. As the cost of energy increases, this advantage becomes more important.

Air Distribution Within Greenhouses

Air movement is important to plant growth within greenhouses. Though the optimum air velocity has never been thoroughly investigated, it is suggested that a minimum velocity of 40 feet per minute should be provided. Below this level air flow is unpredictable, and mixing throughout the greenhouse area will not be achieved. A velocity of 40 feet per minute will cause slight leaf movement with plants having long branched leaves. Fans are generally necessary to provide this level of positive air movement. Continuous positive air movement within greehouses is highly desirable since it equalizes temperature, carbon dioxide and humidity conditions within the greenhouse. Through improved conditions, healthier plant growth can be obtained and problems with disease associated with high humidity lessened. Since high temperatures are reduced in the upper portions of the house, air circulation may reduce heating costs to some limited extent.

For effective air circulation a mechanical ventilation system is necessary. A horizontal convection system, where all the air in the house is moved in a horizontal, circular pattern, is recommended. Such a system is simple in concept and easily installed. A perforated polyethylene sleeve system or sidewall ventilation-recirculation system is also satisfactory. Both of these systems are more difficult to install properly, but when correctly installed and balanced, they are quite effective in developing uniform and desirable air circulation patterns. These systems have the advantage that the system can effectively be used for heat distribution as well as air circulation. The perforated sleeve system is also widely used for the introduction of ventilation air in the winter.



SURFACE	AREA
ROOF	29,648 ft^2
SIDE WALLS	4,464 ft^2
END WALLS	1,368 ft^2

Figure 1.

TOTAL VOLUME = 254,448 ft^3

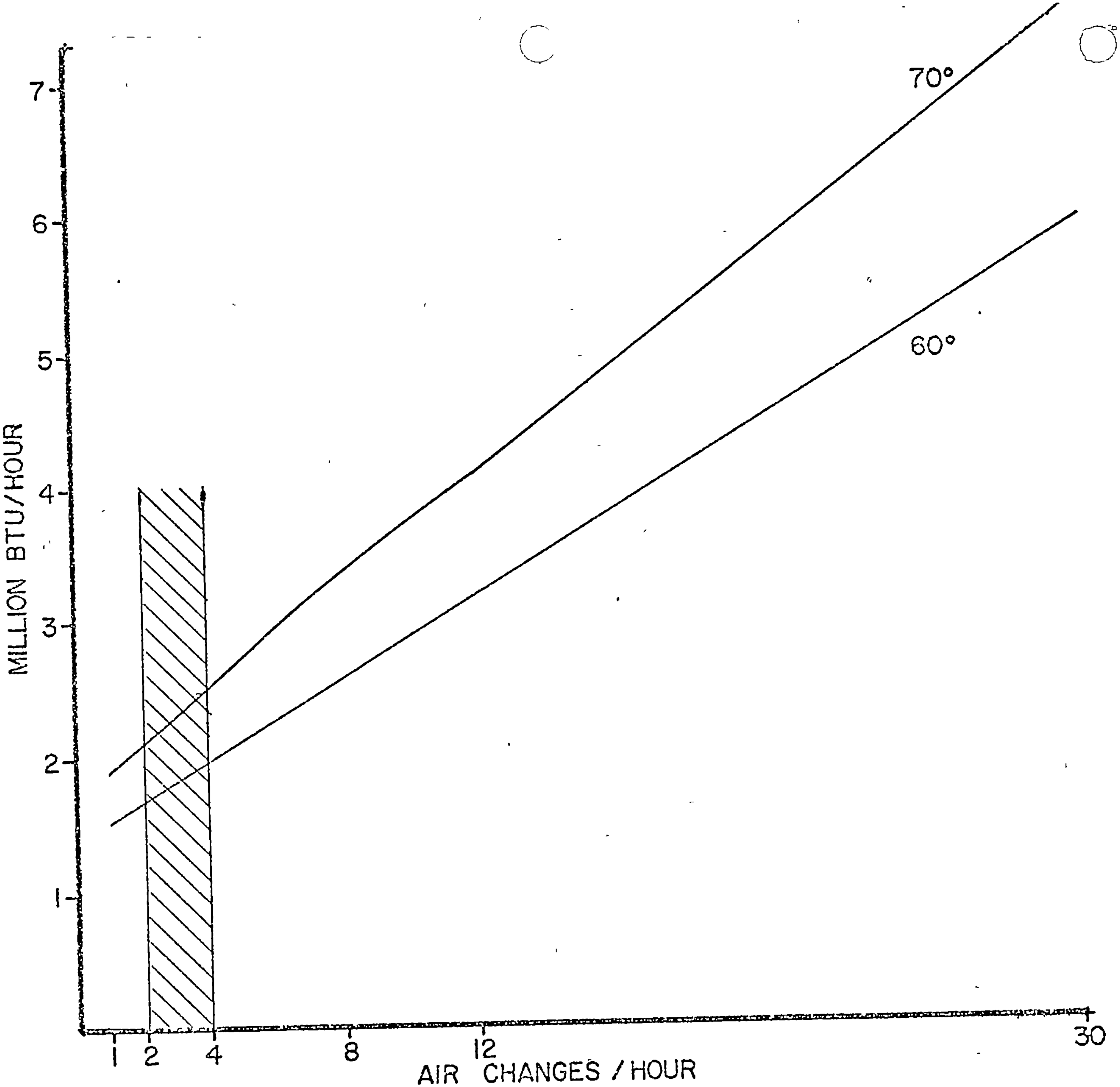
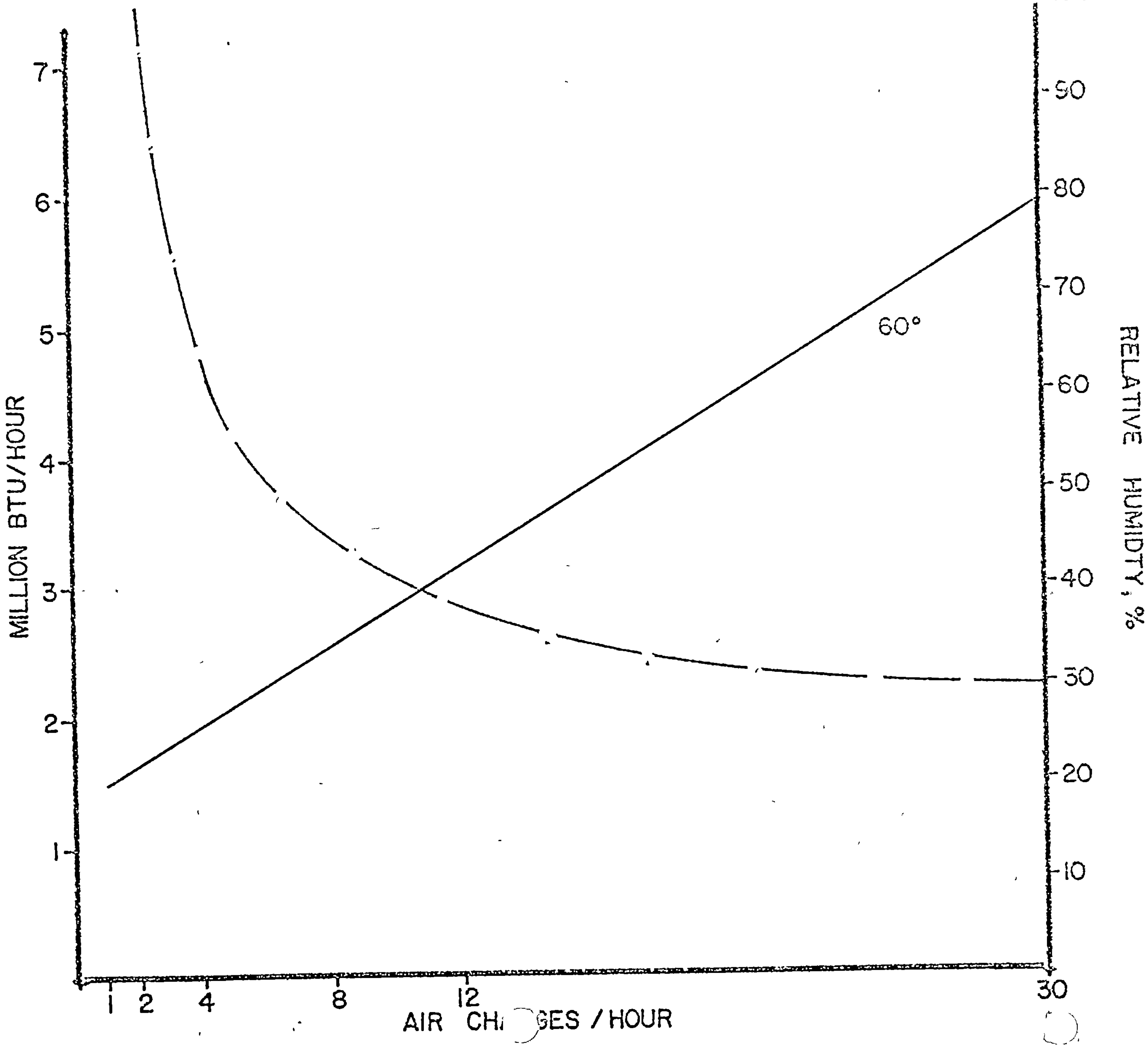
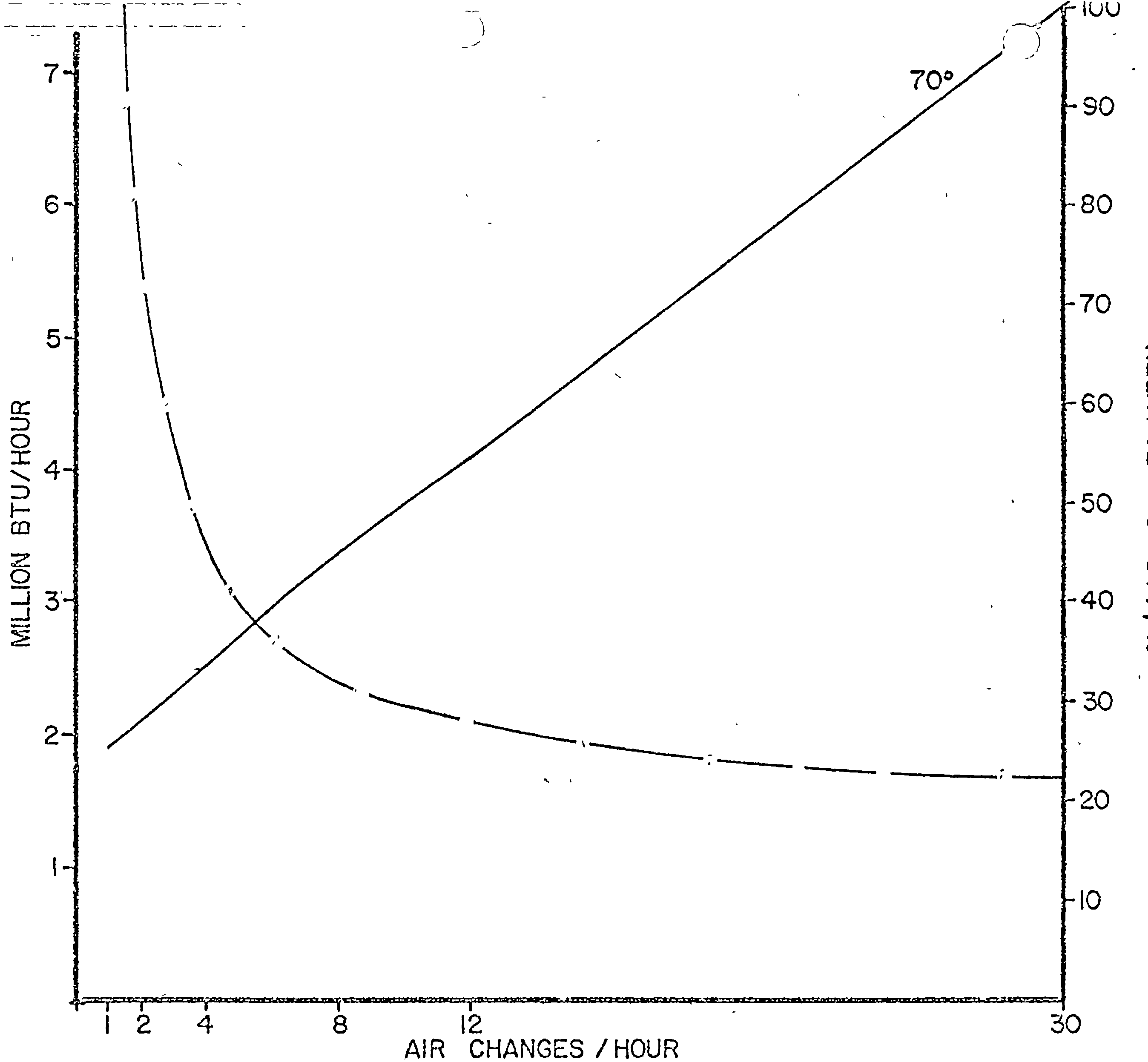


Figure 2.



MILLION BTU/HOUR
7
6
5
4
3
2
1
RELATIVE HUMIDTY, %
90
80
70
60
50
40
30
20
10
60°
1
2
4
8
12
30
AIR CH GES / HOUR

Figure 3.



70°
MILLION BTU/HOUR
AIR CHANGES / HOUR
1
2
3
4
5
6
7
1 2 4 8 12 30
10
20
30
40
50
60
70
80
90
100

Figure 4.

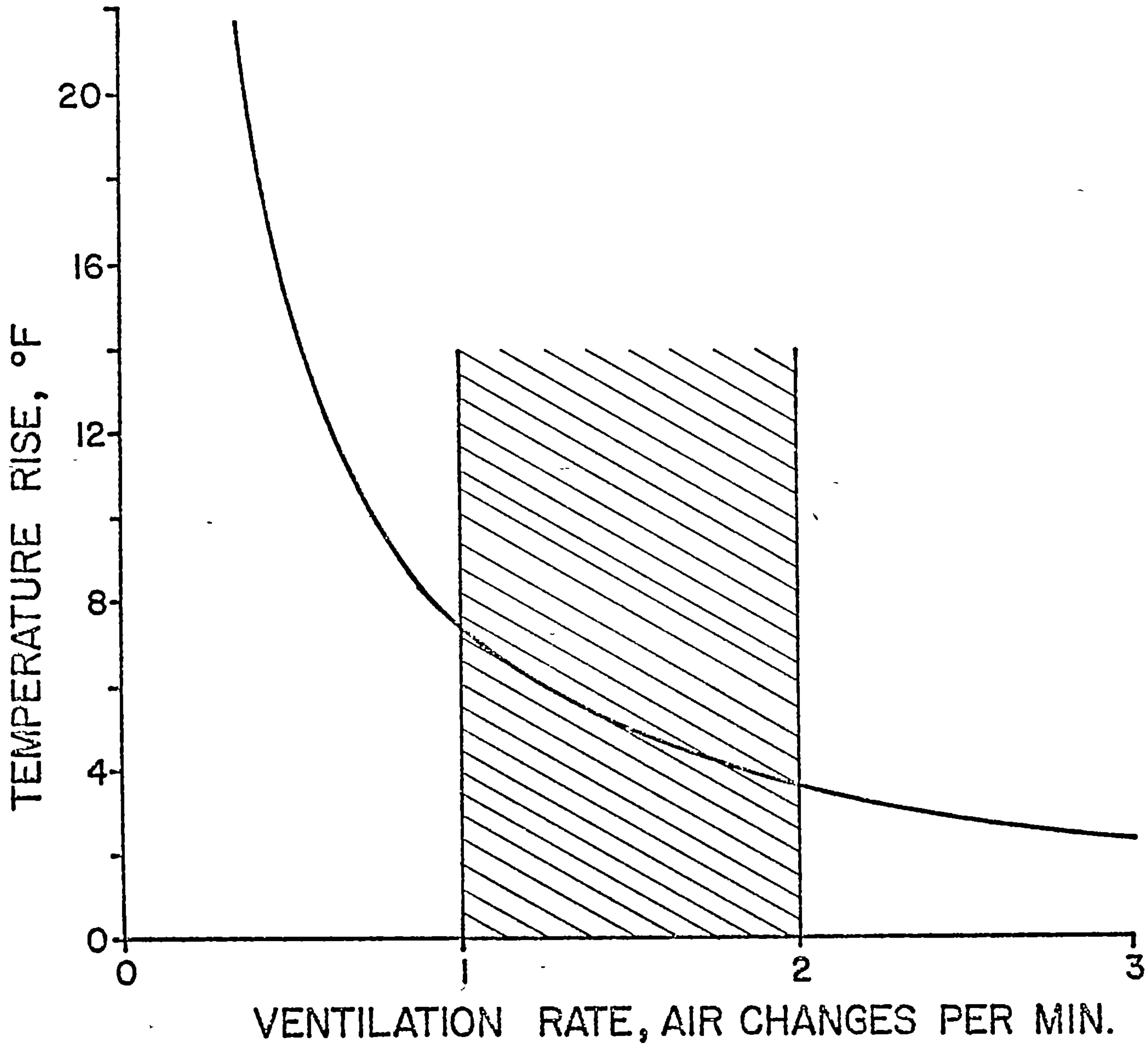

20
16
12
8
4
0
TEMPERATURE RISE, °F
0
1
2
3
VENTILATION RATE, AIR CHANGES PER MIN.

Figure 5.

SOIL, MIXES

AND

FERTILIZATION

SOIL MIXTURES FOR CONTAINER-GROWN NURSERY STOCK

E.W. McElwee & C.A. Conover

Good soil mixtures for container grown nursery stock have similar physical and chemical properties. When these properties are absent or limited, special attention and usually a higher cost will be required to produce good plants. In fact, the soil mixture can so increase problems and costs as to make it difficult to produce plants economically under a given cultural system.

An ideal soil, according to authorities, is one composed of 25% water, 25% air, 45% mineral material and 5% organic matter. These percentages can be used, particularly amount of water and air, as guides for formulating and judging a soil mixture for container nursery stock. Soil mixtures containing more than 50% sand dry out rapidly and growers have to add peat and other organic materials to increase the water-holding and nutrient-holding capacities of mixtures. Many soil mixtures used in Florida nurseries contain, by volume, 50% sand and 50% organic matter of some type. These proportions result in a mixture that is approximately, by weight, 80% sand and 20% organic matter, which seem to be satisfactory for most nursery stock grown in Florida, provided the right sand and organic materials are used.

SOIL MIXTURE

Soil mixtures function in a number of ways but certain factors must be present to reduce problems nurserymen will have in growing plants in containers and to maximize profits. Important physical characteristics include pore space (aeration), water-holding capacity, available water and weight. These factors interact to affect the air-water ratio that is so necessary for good plant growth. Heavy mixtures affect shipping costs, but are sometimes necessary to support plants - to prevent conatiners from turning over. Chemical factors are equal in importance to physical characteristics, and include; nutrient-holding capacity (technically cation exchange capacity), the ratio or amount of woody, fiberous, decomposable material to available nitrogen (technically, the carbon/nitrogen or C/N ratio), rate or organic matter decomposition, pH and soluble salt level. Therefore all physical and chemical properties must be considered and adjusted to economically produce high quality nursery stock.

SOIL AERATION

Particle size and the relation of materials of different sizes in a soil mixture play an important part in soil aeration. Coarse sands used in conjunction

(continued on next page) - - - - - - -

with a fine-textured organic matter usually result in a poor container mixture. Fine, and medium sands are desirable for soil mixtures when particle sizes range from .002 to .01 inches in diameter. Selection of the sand is a very important function in preparing a soil mixture. Coarse sands should not exceed 12% and silt or clay should make up less than 15% of the total for a good soil mixture. Inclusion of a large amount of silt or coarse sand (extremes in size) in conjunction with fine sand will result in mixtures having very poor aeration. Sand from either the surface or subsoil are acceptable since fertility of the sand is unimportant - the important characteristic is particle size. Some areas of Florida have sands that are satisfactory for container mixtures, however, in other areas it will be advisable to import builder's sand when local sands do not have acceptable particle sizes.

WATER HOLDING CAPACITY

Various organic and inorganic materials not only hold different amounts of water but different percentages of the water are available for plant growth. (See Table 1 below).

Table 1. Some chemical and physical properties of several soil amendments.

Amendments	Avg. pH	% water holding capacity*	Cation exchange capacity m.e./100g.**
Inorganic			
Calcined clays	5.5-6.5	50-75	15-25
Perlite	7.0-7.5	10-20	--
Organic			
Florida peat	4.0-6.0	100-200	20-40
Imported peat	3.5-4.5	100-200	25-50
Shavings	5.5-6.5	75-100	--
Sawdust	5.5-6.5	100-125	10-15
Shredded pine bark	4.0-4.5	100-125	15-20

*Water-holding capacity is percentage of water, based on dry weight of soil, remaining in the soil after gravitational water has drained downward.

**Cation exchange capacity (C.E.C.) is a measure of the soil's ability to hold fertilizer nutrients against leaching and is measured in milliequivalents per 100 grams of dry soil. C.E.C. readings appear low because they were determined on the standard media particle sizes without first pulverizing them.

The water-holding capacity of a soil mixture for containers must be high since water loss from the relatively small volume of soil in the container is rapid. Organic amendments hold more than their own weight of water so that, when mixed with sand and other inorganic components, the water-holding capacity of the resulting mixture will be 35 to 50 percent by volume.

Excessive use of very coarse organic materials can, in some cases, reduce total amount of water available to the plant, that is, some water may be held by organic matter against the plant's ability to absorb it or the organic material may increase pore space to the point that a limited amount of water is held in the mix. When selecting organic materials for a soil mixture, nurserymen must consider their effect on water-holding capacity, aeration (pore space) and drainage.

NUTRIENT HOLDING CAPACITY

Since the nutrient-holding capacity (cation exchange capacity) of Florida sands is very low, organic or inorganic materials must be added to soil mixtures to hold nutrients against leaching, provide a buffer capacity to prevent rapid changes in nutrient availability and act as a nutrient reservoir. However, addition of more than 50 to 60% by volume of organic matter can cause problems from the lack of leaching and build-up of soluble salts unless watering is increased at least periodically to leach excess salts from the container. Although a high nutrient-holding capacity is desirable, some thought must therefore, be given quantity of soil (millequivalent per 100 grams of soil). Heavy sandy-clay soils may therefore, have more nutrient-holding capacity than a lightweight 100% organic soil. The weight per unit of volume or bulk density of the soil mixture determines this factor. A nutrient-holding capacity (cation exchange capacity) of 5 to 10 in a sand-peat mixture is satisfactory for good plant growth while a level of 30 units may be necessary in a mixture made up primarily of light-weight peat or other organic matter to have equal total nutrient-holding capacities. Table 1 provides information on nutrient-holding capacities (cation exchange capacities) of some soil amendments.

ORGANIC AMENDMENT

When selecting organic materials for use in soil mixtures the ratio of fiberous or carbonaceous material to nitrogen in the organic matter (carbon/nitrogen ratio) must be considered.

Rapid decay of organic matter can be a problem in soil mixtures containing bark, sawdust, shavings or other similar soil amendments The rate of decomposition depends on the amount and type of organic matter and on fertilization levels, particularly the amount of available nitrogen. Mixtures high in organic matter (except peats) containing a high percent of fiberous material should be fertilized lightly and regularly with a nitrogen containing fertilizer to prevent nitrogen starvation of plants while the organic matter is decomposing. Sawdust, for instance, has a C/N ratio of about 1,000 to 1 while bark has a ratio of about 300 to 1, and decomposition of one ton of sawdust requires 24 pounds of nitrogen (N) (about 70 pounds of ammonium nitrate) while 7 pounds of nitrogen (about 20 pounds of ammonium nitrate) will decompose 1 ton of bark. Not only is extra nitrogen needed when most organic materials, except peat, are used in soil mixtures but the timing of these applications of fertilizer is important. The fertilizer should be split into several applications so that the nitrogen will not leach or be lost before microorganisms can use it in decomposing the organic matter. In summary, selection of organic materials for use in soil mixtures depend on cost, availability, physical characteristics and chemical properties.

ACIDITY OR pH

The acidity or pH of a soil mixture can be readily controlled. Some organic materials markedly lower the pH and dolomite or lime can be used to raise it to the desired level. Wettable or superfine sulfur may be used to lower the pH of alkaline or "sweet" soil mixtures. Table 2 below can be used as a guide for determining approximate amounts of dolomite and sulfur needed to change pH of different soil types.

Table 2. Approximate amount of materials required to change the reaction (pH) of some soils.

A. To increase acidity or lower pH of an alkaline or "sweet" soil.

Present pH of the soil	Pounds wettable or superfine sulfur [1] per cubic yard to lower pH to 6.0		
	Sandy soil	Loam soil	Muck or Peat
7.0	1/2	1	1 3/4
6.5	-	1/2	1

B. To lower acidity or raise the pH of an acid soil.

Present pH of the soil	Pounds dolomite per cubic yard to raise pH to 6.0		
	Sandy soil	Loam soil	Muck or Peat
5.0	1 1/2	2 1/3	5 1/2
4.5	2 1/4	3 1/2	8
4.0	3 1/2	6 1/4	13 1/2

[1] Do not use more than 3/4 pound of wettable or superfine sulfur per cubic yard if soil is to be used for planting soon after mixing. For more than one application apply proportional amounts to containers and water thoroughly once every 6 weeks, until pH reaches desired level. More than one application will be needed to lower a high pH.

SOLUBLE SALTS

The soluble salt level of a soil mix should be low to begin with, since a build-up can be expected from the fertilization program. A soluble salt level below 200 ppm is desirable in a new soil mixture. Levels of about 600 soluble salts will not damage most woody plants under good management practices, but the nurseryman who starts with such a mixture will need to use a fertilizer program that does not add appreciable amounts of excess soluble salt to the soil and closely regulate watering. If one of the components of the mix is unusually high in soluble salts it is better to drop it out of the mix and change mixture components than to adjust production practices to the mixture or try to make a profit on poor quality plants

MICRO (MINOR) ELEMENTS

Deficiencies of micro (minor) elements can markedly affect growth of woody ornamental plants Many materials and components (sand, perlite and peat) used in soil mixtures for container nursery stock are deficient in certain micro (minor) elements, notably copper, iron, manganese and zinc. Materials in the amounts listed below should be added during soil mixing and mixed thoroughly to prevent possibility of deficiencies.

Micro (Minor Elements)	Oz. per cu. yd.
1. Copper sulphate	1 oz.
2. Zinc sulphate	1 oz.
3. Manganese sulphate	2 oz.
4. Iron chelate	1 oz.

*A proprietary micro (minor) element nutritional mixture may be used to provide similar rates of elements.

Additional factors to be considered as desirable in a soil mixture are low cost, made up of readily available materials, weight and a mixture that can be reproduced repeatedly with relatively the same characteristics. A cheap organic material may turn out to be expensive if it reduces quality by holding too little water which results in leaf scorch, tying up nitrogen needed by the plants, root damage or poor root growth resulting from poor drainage and aeration, introducing weed seed and diseases and shrinking of soil mass ties or introduces weed seed and diseases. The weight of a mixture should be held to a minimum if many plants are to be shipped, however, it may be desirable to use a higher proportion of sand or calcined clay to add weight to mixtures for tall plants, for large containers, or for local sales, to reduce falling and lodging; particularly when plants are to be grown in a windy unprotected site. A reproduceable soil mixture enables a nurseryman to standardize watering, fertilization and other production practices thus reducing production cost. The important function of a soil mixture is to aid the nurseryman in producing a high quality plant at a profit.

Many materials are available for soil mixes and a great deal of confusion and uncertainty exists in nurserymens' minds as to which materials are best. The following are some of the factors and characteristics of some of the many materials available for soil mixes.

IMPORTED PEATS

These are the most widely-used peat for soil mixtures, provided soluble salt levels are not too high. Imported peats usually do not decompose as much as Florida peat and therefore, are usually coarser, contain more fiber and provides better aeration and drainage than fine Florida peats. Many nurserymen feel that imported peats are more expensive than local peats. Their evaluation is usually based on price alone. A factor to consider is that, - when shredded - a 6 cubic feet bale of imported peat yields about 18 cubic feet (cu. ft.) or 2/3 cubic yard (cu. yd.) of air-dry peat. Therefore, Florida peat, with a 40% shrinkage rate, selling for \$4.00 per cubic yard is about 1½ times as expensive as imported peats selling for \$4 25 per bale. In other words, local Florida peat would have to sell for about \$2 55 per cubic yard to compete with imported peats at \$4.25 per bale, on the basis of cubic feet of air-dry peat. However, growers should add cost of shredding imported peats and cost of sterilizing Florida peats.

FLORIDA PEATS

Many Florida peats are acceptable for use in soil mixes for containers provided careful consideration is given to watering and fertilization. Florida peats with high pH should be checked for soluble salts, as peat is very difficult to leach, and peats high in soluble salts and with a high pH should not be used.

Low pH Florida peats are less of a problem since applications of dolomite or lime can be used to raise pH to desirable level. The primary considerations as to use of Florida peat versus imported peat are cost and aeration or porosity.

PINE BARK

Work at the University of Florida, has shown processed (shredded) bark to be an acceptable substitute for peat. Shredded and ground pine bark are slowly becoming available. Pine bark has many characteristics of peat; water-holding capacity and nutrient-holding capacity are excellent and carbon/nitrogen ratio is not high as compared to sawdust. During the early stages of growth extra nitrogen should be applied to prevent nitrogen starvation as the bark decomposes. One of the factors in favor of bark is the consistency of material, since percent of various nutrients in pine bark remains the same throughout the pulp-wood growing region. Ground pine bark is being used by some nurserymen. Use of pine can mean substantial savings, as compared to using peat provided bark is purchased in large quantities.

SHAVINGS

Use of shavings is widespread, but supply is low and cost is high in many cases. Shavings can be used for 1/4 to 1/3 of the volume in soil mixes to good advantage. Close attention must be given to supplying extra nitrogen to prevent nitrogen starvation due to decomposition of shavings. Some peat will be needed in mixes containing shavings to increase water-holding and nutrient-holding capacities of the mix.

SAWDUST

Sawdust has good moisture-holding characteristics but a high carbon/nitrogen ratio (high nitrogen depressing ability) which limits wide usage. However, materials for soil mixes are becoming so scarce and expensive in some sections of Florida that sawdust is being widely used in these areas. No more than 1/4 to 1/3 by volume of sawdust should be used in any mix. Wide availability and low cost in most sections of Florida make sawdust seem very attractive. However, cost of loading, transportation and additional nitrogen necessary to prevent nitrogen starvation can materially increase cost.

SAND

Sand is the primary constituent of most Florida soil mixes. Local sand is used by most growers, but this is not always the best policy since sand particles should be .002 to .01 inches in diameter. Therefore, fine to medium grades or builder's sand are necessary to be acceptable for soil mixes.

CALCINED CLAYS

A number of calcined clays are available and they have quite different characteristics. Turface is popular but expensive and cost limits its use except in special mixtures. Turface has a good nutrient-holding capacity, but its water-holding capacity is low. Sorbolite, another calcined clay, has an acceptable nutrient-holding capacity and good water-holding capacity. The calcined clays are used in some container mixes to supply weight when the other components of the mix are very light.

PERLITE

Inclusion of perlite in mixes increases aeration and lightens the mix. Nutrient-holding capacity and water-holding capacity are both low, and cost precludes use of perlite in many soil mixtures except in cases where proper grades of sand are scarce or expensive, soil mixes for small potted and specialty plants, propagation beds and wherever aeration and weight are a problem.

Soil mixes should be developed for growing and adapted to the production practices of a particular nursery. Some of the practices that should be considered are major type of plant(s) being grown - particularly whether or not plants are subject to root diseases and problems associated with poor aeration and drainage - watering and fertilization practices, length of time plants are grown - fast-growing or to be sold in small sizes or slow-growing or to be grown on to large sizes - and whether plants are to be marketed, locally or shipped. The following mixes, by volume, are suggested for trial·

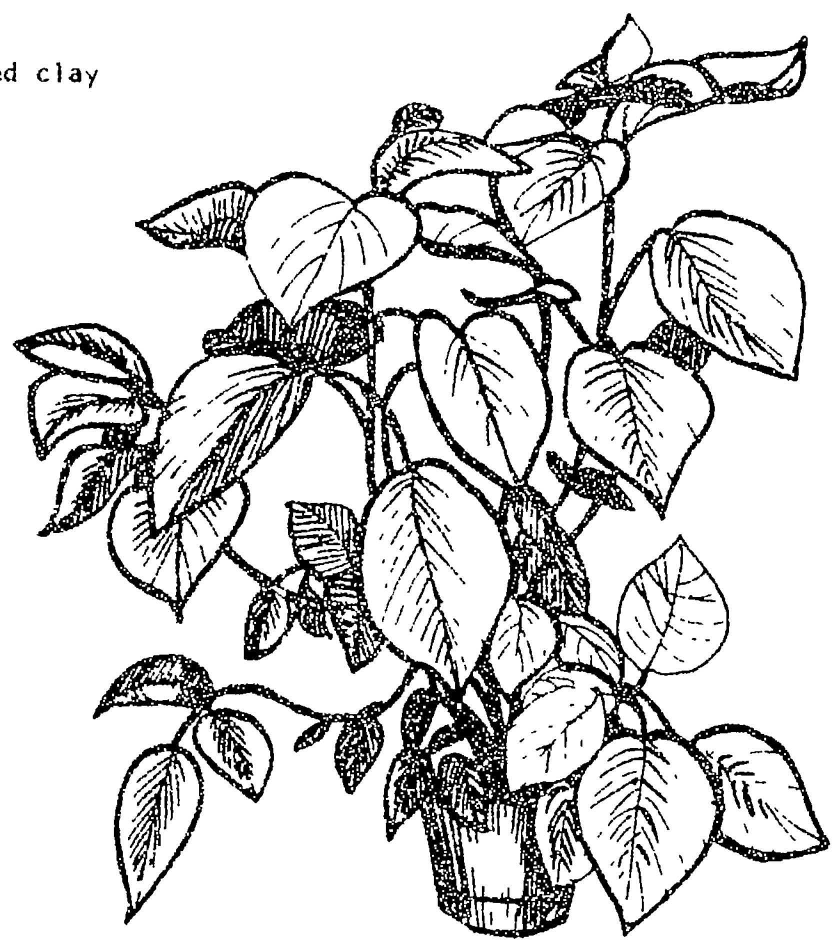
1. 1/2 sand
   1/4 peat
   1/4 sawdust or shavings.

2. 1/3 perlite
   1/3 peat
   1/3 sandy soil

3. 1/3 sand
   1/3 calcined clay
   1/3 peat

4. 1/2 sand
   1/4 calcined clay
   1/4 peat moss or pine bark

5. 1/2 sand
   1/2 peat



LIGHT AND FERTILIZER RECOMMENDATIONS ON PRODUCTION OF FOLIAGE STOCK PLANTS AND ACCLIMATIZED POTTED PLANTS

C. A. Conover and R. T. Poole
Agricultural Research Center-Apopka
ARC-A Research Report RH-76-6

The objective of foliage plant producers should be to maximize production of quality plants that can be sold at a profit. Of the cultural factors that influence plant growth, light and nutrition are two of the most important.

STOCK PRODUCTION

Light--Selection of light levels for production of stock plants must take into consideration growth rate, quality and pest control factors. Some factors of special importance are carbohydrate reserves, foliar color and leaf size and shape. Therefore, selection of light intensities for stock production must consider the rootability of cuttings as well as appearance. Other factors that must be considered include increased disease control problems under shade where plants stay wet longer, increased fluoride problems on susceptible plants grown under high light intensities and increased insect pest problems on outdoor plantings and those where foliage is kept dry. Fertilizer--Nutrition of stock plants depends on light intensities provided as well as soil cation exchange capacity and amount of rainfall or irrigation. Each of the factors listed above must be considered by the grower when using the information provided in Table 1. The fertilizer rate listed is for the light intensity listed, and use of higher light intensities will require more fertilizer, while use of lower light levels will require less fertilizer.

Information provided is for use of a 1-1-1 ratio fertilizer such as 20-20-20, although limited research has shown that a 3-1-2 ratio such as 18-6-12 is just as acceptable. Producers who desire to use the 3-1-2 ratio will be able to reduce fertilizer costs and soluble salts levels. Producers using a 3-1-2 ratio on stock should calculate the level by using the fertilizer rate in Table 1 as the nitrogen rate. Data provided in Table 1 for stock production have been developed through research as well as observation of commercial plantings in Florida.

ACCLIMATIZED POTTED PLANT PRODUCTION

Light--The ability of plants to adapt to varying light intensities has been known for years. As an example, under high light levels the plant may produce small thick leaves with stacked chloroplasts in many cells and vertical orientation of grana within chloroplasts. This is a protective mechanism which prevents injury to cell components from high light intensities, but reduces the ability of plants to produce carbohydrates (food) through photosynthesis under lower light levels. Although leaves developed under high light levels present no problem while the plant remains under high light, movement of the

Table 1: Suggested light and nutritional levels for production of foliage stock plants.

Botanical name	Light intensity (foot-candles)	Shade cloth % (listed as actual shade)	Fertilizer requirements[1] lb $N-P_2O_5-K_2O$/A/yr
Aglaonema spp.	2000 - 3500	80 or 73%	1200
Aphelandra squarrosa	500 - 1000	90%	1200
Brassaia arboricola	8000 -12000	30% to 0	2100
Calathea spp.	3000 - 3500	73%	1200
Codiaeum variegatum	8000 -12000	30% to 0	1800
Cordyline terminalis	3500 - 4500	63%	1500
Dieffenbachia spp.	3500 - 4500	63%	1500
Dracaena deremensis (cultivars)	3000 - 3500	73%	1200
Dracaena fragrans 'Massangeana' (tips)	6000 -12000	47% to 0	1500
Dracaena godseffiana	3500 - 4500	63%	1500
Dracaena marginata	6000 -12000	47% to 0	1800
Dracaena marginata 'Tricolor'	4500 - 8000	63 to 30%	1800
Dracaena sanderiana	3500 - 4500	63%	1500
Ficus benjamina	Full Sun	0	2400
Ficus elastica (cultivars)	Full Sun	0	1800
Ficus lyrata	Full Sun	0	1800
Maranta spp.	2000 - 2500	80%	900
Monstera deliciosa (*P. pertusum*)	3500 - 4500	63%	1500
Nephrolepis exaltata (cultivars)	3000 - 3500	73%	1200
Peperomia spp.	3000 - 3500	73%	600-900
Philodendron hastatum	3500 - 4500	73 or 63%	1500
Philodendron (Hybrids)	3000 - 3500	73%	1500
Philodendron micans	3500 - 4500	63%	1500
Philodendron oxycardium	3500 - 4500	63%	1500
Pilea spp.	3000 - 3500	73%	600-900
Sansevieria spp.	6000 -12000	47% to 0	600-900
Scindapsus aureus	3500 - 4500	63%	1500
Syngonium podophyllum	3500 - 4500	63%	1500
Yucca elephantipes	Full Sun	0	1800
Zygocactus truncatus	3000 - 4500	73 or 63%	1200

[1]See Tables 3, 4 and 5 for further information on fertilization.

plant to low light levels of an interior location present problems because of the plants compensation point. Therefore, producers of foliage plants for indoor use must consider the quality at time of sale as well as future quality under interior conditions. Production of potted plants under the light intensities provided in Table 2 will provide high quality plants adapted to interior use.

Fertilizer--Nutrition of potted plants is based on most of the same factors which influence growth of stock plants. The major difference is reduced levels in those instances where potted plants are grown under lower light intensities than stock plants. Nutrition of potted foliage plants influence growth rate, which has a major effect on profitability of a particular foliage plant to growers and ultimate cost to consumers, as slow growing varieties cost more since they utilize labor and space for a longer time span. Quality of foliage plants is also important, since appearance is a prime factor in stimulating sales. Appearance can be altered considerably by fertilization, since plant nutrition influences plant and leaf size as well as color.

Longevity of foliage plants is of prime interest to consumers, and often determines consumer satisfaction and repeat sales. During the first few months in the home, plants are influenced by fertility regimes of the original grower, which in turn affects longevity. Growth rate, quality and longevity of foliage plants, may therefore be increased or decreased by changing nutritional levels.

Maximum growth rate can be obtained from many foliage plants with moderate levels of soluble, organic or slow-release fertilizers. Excessive nutritional levels produce root-shoot ratios of less than one, resulting in plants with excessive top growth and relatively small root systems; and under conditions of high humidity and frequent watering these plants often appear attractive and of high quality. However, when these plants are placed under low humidities common to most building interiors, many older leaves become yellow and drop. This leaf drop occurs even though soil moisture is satisfactory, because inadequate root systems cannot maintain proper tissue moisture levels. Nutritional levels higher than those listed should not be provided, or injury from soluble salts may occur. As stated earlier, injury may not appear in the growing range, but in the home under reduced light or when soils are allowed to dry.

Information provided is for use of a 1-1-1 ratio fertilizer such as 20-20-20, although limited research has shown that a 3-1-2 ratio such as 18-6-12 is just as acceptable. Producers who desire to use the 3-1-2 ratio will be able to reduce fertilizer costs and soluble salts levels. Producers using a 3-1-2 ratio on stock should calculate the level by using the fertilizer rate in Table 2 as the nitrogen rate. Data provided in Table 2 for potted plant production have been developed through research. This data is based on potting soils being composed of at least 75% organic matter that has a moderate to low C-N ratio.

Table 2. Suggested light and nutritional levels for production of potted acclimatized foliage plants.

Botanical name	Light intensity (foot-candles)	Shade cloth % (listed as actual shade)	Fertilizer requirements[1] lb N-P_2O_5-K_2O/A/yr
Aglaonema spp.	2000-2500	80%	1200
Aphelandra squarrosa	1000-1500	80% winter 90% summer	1500
Araucaria excelsa	6000-8000	47 or 30%	1200
Asparagus spp.	3500-4500	63%	900
Brassaia spp.	5000-6000	47%	1800
Calathea spp.	3000-3500	73%	1200
Chamaedorea erumpens	4500-6000	63 or 55%	1500
Chamaedorea elegans	3000-3500	73%	1200
Chrysalidocarpus lutescens	5000-6000	47%	1500
Codiaeum variegatum	7000-8000	30%	1800
Cordyline terminalis	3500-4500	63%	1200
Dizygotheca kerchoviana	5000-6000	55%	1200
Dieffenbachia spp.	3000-4500	73 or 63%	1200
Dracaena deremensis (cultivars)	3000-3500	73%	1200
Dracaena fragrans (cultivars)	3000-3500	73%	1200
Dracaena marginata	5000-6000	47%	1800
Dracaena - others	3000-3500	73 or 63%	1200
Ficus benjamina & *F. nidita*	3500-6000	63 or 47%	1800
Ficus elastica (cultivars)	7000-8000	30%	1800
Ficus lyrata	5000-6000	47%	1800
Maranta spp.	2000-2500	80%	900
Monstera deliciosa (*P. pertusum*)	3500-4500	63%	1500
Nephrolepis exaltata (cultivars)	3000-3500	73%	1200
Peperomia spp.	3000-3500	73%	600
Philodendron selloum	5000-6000	55%	1800
Philodendron spp.	3000-3500	73%	1500
Pilea spp.	2000-3500	80 or 73%	600
Sansevieria spp.	3500-4500	63%	600
Scindapsus spp.	3500-4500	63%	1500
Spathiphyllum clevelandii	2000-3500	80 or 73%	1200
Syngonium podophyllum	3000-4500	73 or 63%	1500
Yucca elephantipes	3500-4500	63%	1200
Zygocactus truncatus	3000-4500	73 or 63%	1200

[1]See Tables 3, 4 and 5 for further information on fertilizer.

Table 3. Amounts of 20-20-20 fertilizer to use to supply suggested fertilizer levels for specific crops (See Table 1 for stock plants, Table 2 for potted plants).

Lbs. $N-P_2O_5-K_2O$/ Acre/year	Lbs. 20-20-20/ 1000 ft^2/month	gms. 20-20-20/pot/month[1] 4"	6"	8"	10"	12"
600	6[2,3]	0.2	0.4	0.8	1.2	1.8
900	9	0.3	0.6	1.2	1.8	2.7
1200	12	0.4	0.8	1.6	2.4	3.6
1500	15	0.5	1.0	2.0	3.0	4.5
1800	18	0.6	1.2	2.4	3.6	5.4
2100	21	0.7	1.4	2.8	4.2	6.3
2400	24	0.8	1.6	3.2	4.8	7.2

[1]One teaspoon 20-20-20 equals approximately 5 gms.
[2]If fertilizing with each irrigation is desired, divide by expected number of irrigations during the month.
[3]One quarter inch of 100 ppm N applied ten times monthly equals approximately 6 lbs. 20-20-20/1000 $ft.^2$.

Table 4. Amounts of 14-14-14 Osmocote to use to supply suggested fertilizer levels in various sized pots for specific crops (See Table 1 for stock plants, Table 2 for potted plants).

Recommended level lbs. $N-P_2O_5-K_2O$/A/yr	Surface application gm[1]/pot/3mo. 4"	6"	8"	10"	12"	Incorporation lb/cu yd/3 mo when used in 2 to 6" pots	7 to 12" pot
600	1.0	2.0	4.0	6.0	9.0	4	3.0
900	1.5	3.0	6.0	8.0	13.5	6	4.5
1200	2.0	4.0	8.0	12.0	18.0	8	6.0
1500	2.5	5.0	10.0	15.0	22.5	10	7.5
1800	3.0	6.0	12.0	18.0	27.0	12	9.0

[1]1 level teaspoon = approximately 5 gms.

Table 5. Amounts of 18-6-12 Osmocote to use to supply suggested fertilizer levels in various sized pots for specific crops (See Table 1).

Recommended level[1]	Surface application gm[2]/pot/6 mo. 4"	6"	8"	10"	12"	Incorporation lb/cu yd/6 mo when used in 2 to 6" pots	7 to 12" pot
600	1.5	3.5	6.0	9.5	13.5	6	4.0
900	2.25	5.3	9.0	14.3	20.3	8	5.5
1200	3.0	7.0	12.0	19.0	27.0	10	8.0
1500	3.75	8.8	15.0	23.8	33.8	12	9.5
1800	4.5	10.6	18.0	29.6	40.6	14	11.0

[1]Based on nitrogen level the 3-1-2 ratio of 18-6-12 has proven to be adequate for foliage.
[2]1 level teaspoon = approximately 5 gms.

A List of Floiage Plants Sensitive to Fluoride[1]

Horticulture name	Common name
Plants sensitive to fluoride	
Chlorophytum comosum	Spider Plant
Cordyline terminalis	Ti Plant
Cordyline terminalis 'Baby Doll'	Baby Doll Plant
Dracaena deremensis 'Janet Craig'	Janet Craig Dracaena
Dracaena deremensis 'Warneckii'	Warneck Dracaena
Plants slightly sensitive to fluoride	
Dracaena fragrans 'Massangeana'	Massange Dracaena
Maranta erythroneura	Redvein Prayer Plant
Maranta kerchoveana	Prayer Plant
Spathiphyllum cannaefolium	
Stromanthe amabilis	
Yucca elephantipes	Spineless Yucca
Plants suspected to be sensitive to fluoride	
Aspidistra elatior	Cast Iron Plant
Calathea insignis	Rattlesnake Plant
Calathea makoyana	Peacock Plant
Dracaena marginata	Madasgascar Dragontree
Dracaena sanderiana	Ribbon Dracaena
Pleomele thalioides	Lance Pleomele

When growing fluoride sensitive plants try to use the following procedures:

Elevate pH of medium to 6.0 to 6.5, use water with low fluoride content, avoid media containing fluoride, avoid use of superphosphate, and reduce transpiration by manipulation of light intensity and temperature.

[1]Adapted from ARC-Apopka Mimeo RH-76-2.

THE CHEMICAL PROPERTIES OF SEVERAL PEAT SOURCES

D. McConnell, W.E. Waters, & R.T. Poole

Peats from Canada, Europe, Louisiana and 5 locations in Florida were chemically analyzed to determine their suitability for use in ornamental plant production. Peat is partially decomposed vegetable matter which has accumulated under anaerobic conditions in bogs and marshes. The plant material is not completely decomposed because the bacteria and fungi existing under these conditions are capable of decomposing only part of the plant material. Peats are classified according to the type of plant material from which they originated. Fibrous peats commonly used in the ornamentals industry consist of decayed sedges, mosses, reeds and other grasses. Native Florida peats were formed under tropical or sub-tropical conditions while imported peats from Europe or Canada were formed under cool, moist conditions.

Most pot and container grown plants produced in Florida and elsewhere are grown in synthetic soil mixes containing at least 1/3 peat. The majority of this plant material has been propagated in media composed of at least 1/2 peat. Peat is an excellent soil amendment because it increases moisture and nutrient holding capacities and provides some "buffer" capacity against rapid pH changes and excessive soluble salts accumulation from fertilizers.

This study was initiated to provide the commercial producers of ornamental plants with information to assist them in comparing Florida peats to imported peats. Two methods were used to analyze the peat sources: (1) tissue analysis procedure and (2) ammonium acetate soil test procedure. The data from the two methods are complimentary but not comparable. Data in Table 1 (tissue analysis) are given as percent of the total amount of the element present on a dry weight basis equivalent to the total amount of each chemical present in the sample. Data in Table 2 (ammonium acetate extraction) is an approximation of the amount of each chemical available for plant growth.

Chemical analyses of imported peats are relatively uniform. Variations in chemical content among Florida peats reflects the differences in plant materials forming the peats, the mineral content of the water in which the plants were growing, the type of soil surrounding the peat deposit, stage of decomposition of the peat and the downward movement of water through the deposit. Florida peats are consistently higher in total-nitrogen than the imported ones (Table 1) because of differences in the original plant material from which the peats were formed. The phosphorus (P) and potassium (K) of both imported and native peat are extremely low when compared to ornamental plant tissue. The calcium (Ca) and magnesium(Mg) content are moderately high in the Ft. Pierce and Zellwood peat source and relatively low in all others.

This was shown by the soil test results in Table 2. Manganese level in peats and soil mixes are important since steam sterilization increases the amount of available manganese. High levels of manganese and copper can be toxic to seedlings. The peat samples listed in Table 1 are low in both manganese and copper.

Other important chemical criteria to consider when evaluating peat sources include the % ignition loss, pH, and soluble salts. The % ignition loss is the residue. The higher the percentage ignition loss, the greater the amount of organic matter in the peat. Most peat will have over 75% ignition loss and high quality peat will usually exceed 90%. Table 2 shows all peat tested was in the acceptable range. Peat pH should be between 3.5 and 5.0. Peats with high pH usually contain excessive amounts of calcium which may result in nutritional problems before a potted crop is matured. Peats having Ca levels over 10,000 ppm should not be used. The procedure used in these evaluations resulted in numerically high soluble salt readings when compared to readings of other methods (see legend Table 2). Both sodium and chlorine levels should be low (Low salt = 2,000 ppm).

These chemical analyses show that Florida peats compare favorably with imported peats. However, because individual Florida peat deposits are limited in size, both physical and chemical properties may show more variance than imported peats.

Table 1. Chemical analyses of several peat sources.

Sample	% oven dry wt					ppm oven dry wt			
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
Canadian	1.16	.04	.08	.11	.123	385	1.75	145.0	4.8
European	0.96	.05	.08	.09	.147	247	1.15	130.0	4.7
Bartow, Fla.	2.30	.05	.03	.15	.095	502	0.30	132.0	4.6
Floral Home, Fla.	1.70	.03	0	.11	.140	1020	1.50	90.0	5.0
Ft. Pierce, Fla.	2.96	.05	.10	.32	.266	390	1.00	126.0	4.6
Oxford, Fla.	3.40	.09	0	.90	.088	762	0.50	132.0	5.2
Zellwood, Fla.	2.83	.04	.04	.08	.290	1146	2.66	110.0	5.1
Louisiana	1.50	.04	.20	.40	.213	1107	203.0	110.0	38.0

Table 2. Soil analyses of several peat sources by the acid ammonium acetate procedure as determined by University of Florida Extension Service Testing Laboratory.

Sample	% ignition loss	pH	Soluble salts*	ppm air dry weight						
				Ca	Mg	Na	K	P	NO_3	Cl
Canadian	95	3.8	1995	1125	744	711	139	20	51	122
European	95	3.6	2870	725	781	646	92	13	45	147
Bartow, Fla.	92	3.5	3360	1395	156	405	35	9	43	176
Floral Home, Fla.	95	3.6	1330	1380	660	360	48	19	52	60
Ft. Pierce, Fla.	95	4.6	5670	3866	1356	970	113	4	153	416
Oxford, Fla.	87	3.7	3010	610	149	430	87	119	148	117
Zellwood, Fla.	87	5.0	2109	5986	1553	610	41	11	102	138
Louisiana	76	4.9	4900	497	250	1600	46	1	36	1040

*Soluble salts were determined by utilizing 2 parts water to 1 part peat by weight and on peats is interpreted as follows: 2000 ppm = low salts, 5000 = medium salts and 8000 ppm = high. This scale applies to peat and peat-like mixes only.



7/72

INSECT, MITE,

AND

NEMATODE CONTROL

Detect And Control Insects And Pests On Tropical Foliage Plants

by R A. Hamlen, D E Short and R W Henley

INSECTS AND MITES are a major cause of tropical foliage plant losses to growers and retailers Their presence on plants often constitutes a nuisance to the consumer, too

Establishment of control programs during production and after sale requires basic knowledge of the life cycle of these pests It is important to know how the pest was introduced into the greenhouse or retail shop, how it spreads, and its relative rate of multiplication

Since pesticides so often are required, it is necessary to decide on the most effective chemical to use, what formulation is best, the correct dosage rate, and the proper method, as well as the time and frequency of application Major emphasis must be given to select pesticides safe both to the crop and the people who may come in contact with these plants

It is therefore important to recognize the most common insect and mite pests that infest tropical foliage plants — to know how they develop and what can be used to control them.

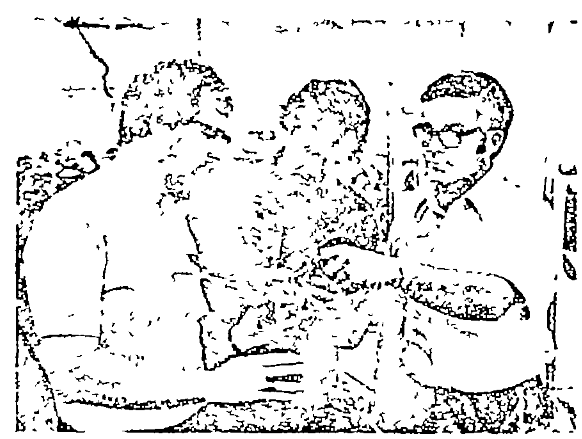
EDITOR'S NOTE The authors, Drs R A Hamlen, D E Short and R W Henley are Assistant Professor of Entomology, Agricultural Research Center (ARC), Apopka, University of Florida, Assistant Extension Entomologist, Department of Entomology and Nematology, University of Florida, Gainesville, and Associate Professor, Foliage Extension Specialist, ARC-Apopka, IFAS, University of Florida, respectively To simplify information, trade names of products have been used No endorsement of named products is intended, nor is criticism implied of similar products not mentioned Mention of a chemical does not imply guarantee of effectiveness or safety, nor that the chemicals or uses discussed have been registered by appropriate state and federal agencies.

Select specific pesticides

Before discussing the specific pests themselves, a comment on the types of pesticides may aid in understanding why specific pesticides (Table 1) are selected for controlling particular pests A major consideration is that both cultural conditions and types of plants grown in the foliage plant industry are so varied that no single pest control program can be suggested One possible program is the application of maintenance or preventative sprays at one-to three-week intervals, depending upon the pest, crop and the length of pesticide residue Such a program should kill most of the initial pest invaders and prevent pest populations from further development

It is far easier to maintain relatively pest-free stock, propagation and production areas than to eradicate pests once they become well established in high populations Where a preventative program is not followed, it is essential to inspect plants closely at weekly intervals to detect initial pest populations and once found, to apply effective control measures before pests reach damaging levels

Systemic pesticides like Meta-Systox-R or dimethoate, usually provide the most effective control



Drs R A Hamlen, D E Short and R W Henley, Florida researchers who studied the detection and control of common insect and mite pests on tropical foliage plants

of pests that feed by sucking plant sap (aphids, mealybugs, scales and whiteflies) Systemic pesticides applied as sprays enter the plant and are transported to the leaves and stems Thus, when an insect punctures and feeds on sap of a plant treated with a systemic, it receives a lethal dose of the chemical Systemics are of particular advantage when pests are covered by foliage and are therefore inaccessible to pesticides that kill only on contact

Spray both sides ...

In the application of any insecticide or miticide both leaf surfaces, especially the lower side must be reached by the spray Systemic activity of the pesticide is no excuse to justify poor spraying techniques A spreader-sticker, such as Plyac (Allied Chemical Co , Atlanta, Ga– usually added at a concentration of 2-4 oz in 100 gal or 7-14 drops in 1 gal) should be added to the spray solution to

Reprinted from the August, 1975 issue of FLORIST magazine.

insure proper coverage and retention of the pesticide on the foliage This is especially important if plants are watered overhead, a technique which quickly washes pesticides off the foliage if a sticker is lacking Where mites are troublesome, miticides (chemicals with activity specifically against mites) should be used These will be discussed later

Some systemic emulsifiable concentrates (Meta-Systox-R or dimethoate) are effective when applied as soil drenches Never apply these chemicals as soil drenches to plants under water stress as plant injury is likely to result A granular, systemic insecticide, miticide and nematicide called Temik 10 G, has been highly effective against sucking insects and mites

To correctly apply Temik, the recommended weight of granules (Table 2) must be distributed over specific soil surface areas of containers, benches or beds One-quarter to ½-inch of water should follow to flush the chemical off the granules and into the root zone where it can be absorbed and translocated to the upper plant parts Temik usually will provide effective control for one to three months, but it is available for use only in commercial nurseries, it is extremely poisonous, and treated plants must be held for four weeks prior to sale

Additional suggestions on the use of Temik are contained in the *Florida Foliage Grower*, Volume II, No 3, 1974.

Pesticides can damage plants

Phytotoxicity is a term used to define plant injury often caused by pesticides It frequently appears as damage to foliage such as

Table 1. Insecticides And Miticides Effective For Control Of Insect And Mite Pests Of Tropical Foliage Plants.

		Dosage	
Insect	Pesticide and Formulation	1 Gal	100 Gal
Aphids	Diazinon 4E	1 Tsp	1 Pt
	Diazinon 50% WP	1 Tbsp	1 Lb
	Dimethoate 2E*	1½ Tsp	1½ Pts
	Dimethoate 2E (soil drench)*	1 Tsp	1 Pt
	Malathion 57% EC	1½ Tsp	1½ Pts
	Malathion 25% WP	2½ Tbsp	2½ Lbs
	Meta-Systox-R 25% EC*	1½-2 Tsp	1½-2 Pts
	Meta-Systox-R 25% EC (soil drench)*	1 Tsp	1 Pt
	Temik 10% G**	Table2	
Caterpillars armyworms, loopers, cutworms	Bacillus thuringiensis (Biotrol, Dipel, Thuricide)	½-1 Tbsp	½-1 Lb
	Sevin 50% WP	2 Tbsp	2 Lbs
	Sevin 80% S	1¼ Tbsp	1¼ Lbs
Fungus gnats (larvae)	Diazinon 4E (soil drench)	½ Tsp	½ Pt
	Diazinon 50% WP (soil drench)	½ Tbsp	½ Lb
Foliar mealybugs, soft and armored scales	Diazinon 25% EC (scales)	2 Tsp	2 Pts
	Diazinon 4E	1 Tsp	1 Pt
	Diazinon 50% WP	1 Tbsp	1 Lb
	Dimethoate 2E*	1½ Tsp	1½ Pts
	Dimethoate 2E (soil drench)*	1 Tsp	1 Pt
	Malathion 57% EC	2-3 Tsp	2-3 Pts
	Malathion 25% WP	4-6 Tbsp	4-6 Lbs
	Meta-Systox-R 25% EC*	1½-2 Tsp	1½-2 Pts
	(soil drench for mealybugs)*	1 Tsp	1 Pt
	Temik 10%G**	Table 2	
Root mealybugs	Diazinon 4E (soil drench)	½-2 Tsp	½-2 Pts
	Dimethoate 2E (soil drench)*	¾-1½ Tsp	¾-1½ Pts
	Sevin 50% WP (soil drench)	1 Tbsp	1 Lb
	Temik 10G**	Table 2	
Mites Broad, Cyclamen, False Spider, and Spider	Kelthane 18 5% EC	1-2 Tsp	1-2 Pts
	Kelthane 35% WP	1 Tbsp	1 Lb
	Omite 30% WP (spider mite)	4½ Tsp	1½ Lb
	Pentac 50% WP (broad and spider mite)	1½ Tsp	½ Lb
	Temik 10%G**	Table 2	
Thrips	Dimethoate 2E*	1½ Tsp	1½ Pts
	Malathion 57% EC	2 Tsp	2 Pts
	Malathion 25% WP	5 Tbsp	5 Lbs
	Meta-Systox-R 25% EC*	1½-2 Tsp	1½-2 Pts
	Temik 10%G**	Table 2	
Whiteflies	Diazinon 25% E P	2 Tsp	2 Pts
	Diazinon 4E	1 Tsp	1 Pt
	Diazinon 50% WP	1 Tbsp	1 Lb
	Dimethoate 2E*	1½ Tsp	1½ Pts
	Malathion 57% EC	1½ Tsp	1½ Pts
	Malathion 25% WP	2½ Tbsp	2½ Lbs
	Meta-Systox-R 25% EC*	1½-2 Tsp	1½-2 Pts
	Temik 10%G**	Table 2	

Abbreviations *Tsp = Teaspoons, Tbsp = Tablespoons, Pt = Pint, Lb = Pounds, EC = Emulsifiable Concentrate, WP = Wettable Powder, G = Granular*

**Systemic Pesticides* ***Temik is also a systemic pesticide but for use only in commercial nurseries Do not apply Temik for at least 4 weeks before plants go to retail shops*

To minimize phytotoxicity, pesticides should be applied during the cooler parts of the day.

Table 2. Amount Of Temik 10G To Be Applied To Beds, Benches, Row Stock, Grouped Or Individual Pots And Containers.

	Pounds per Acre (Broadcast Equivalent)		
	50	75	100
Ounces per 1000 ft of row*	60	90	120
Ounces per 1000 sq ft	20	30	40
Ounces per 100 sq yd	16	24	32
Grams per sq meter	5 0	7 5	10
Grams per sq ft	0 5	0 75	1 0

Container diameter (inches)	Level teaspoons Temik 10G per pot**	Grams Temik 10G per pot**
3	—	0 05
4	—	0 1
5	1/16	0 15
6	1/8	0 2
8	1/4	0 4
10	1/3	0 6
12	1/2	1 0

*Based on 40-inch row spacings **Equivalent to 40 ounces per 1000 sq ft or 100 lbs per acre

Table 3. Safety Of Insecticides And Miticides For Selected Foliage Plants.

Botanical Name	Diazinon 25% EC	Dimethoate 2E	Kelthane 18 5% EC	Kelthane 35% WP	Malathion 57% EC	Meta-Systox-R 25% EC	Omite 30% WP	Pentac 50% WP	Sevin 80% S	Temik 10G
Alphelandra squarrosa		?	S			S		S		S
Araucaria excelsa	S	S			S	S			S	S
Ardisia sp	S	S			S	S	S		S	S
Brassaia actinophylla	S	U	S	U	U	?	?	S	U	S
Collinia elegans		U	U	U		U	?	S		S
Dieffenbachia amoena	S	S			S	S			S	S
Dieffenbachia exotica	S	?	S	S	U	S	?	S	S	S
Dracaena godseffiana	S	S			S	S	S		S	S
Dracaena sanderiana	U	S			S	S			S	S
Ficus benjamina										S
Hoya carnosa	U	S			S	S			S	
Maranta erythroneura		U	S	S		S	S	S		S
Monstera deliciosa	S	S			S	S			S	
Nephrolepis exaltata	?	U			U	S	U		?	
Peperomia obtusifolia	?	?			S	?	U		S	S
Philodendron oxycardium	S	S			S	S	S		S	S
Philodendron panduraeforme	S	S			S	S			S	S
n cadierii	?	U			S	S			S	
sevieria spp	S	S			S	S			S	S
idapsus aureus	S	S			?	S	U		S	S
Syngonium spp	S	S			U	S	?		S	S

S = safe at recommended rates, U = unsafe and ? = an inconsistent reaction following spray applications

marginal burn, cnıuıosis, spotting and distorted or abnormal growth Although any portion of the plant may be affected, the new growth is most likely to show damage In the use of soil drench applications, root tissue may be injured causing stunting or slow plant decline

To minimize phytotoxicity, pesticides should be applied during the cooler parts of the day Application should be made in the early morning in order that the foliage will be dry before temperatures reach 85° to 90°F Generally wettable powders are considered less phytotoxic than emulsifiable concentrate sprays, however wettable powders often leave objectionable residues on the foliage Table 3 contains information on the safety of routinely used insecticides and miticides for tropical foliage plants

Since some plants are more easily injured by certain insecticides, it is advisable to make three or four preliminary sprays at weekly intervals to a few plants under each growing environment, before proceeding to treat an entire crop If combinations of chemicals are to be used in a single spray (for instance Pentac plus Meta-Systox-R for mite and scale control) be especially careful to make preliminary treatments Since there may be several formulations of a chemical compound labeled for market with different concentrations of the active ingredient, recommendations on the manufacturer's label should be followed explicitly

APHIDS

Aphids are small, soft-bodied insects which feed on young developing leaves and stems, causing

Figure 1 *Apical leaves of the Zebra plant infested with wingless adult females and nymphs of the green peach aphid*

distorted or stunted plant growth (Fig 1) Their body color is quite variable, most commonly including green, yellow or black forms An alert plantsman can often detect their white skins shed on older leaves which are frequently the first indication of an aphid infestation

Multiplication rate of aphids when uncontrolled, is enormous When aphid populations become overcrowded, winged forms may be produced and disperse to begin new infestations Many growers first notice an infestation on plants adjacent to greenhouse vents or evaporative cooling pads because these are the locations where aphids frequently gain entry

Winged forms caught in air currents may be rapidly spread throughout a greenhouse The initial source of these aphids may be partially eliminated by strict sanitation and weed control both outside and inside the greenhouse

Aphids excrete a sticky honeydew which coats the infested foliage This honeydew is ideal for growth of the black sooty-mold fungus rendering the affected plant unsightly and unsalable Good aphid hosts are *Aphelandra*, *Brassaia*, *Gynura*, *Hoya*, and *Dieffenbachia*

Control is usually achieved by a single, properly applied spray, drench or granular treatment (Table 1) Occasionally, reinfestations occur and a second spray application may be necessary after four to six weeks

CATERPILLARS

Caterpillars are immature forms (larvae) of moths and are commonly referred to as armyworms, loopers or cutworms These insects actively feed on and damage a wide range of foliage plants Infestations often occur when adult moths fly into greenhouses from outdoor areas and deposit eggs on foliage

Initial infestations are difficult to detect because larvae often feed only at night Only after they grow to good size do larva actually feed on the whole leaf When small, the feeding larvae remove the undersurface layers of leaf tissue and produce a "window" effect on the leaf surface, a condition commonly observed with *Brassaia* seedlings

Caterpillars are chewing insects and are susceptible to contact or stomach poison insecticides and are unaffected by systemics like Temik Exclusive use of Temik often allows larvae populations to increase to the point where severe losses occur It is much easier to suppress infestations if controls are applied when caterpillars are small (Table 1).

A relatively new biological control material which is very safe to humans is a bacterium which causes a fatal disease of caterpillars The bacterium, *Bacillus thuringiensis* (commonly referred to as Bt) is commercially available as Biotrol, Dipel or Thuricide

To be effective, caterpillars must actually eat plant parts containing Bt residues Many growers have tried Bt and have had little success Upon investigation we have found that they had failed to use a spreader-sticker with the Bt to improve coverage and retention on the foliage

Once Bt is ingested, affected larvae cease to feed and die in two to three days Repeated applications at seven to fourteen days may be needed to maintain residues on rapidly growing foliage

FUNGUS GNATS

Foliage growers frequently become concerned about tiny "black flies" which can become abundant under greenhouse conditions These flies often are fungus gnats and represent a potential threat The 1/8-inch long adult fly is most visible near or on the soil surface or under leaves The immature legless form, the black-headed larvae is less than 1/4-inch long and lives in the soil.

These larvae have been associated with feeding on and decay of plant roots and lower stem tissues Highly organic soils appear to promote infestations, especially in the presence of decaying plant tissue. Feeding may be particularly injurious to seedlings, rooted cuttings or young plants Controls are usually directed against the larval stages by applications of

Figure 2. *Infestation of solanum mealybugs on* Gynura *Notice the clumping of individuals and the waxy accumulations which make it difficult for insecticides to effectively control this pest*

Systemic chemicals are often more effective for control of mealybugs than contact insecticides.

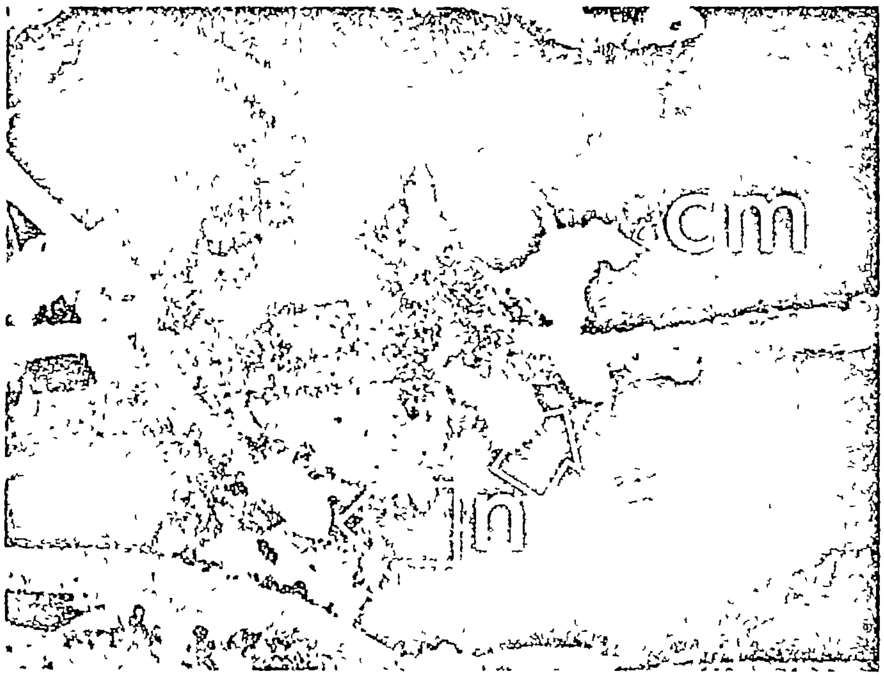


Figure 3. *Root mealybug infestation of bromeliad* (Aechmea) *roots Note the cottony-like masses (cm) and nymphs (n) located on the root tissue*

chemical drenches to infested soils (Table 1)

MEALYBUGS

These are soft-bodied insects possessing a covering of fuzzy, white, waxy threads Although there are various types that attack foliage, the longtailed, solanum and citrus mealybugs are most troublesome

As with aphid infestations, affected foliage most often is coated with honeydew Adults and nymphs (young) tend to clump on affected foliage making it difficult for insecticides to penetrate the waxy deposits that surround them (Fig 2) For this reason, systemic chemicals are often more effective than contact insecticides

Reproduction is continuous in greenhouses, consequently it is important to make several insecticide applications at intervals of approximately 14 days Systemic drench and granular (Temik) insecticides are also effective Frequent hosts are *Aphelandra, Ardisia, Dieffenbachia, Gynura, Scindapsus, Asparagus, Dracaena, Maranta* and *Dizygotheca*

In addition to foliar mealybugs, several mealybug species live below the soil surface and feed on root tissue This small, below ground pest is often overlooked until infestations are severe and widespread In the retail shop, how frequently are plants removed from containers to inspect their roots?

White masses contain eggs

If root mealybugs are present, a careful examination may reveal white, cottony-like masses which contain eggs and females (Fig 3)

Root mealybug nymphs are active and may crawl from pot to pot via drainage holes or be spread in irrigation water Populations may become established in soils beneath infested plants, forming a source of reinfestation to following crops

To eradicate this pest, be sure to sterilize all soil, pots, tools and destroy any infested plants which have not responded to previous insecticide applications Clean bench and potting areas, apply effective insecticide drench treatments to stock plants (Table 1)

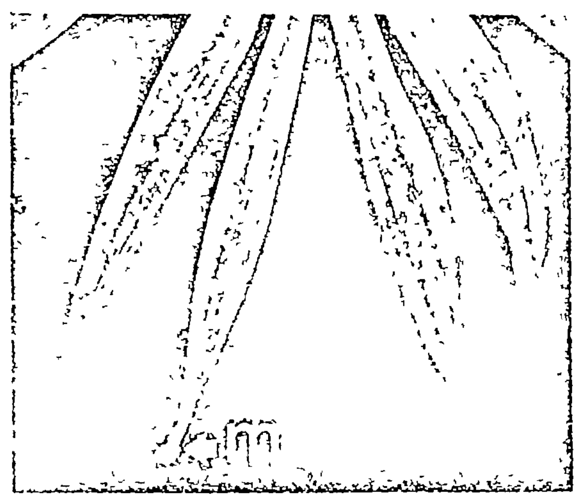


Figure 4 *Spider mite infested foliage of the parlor palm Notice the webbing, speckling of upper leaf surfaces due to feeding injury and the mass of living mites (m) which are about to disperse from the leaf tip*

and practice strict sanitation in the future

Temik is also effective when care is given to uniformly apply the proper amount over the soil surface before watering Good host plants are *Collinia, Peperomia, Dieffenbachia, Philodendron, Syngonium, Scindapsus,* *Injury caused by small mites is often mistaken for spray injury or cultural mismanagement.*

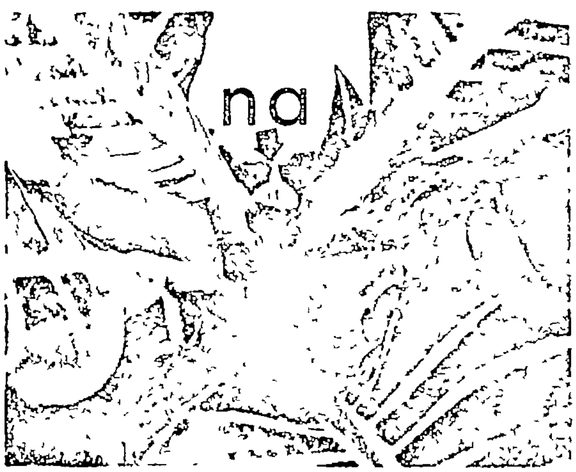


Figure 5 *Damage to the Zebra plant by the microscopic broad mite Note the necrosis of the shoot apex (na) which results under severe infestations*

Ficus, *Dizygotheca*, *Chlorophytum* and *Bromeliads*

MITES

The two-spotted spider mite is the most common and destructive mite on tropical foliage plants. This mite is small, may be brown, greenish or orange-red, is eight-legged and hardly visible even when full grown You will need a 10X or greater magnifying glass to readily see them and populations often become quite large before they are detected.

Most plantsmen readily recognize this pest when it produces webs over the foliage, especially on the new leaves Mites feeding on the underside of leaves produce a greyish or yellowish speckling which is especially prominent when viewing the upper leaf surface In severe infestations and leaf injury, affected leaves become dry and drop off.

A point of importance in understanding this pest's habits in the greenhouse is its dispersal mechanism When their numbers and subsequent competition for food increase, mites congregate in an orangish mass at the apex of the plant, typically at the tip of the apical leaf (Fig 4) Individual mites then drop on silken threads, forming a "rope" of living mites

Spread to new plants can then occur by air movement, on clothes or by cultural operations Once this dispersal phase begins, severe and irreversible damage has usually occurred resulting in an unsalable crop

Mites develop resistance

Miticides (Table 1) should be applied a minimum of two times at a five to seven day interval to allow for egg hatch between applications so that both adults and individuals that hatch from eggs are killed If a miticide is properly applied and is not providing control, shift to another because mite populations easily develop resistance to most miticides

Kelthane, Omite, Pentac and Temik each belong to a different class of chemicals and may be used alternately every few months to avoid development of resistant mites Growers must learn from experience which chemicals, when correctly applied, fail to give satisfactory control, and to then try other non-chemically related products

Often, a severe mite problem occurs on plants in the retail shop because a few mite eggs or nymphs survived even the best and most conscientiously followed control program during production It is imperative therefore, that a miticide be applied to major mite host plants as close to the date of shipment as possible

Apply miticide before marketing

The retailer might also consider applying a miticide to major mite

Figure 6 *False spider mite infested foliage of the Lipstick plant showing mite damaged (md) basal areas of affected leaves*

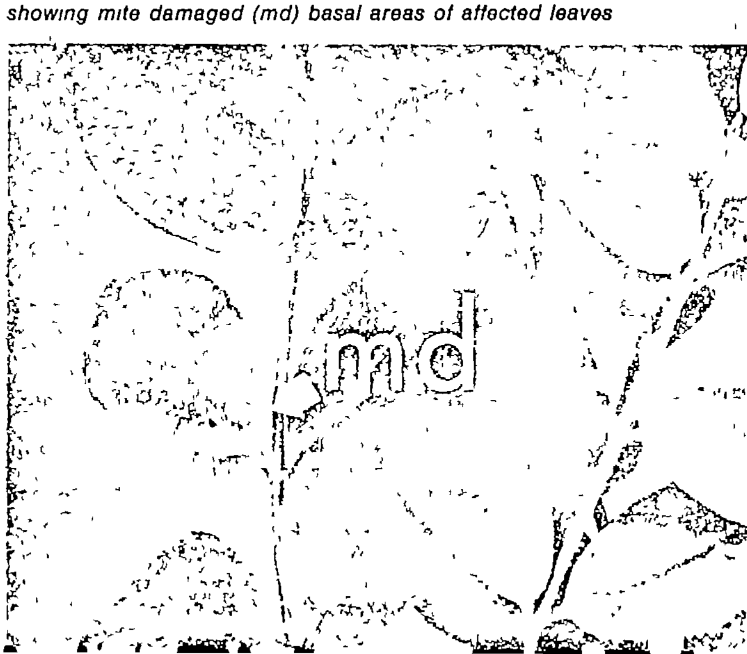


Figure 8 *Foliage of the Zebra plant infested with a soft bodied scale, the hemispherical scale These are all females and notice their location along veins on the underside of affected leaves*

Figure 7. *Heavy infestation of the false oleander scale, an armored or hard bodied scale, a severe pest of parlor and Areca palms Note the female scale (f) and the cottony-like masses of males (m)*

host plants prior to placement into retail operations Major hosts of this pest are *Brassaia*, *Codiaeum*, *Collinia*, *Cordyline*, *Dieffenbachia* and *Maranta*

Other than the spider mite, several microscopic, injurious mites also have been repeatedly detected on foliage plants The most important of these appear to be the broad and cyclamen mites These mites are transluscent and so small that their presence is usually first detected by the plant injury symptoms rather than by visual observation

Affected leaves are curled or cupped, smaller than usual and frequently newly produced leaves will not mature *(Hedera)* or developing leaves will have serrated margins *(Alphelandra)* Heavy infestations often cause death of the shoot apex (Fig 5)

The false spider or flat mite, another microscopic mite, is reddish in color and heavy infestations produce a bronze or reddish discoloration on basal areas of affected leaves (Fig 6) Damage by this pest has been especially serious on *Aphelandra*, *Columnea* and ornamental cacti

These preceding small mites are readily moved about on infested plants, equipment or nursery personnel Injury caused by these tiny pests is often mistaken by growers, florists, consumers and researchers for spray injury or cultural mismanagement and, therefore, effective controls are not applied

As with the spider mite, repeated applications of an effective miticide on a five to seven day interval is advised (Table 1)

SCALES

Scales are usually small and inconspicuous and by the time an infestation is noted, the population is usually so great that the plant is unsalable (Fig 7) Once again, the enormous amounts of honeydew excreted by feeding scales allows the prolific growth of sooty mold

Eggs, produced beneath a relatively hard female shell, hatch into translucent crawlers, the only stage usually not covered by a relatively hard covering Crawlers move over new foliage to locate feeding sites, usually on or near veins on the underside of leaves (Fig 8) This stage is practically invisible to the unaided eye making it nearly impossible to detect new infestations on cuttings or other propagation material It is also at this stage that introduction of scales into production areas occurs Consequently, it is imperative to maintain stock areas "scale-free"

Quarantine new plants

It is wise to quarantine newly acquired plants and if careful examination shows living scales present, apply effective insecticides (Table 1) until the infestation is eliminated

To check for living scales, lift the female scale shell (Fig 7 and 8) using the point of a knife If it is firmly attached to the plant or if the top cover pops off revealing a yellow-orangish, plump mass attached to the leaf surface, consider the scale alive

Figure 9 *Thrips feeding injury to* Ardisia *foliage Note the silver flecked appearance of affected areas*

Apparently dead female scales, however, may contain living eggs that will produce crawlers Use at least a 10X hand lens to look for the miniature "jelly bean-like" eggs beneath the empty female shell

Chemical control is difficult because of the shell-like body of the females which protects both feeding scales and eggs from the toxic chemicals Sprays or drenches of systemic insecticides such as Meta-Systox-R or dimethoate, are effective when correctly applied (Table 1) Sprays may need to be repeated at two to three week intervals

Continue to check for living scales, especially on new foliage, keeping in mind that scale populations are slow to respond to treatment and they breed constantly in the greenhouse Therefore, persistence in treatment and careful observation of results will be required to bring success

Figure 10 *Adult whiteflies congregating and feeding on the underside of infested young foliage*

THRIP

These small, slender, gregarious, fleet-footed insects feed by rasping or shredding plant tissue surfaces with their mouth parts Tissue around feeding punctures dries out giving a silver flecked appearance to wounded areas (Fig 9) Larvae are frequently pale yellowish and highly active Adults are often darkly colored and are able to jump when disturbed

Thrips feed primarily on young tissue in the bud or shoot apexes where new leaves are expanding Once again a keen eye and the frequent use of a good hand lens may avoid expensive losses Repeated sprays at seven to ten days with Meta-Systox-R have been effective (Table 1) Primary hosts are *Brassaia, Ficus, Philodendron, Sansevieria* and *Syngonium* .

WHITEFLIES

This pest is most noticeable when infested plants are moved The winged adults which collect in vast numbers on the upper or young foliage take to the air producing a miniature "snowstorm" (Fig 10) Whiteflies also produce enormous amounts of honeydew

Greenhouse infestations more than often occur through the introduction of infested plants or by migration of winged adults from infested areas outside of the greenhouse Again, inspect newly received plants and remove all extraneous plant material from in and around your operation.

In controlling this pest the adults are easily killed, but the remaining stages usually continue to develop and produce more adults It is, therefore, advisable to apply an insecticide repeatedly at a seven to ten day interval for three to four weeks (Table 1). Temik, when applied properly, may control whitefly for periods up to two months. □

CHEMICALS FOR CONTROL OF DISEASES OF TROPICAL FOLIAGE PLANTS

J. F. Knauss
University of Florida, IFAS
ARC-Apopka Research Report
RH-75-2

FOLIAR FUNGAL DISEASES

Material	Concentration per 100 gal	Comments
Benlate 50 WP[b]	8 oz	Active against *Fusarium*, *Rhizoctonia* and *Cercospora*. Must be alternated with other fungicides. Non-phytotoxic.
Captan 50 WP[b]	1 1/2 lb	Broad spectrum of activity. Fair to good control. Non-phytotoxic.
Daconil 75 WP 6 F	1 1/2 lb 1 1/2 pt	Best choice for broad spectrum compound. Can be very phototoxic when tank mixed with other chemicals, otherwise non-phytotoxic. No spreader sticker needed.
Zinc + Maneb[a,b]	1 1/2 lb	Good broad spectrum activity. Relatively non-phytotoxic.
Zineb 75 WP[b]	1 1/2 lb	Broad spectrum. Moderate to good control. Non-phytotoxic. Reported to be discontinued by company.

[a]Includes Dithane M-45, Fore, Manzate 200

[b]Add spreader-sticker (adjuvant). Plyac (2-4 oz/100 gal) employed at ARC-Apopka.

FOLIAR BACTERIAL DISEASES

Streptomycin Sulfate 21.2 WP[a,c]	100 - 200 ppm	Good activity against *Erwinia* diseases. Do not increase concentration above 200 ppm as resistance can occur. May be used for a 10 - 30 min dip of propagative units.
Combination of Kocide 101 86 WP & zinc + maneb[b,c]	1 1/2 & 1 1/2 lb	Good activity against *Xanthomonas* diseases. May by phytotoxic on many foliage plants. Should never be used as general spray for fungal and bacterial control.

[a]Available as Agri Strep, Agrimycin 17

[b]zinc + maneb = Dithane M-45, Fore, Manzate 200

[c]Add spreader-sticker (adjuvant). Plyac (2-4 oz/100 gal) employed at ARC-Apopka.

SOIL-BORNE FUNGAL DISEASES AND FUNGICIDES FOR DRENCH APPLICATIONS

Rhizoctonia

Banrot 15-25 WP	8 - 12 oz	Good activity, also contains ethazol (Truban or Terrazole) which is active against *Pythium*.
Benlate 50 WP	8 oz	Excellent control, must be used in combination with ethazol or with Dexon if *Pythium* or *Phytophthora* also present.
Fermate 76 WP	1 - 1 1/2 lb	Good control, may cause stunting of seedlings and cuttings.
Terrachlor 75 WP	3/4 - 1 1/2 lb	Good control, should be applied only once a year. May cause stunting.

Pythium

Banrot 15-25 WP	8 - 12 oz	Good activity, also contains methyl thiophanate which is active against Rhizoctonia and Fusarium.
Dexon 35 WP	8 - 16 oz	Good control. Also active against Erwinia spp. Reported to be discontinued by company.
Ethazol (Truban 30 WP or Terrazole 35 WP)	8 - 12 oz	Excellent control of Pythium.
Nurelle 7.2 EC	1 - 2 pt	New compound due to be available late 1975. Excellent control, non-phytotoxic, systemic. Should be tried and compared to presently-used compounds.

Phytophthora

Ethazol (Truban 30 WP or Terrazole 35 WP)	8 - 12 oz	Moderate to good control.
Nurelle 7.2 EC	1 - 2 pt	Excellent control. See Above

Sclerotium rolfsii

Fermate 76 WP	2 - 3 lb	Good control. May cause severe stunting of seedlings or cuttings.
Terrachlor 75 WP	1 - 1 1/2 lb	Good control. Should be applied only once a year. May cause stunting.

Broad Spectrum Drenches

Banrot 15-25 WP	8 - 12 oz	At currently suggested concentrations will provide control of *Pythium*, *Rhizoctonia* and *Fusarium*.
Truban 30 WP + Benlate 50 WP[a]	12 oz + 8 oz	Best combination for broad spectrum control of *Pythium*, *Rhizoctonia*, *Fusarium*, and *Phytpphthora*.

[a]If control of *Sclerotium rolfsii* is desired also, either Fermate 76 WP (2-3 lb/100 gal) or Terrachlor 75 WP (1-1 1/2 lb/100 gal) must be used in place of Benlate.

Suggestions on Drench Rate (Volume)

How much to apply to a bed or to pots is often a difficult question to answer. The following suggested rules, if followed, will provide control with the least phytotoxicity.

Type Unit	Rate (volume) applied per sq. ft. surface area
Mini-pots and shallow flats	3/4 pint/sq. ft.
Other pots... 4 inches in diameter and propagative beds 4 inches in depth	1 pint/sq. ft.
Pots 4 inches in diameter and propagative beds 4 inches in depth	1 1/2 - 2 pints/sq. ft

NOTE: If mixes or soils contain less than 50 per cent peat moss never exceed application rate of 1 pint/sq. ft.

General Rules for Soil Fungicide Drench Application

1. Repeat drench applications should be applied no sooner than every 3 mos.

2. With all drench applications except Nurelle, come back and lightly rinse fungicide off foliage after application.

3. Where preventative drench is applied to leafy unrooted cuttings, apply drench prior to sticking cuttings. Have all workers wear Playtex-type rubber gloves when sticking cuttings.

Fungicide-Bactericide Dips

Although only limited research work on dips has been done on foliage plants, a 10 - 30 minute dip containing Captan 50 WP (1 1/2 - 2 lb/100 gal) and Streptomycin sulfate 21.2 WP (200 ppm) + 2 oz Plyac/100 gal. will provide broad spectrum activity. Benlate 50 WP (1 - 1 1/2 lb /100 gal) can also be included and may provide additional benefit. Remember to keep the suspension agitated during dipping and to allow the dipped units to drain and become relatively dry before placing into propagative beds or pots.

Literature Dealing with Diseases of Tropical Foliage Plants

1. Selected issues of "Florida Foliage Grower". Check index issues for articles dealing with plant diseases. Obtain From: IFAS Extension Service, University of Florida, Gainesville, 32611.

2. Plant Pathology Circular Series. Obtain From: Division of Plant Industry, Doyle Connor Building, Gainesville, Florida, 32602.

3. "The U. C. System for Producing Healthy Container-Grown Plants - Manual 23". Costs $1.00 and is the best buy one can make. Get it! Obtain From: Agricultural Extension Service, University of California, Berkeley California, 94720.

4. Articles by J. F. Knauss entitled "Common diseases of tropical foliage plants". A series of three articles covering fungal, bacterial and soil borne diseases of tropical foliage plants. Appeared in:

Florists' Review Publication Dates:

May 17, 1973
October 11, 1973
May 2, 1974

For information on availability of single issue copies write Florists' Review Publishing Company, 343 South Dearborn St., Chicago, Illinois. 60604.

Also in:

The Florida Nurseryman Publication Dates:

November 1974, Volume 19(11)

December 1974, Volume 19(12)

January 1975, Volume 20 (1)

For information on availability of single issue copies write The Florida Nurseryman, 919 N. W. 13th Court, Ft. Lauderdale, Florida 33311.

COMMON DISEASES OF TROPICAL FOLIAGE PLANTS:

III. Soil-Borne Fungus Diseases[1]

J. F. Knauss
IFAS, University of Florida
Apopka, Florida
ARC-Apopka Research Report RH-75-8

The first two articles of this series dealt with the more important tropical foliage plant foliar diseases caused by fungal and bacterial plant pathogens. Although these previously discussed pathogens are economically significant in the Florida foliage plant industry, the fungal pathogens referred to as soil-borne and causing root, stem and crown rots are by far the most destructive and important.

Severe economic losses caused by soil-borne fungal pathogens are often experienced by Florida foliage plant growers These losses probably comprise 25 to 50 percent of the total disease losses resulting from all foliage plant pathogens. Although these figures are not substantiated by actual data, the author, after spending nearly seven years in the Florida foliage plant industry, agrees that disease losses resulting from attacks by these pathogens are high.

This article describes diseases caused by the more important soil-borne fungal pathogens and includes fungicides found by research to be effective and nonphytotoxic to foliage plants. The fungicide information, however, must not be interpreted as a formal recommendation. Rather, foliage plant growers are advised to consult with their state extension agent as to the legality of employing any fungicide listed.

BACKGROUND INFORMATION

Soil-borne fungal pathogens are capable of attacking seed, seedlings, propagative cane pieces, rooted and unrooted cuttings and established potted plants. Although these diseases are usually more severe at particular times of the year, attack by these fungi may occur year around in Florida because of its subtropical climate. New foliage growers, especially those trained in the north, are amazed at the number and severity of disease problems they must face and overcome to realize a profit. In addition to Florida's environment, so conducive for plant pathogen multiplication, other factors that strongly influence disease development are related to many cultural

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[1]Originally published as ARC-A Mimeo 72-4. A revised form was published with photographs in Florists' Review 154(3987), May 2, 1974 and reprinted in Florida Nurseryman 20(1), January 1975.

methods presently employed.

I. STOCK BED AREA

Without question, the more disease-free the stock plants, the more vigorous and disease-free plants will be in propagative and finishing areas. In Floridá, stock plants of many plant species are often grown in ground beds of native sandy soil amended with peat Effective sterilization of these beds prior to their planting can be accomplished by chemical fumigation or steam sterilization. These beds remain clean (free of pathogens) for only a short time before plant pathogens become reestablished. There is no sense in fooling oneself, maintaining ground beds in a disease-free state is impossible. The best one can hope for in ground bed stock production is to maintain a low population of pathogens with a year-round soil fungicide program. This type of program can be utilized for many foliage plants, but yields and control of crop quality are usually far less than production in raised beds under covered structures where sterilized soil mix, improved watering systems and clean plants are employed. Even with raised bed production, however, a minimum preventative program of soil fungicide application should be employed with disease-prone foliage plants (pothos, dieffenbachia, aglaonema, some philodendrons, maranta and others) to ensure maximum production and profit.

Selection of material to plant in stock beds is difficult because of the lack of certified clean stock. Cuttings for stock should be chosen from plants known to be healthy and which are growing under improved cultural conditions. To minimize the carry-over of soil-borne pathogens, these cuttings should be taken no less than one foot above the soil surface. Hot-water treatment of hardened planting material of certain foliage plants (aglaonemas, aloes, caladiums, dieffenbachias, *Fittonia* spp , *Philodendron* spp., *Syngonium* spp.) has been employed and may rid the planting stock of soil-borne fungal pathogens such as *Rhizoctonia* spp. and *Pythium* spp This technique will, however, demand careful temperature regulation to eliminate possible injury to the plant material.

II. PROPAGATION AREA

Foliage plant propagation by seed, cane or cutting should always be carried out in raised beds, preferably employing sterilized media. In Florida, unsterilized domestic or foreign peats are normally employed as the propagative media. Prior sterilization is probably not so important as it first seems, if the peat is dug from and old, deep bog and has not been recontaminated with plant pathogens after digging Peat from these type of bogs contain few, if any, plant pathogens.

Trouble usually occurs when native peat and/or muck is dug close to the soil surface and especially from areas previously cropped to vegetables or ornamental plants. Peats taken from these areas are usually less desirable horticulturally and also contain an abundance of pathogens that must be eliminated by fumigation or steam sterilization prior to use.

After propagation of each crop, plant remains should be removed and new peat incorporated to replace peat used in the previous propagation. The bed then should be steam sterilized and leached prior to use. Growers who cannot sterilize should use all the other procedures mentioned and employ a preventative soil fungicide program to keep pathogen populations low. These fungicides are normally applied as a preplant dip to the cuttings and/or drench to the propagative media. Experience with peat-containing propagative media indicates drench treatments should be applied prior to planting leafy propagative cuttings and immediately after sticking nonleafy cuttings, cane sections and seed. Drench rates should be applied according to the rules outlined at the end of this article. Keep in mind that the more times a bed is reused without thorough sterilization, the more likely the prospect of a more difficult-to-control, high pathogen population building up in the propagative medium

When it is necessary to use unsterilized media, the foliage plant species should be rotated in propagation areas. Some foliage species that are especially poor risks to propagate repeatedly in the same media without sterilization are syngonium (nephthytis), pothos, aglaonema, dieffenbachia, schefflera, neanthe bella palm and peperomia. One should always follow these crops with a species that is more disease resistant, one that in the past has given few or no problems during propagation.

III. THE FINISHING AREA

Rooted plants should always be potted in a sterilized potting media. Often, apparently healthy foliage plants progressively deteriorate in the finishing or holding areas. These plants are either infected at time of potting or were potted in contaminated media. Even if plant and media are clean at time of potting, the soil may become recontaminated or plants infected in many ways. Therefore, foliage plants grown in Florida should receive a broad-spectrum soil fungicide drench soon after potting. This drench will prevent development of a high pathogen population in the medium thus allowing root growth and proper establishment. Although one treatment is usually enough for most potted material, large plants held in the nursery for long periods should be retreated once every three months.

Other aids to prevent soil-borne fungal disease development in pots are:

(a) Use of well-aerated, easily drained soil mixes.

(b) Care to not overwater. Water only when needed and then water thoroughly.

(c) Place pots on surfaces that will not restrict drainage from the holes in the pot. One should never put pots with holes in the bottom directly on a plastic sheet.

MAJOR PATHOGENS

1. Rhizoctonia solani, Rhizoctonia spp.

Susceptible plants: Aglaonemas, aphelandras, ardisias, azaleas, caladiums, dieffenbachias, ferns, gardenias, Gynura sp., hoyas, pertusums, marantas, the neanthe bella palm, peperomias, Philodendron oxycardium, P. selloum, pileas, pothos, scheffleras, Scindapsus pictus, Syngonium spp. and many others.

Rhizoctonia is active the year around and prefers a warm, not excessively hot, moist environment. When these conditions exist, growers must be on the lookout for this pathogen.

Rhizoctonia has a wide host range and attacks all types of plant tissue. Disease resulting from attack by this pathogen often appears to growers to occur overnight. Although Rhizoctonia grows rapidly, it does not move that fast. This impression by growers is probably caused by the pathogen's wide distribution and its ability to survive conditions unfavorable to its growth and the fact it attacks a wide variety of foliage plants when conditions become favorable for growth.

Rhizoctonia usually attacks seedlings at or near the soil line causing a pre or postemergence damping off. On older schefflera seedlings, Rhizoctonia often causes a reddish-brown constricted lesion at the soil line with healthy tissue above and below. The fungus also may spread rapidly over the foliar surface of closely spaced seedlings and cuttings. Aerial infections occur under warm, moist conditions, especially when seedlings are planted close together. Aerial infections by this fungus often cause a yellowing and eventual collapse of lower leaves and stems of closely spaced plants or pots of aglaonemas, dieffenbachias, pothos and syngoniums. In cases of foliar attack, reduction in watering coupled with wider plant spacing and use of fans and turbulators to increase air movement among the plants go a long way in solving the problem.

Normally, identification of Rhizoctonia infections can be made in the greenhouse or nursery by the grower. Rhizoctonia produces prominent reddish brown threads (which are really the body of the fungus) that may be seen on the diseased tissue. Often these threads can be seen on the soil surface near infected plants. If Rhizoctonia-infected leaves touch the propagation medium they will usually be difficult to lift when raised slowly because the threads of Rhizoctonia are attached to both soil and leaf surfaces. In a sense, these threads act like small ropes holding the leaf to the propagation media. Again, the threads will be visible.

2. Pythium spp.

Susceptible plants: Aglaonemas, aphelandras, ardisias, caladiums, Christmas cactus, dieffenbachias, marantas, pertusums, the neanthe bella palm, peperomias, Philodendron oxycardium, P. panduraeforme, P. selloum, other philodendrons, pothos, scheffleras and many others.

In the Florida foliage industry, attacks by this fungus group are most severe under warm, wet conditions. This temperature effect is somewhat opposite of that in the north where attacks by species of this group are favored by cool, wet conditions. Pythium attacks seed, seedlings, cuttings, propagative cane sections, roots and occasionally stems. Potted plants infected with Pythium usually show a slight to severe wilt often accompanied by a progressive yellowing of the leaves from the base of the plant upward. Roots of infected plants will be collapsed and black in color. Close observation of roots invaded by Pythium will show the gray to black rot initiating at the root tip and progressing backward. The exterior of severely rotted roots will sluff off leaving only the inner core giving the root a hanging-thread appearance. In propagation beds, Pythium alone or in combination with Rhizoctonia may rot the roots and stems of rooted cuttings causing their eventual collapse.

Seed and seedling attack by Pythium may be inhibited by wider spacing of seeds and careful watering. The root rot phase of the disease on rooted cuttings and potted plants may be inhibited by planting in well-aerated, rapidly drained media. Care not to overwater aids in Pythium Root Rot control.

Pythium may be spread on contaminated tools, hands, feet, media, flats, pots or in or on infected plant material. Once established in a growing medium, Pythium can persist for long periods of time, even in the absence of a susceptible host plant.

3. Phytophthora palmivora, P. parasitica.

Susceptible plants: Aglaonemas, azaleas, caladiums, dieffenbachias, Philodendron oxycardium, probably other philodendrons, peperomias, others.

Phytophthora is so closely related to Pythium that much of the information presented previously for Pythium applies here as well. As a pathogen group, however, Phytophthoras are more aggressive when attacking the same host plant and are generally harder to control than Pythiums. Phytophthora may also attack foliage, often causing a serious leafspot of Philodendron oxycardium and at times causing a serious foliar blight of Dieffenbachia species. In contrast to Pythium, Phytophthora has the ability to attack mature tissue of plants such as Dieffenbachia picta 'Perfection' causing plant collapse and cane decay. Stem attacks of D. picta 'Perfection" by Phytophthora are often mistakenly contributed to infection by Erwinia chrysanthemi because of the close resemblance of resulting disease symptoms. On this host, positive diagnosis of either pathogen should never be made on symptoms alone and should be reliant upon actual isolation of the pathogen.

4. Sclerotium rolfsii

Susceptible plants: Caladiums, dieffenbachias, Dracaena godseffiana, the neanthe bella palm, peperomias, pileas, Philodendron micans, P. oxycardium, pothos, Scindapsus pictus, scheffleras, syngoniums and many others.

Sclerotium rolfsii has been reported on a wide variety of agronomic crops. In Florida, the fungus attacks during the warm to hot, wet periods of the year. This pathogen is mainly a problem in the south and is not a major concern to northern growers.

Sclerotium rolfsii is easily recognized by its heavy, white fungus growth on the soil surface and on the affected plants. Almost always, numerous white to tan sclerotia about the size and appearance of mustard seeds or small Osmocote granules can be found where the disease is present. These sclerotia act as resting structures and allow the fungus to remain in an inactive but living state for long periods of time. Once established in a propagation bed, S. rolfsii may spread rapidly and cause rapid and severe losses Losses from S. rolfsii primarily occur in the propagation areas, with scattered instances noted in stock and finishing areas.

When a crop in propagation is severely affected by this pathogen, the bed should be sterilized before reuse. Where impossible, the bed should be cleaned of all plant residue and foliage plants other than those listed as susceptible to S. rolfsii should be chosen for propagation. A preplant fungicide drench may help control the pathogen but lack of phytotoxicity cannot be assured with the fungicides known to control this pathogen. When centers of S. rolfsii infection are noted in propagation beds, the diseased plants should be lifted, put into a bag and destroyed. The infested area plus a 2-foot border should then be drenched with an effective soil fungicide. After one day, the infested area (2-foot border not included) should then be removed and discarded.

5. Fusarium moniliforme

Susceptible plants: Dracaena spp.

Little is known of the importance of Fusarium moniliforme in the decays of unrooted cuttings of Florida foliage plants. Because it can cause a serious cutting decay of Dracaena deremensis 'Warneckii' and D. marginata it probably also attacks other dracaenas and the pleomeles, both known to be susceptible to foliar attack by this pathogen. Understanding the importance of F. moniliforme in the Florida foliage industry depends on future investigations.

FUNGICIDES FOR CONTROL

Several fungicides that are commercially available have been shown to have excellent to good activity for control of the previously discussed pathogens. Growers should not, however, think of fungicides as their only line of defense against soil-borne pathogens but rather incorporate the following fungicide suggestions with the best available methods of plant culture and employment of disease-free plants.

SOIL FUNGICIDES FOR CONTROL OF SOIL-BORNE PATHOGENS

RHIZOCTONIA

Material	Conc./100 gal.	Comments
Banrot 15-25 WP	8 - 12 oz	Good activity, active ingredient m-thiophanate, also contains ethazole (Truban or Terrazole) which is active against Pythium.

Material	Conc./100 gal.	Comments
Benlate 50 WP	8 oz	Excellent control, must be used in combination with ethazole or with Dexon if Pythium or Phytophthora also present.
Fermate 76 WP	1 - 1 1/2 lb	Good control, may cause stunting of seedlings and cuttings.
Terrachlor 75 WP	3/4 - 1 1/2 lb	Good control, should be applied only once a year. May cause stunting.
	PYTHIUM	
Banrot 15- 25 WP	8 - 12 oz	Good activity, active ingredient ethazole (Truban or Terrazole), also contains m-thiophanate which is active against Rhizoctonia and Fusarium.
Dexon 35 WP	8 - 16 oz	Good control. Also active against Erwinia spp.
Ethazole (Truban 30 WP or Terrazole 35 WP)	8 - 12 oz	Excellent control of Pythium.
Nurelle 7.2 EC	1 - 2 pt	New compound due to be available in 1976. Excellent control, non-phytotoxic, systemic. Should be tried and compared to presently-used compounds.
	PHYTOPHTHORA	
Ethazole (Truban 30 WP or Terrazole 35 WP)	8 - 12 oz	Moderate to good control.
Nurelle 7.2 EC	1 - 2 pt	Excellent control. See above.

Material	Conc./100 gal.	Comments
	SCLEROTIUM ROLFSII	
Fermate 76 WP	2 - 3 lb	Good control. May cause severe stunting of seedlings and cuttings.
Terrachlor 75 WP	1 - 1 1/2 lb	Good control. Should be applied only once a year. May cause stunting.
	BROAD SPECTRUM DRENCHES	
Banrot 15 - 25 WP	8 - 12 oz	At currently suggested concentrations will provide control of *Pythium*, *Rhizoctonia* and *Fusarium*.
Truban 30 WP + Benlate 50 WP[a]	12 oz + 8 oz	Best combination for broad spectrum control of *Pythium*, *Rhizoctonia*, *Fusarium*, and *Phytophthora*.

[a] If control of *Sclerotium rolfsii* is desired also, either Fermate 76 WP (2-3 lb/100 gal) or Terrachlor 75 WP (1-1 1/2 lb/100 gal) must be used in place of Benlate.

SUGGESTIONS ON DRENCH RATE (VOLUME)

How much to apply to a bed or to pots is often a difficult question to answer. The following suggested rules, if followed, will provide control with the least phytotoxicity.

Type Unit	Rate (volume) applied per sq. ft. surface area
Mini-pots and shallow flats	3/4 pint/sq. ft.
Other pots to 4 inches in diameter and other propagative beds or units up to 4 inches in depth	1 pint/sq. ft.
Pots > 4 inches in diameter and propagative beds or units > 4 inches in depth	1 1/2 - 2 pints/sq. ft.

NOTE: If mixes or soils contain less than 50 per cent peat moss never exceed application rate of 1 pint/sq. ft.

GENERAL RULES FOR SOIL FUNGICIDE DRENCH APPLICATION

1. Repeat drench applications should be applied no sooner than every 3 months.
2. With all drench applications except Nurelle, come back and lightly rinse fungicide off foliage after application.
3. Where preventative drench is applied to leafy unrooted cuttings, apply drench prior to sticking cuttings. Have all workers wear Playtex-type rubber gloves when sticking cuttings.

To simplify information, trade names of products have been used. No endorsement of named products is intended, nor is critism implied of similar products not mentioned. Mention of a chemical does not imply guarantee of effectiveness or safety, nor that the chemicals or uses discussed have been registered by appropriate state and federal agencies.

FLORIDA COOPERATIVE EXTENSION SERVICE

INSTITUTE OF FOOD AND AGRICULTURAL SCIENCES, UNIVERSITY OF FLORIDA, GAINESVILLE

Florida Foliage Grower

Volume 12, Number 11
November, 1975

COMMON DISEASES OF TROPICAL FOLIAGE PLANTS: II - BACTERIAL DISEASES[1]

J. F. Knauss[2]

Bacterial plant pathogens find the warm-to-hot, moist environment of Florida especially fitting for their continued growth and survival. Some of the most severe and devastating diseases of tropical foliage plants are caused by bacteria belonging to the genera Erwinia, Xanthomonas and Pseudomonas.

The remainder of this article describes the more important bacterial diseases of tropical foliage plants. At the end of each individual disease discussion, the bactericides found by research to be effective and nonphytotoxic will be stated. The bactericide information, however, must not be interpreted as a formal recommendation. Rather, foliage plant growers are advised to consult with their state extension agent as to the legality of employing any bactericide listed.

I. BACTERIAL LEAF SPOT AND TIPBURN OF CORDATUM

Pathogen: Xanthomonas dieffenbachiae
Susceptible plants: Philodendron oxycardium (cordatum), Dieffenbachia spp., Anthurium spp., others

Just a few short years ago, Xanthomonas dieffenbachiae threatened the successful production of cordatum, which was then and probably still is the backbone of the foliage plant industry.

Although the pathogen, X. dieffenbachiae, was first described on Dieffenbachia picta in 1939, it wasn't until 1963 that it was noted on P. oxycardium and not until 1968 that it was definitely found to be X. dieffenbachiae. From 1963 to 1971, the pathogen was disseminated throughout most of the foliage industry and produced what became the foliage industry's most important disease problem. It remains yet today a common and important foliar bacterial disease.

Few stock areas of P. oxycardium are free of this pathogen. The pathogen's

[1] Originally published as ARC-A Mimeo 71-2. A revised form was published with photographs in Florists' Review 153(3958), October 11, 1973 and reprinted in Florida Nurseryman, December 1974, 19(12). This manuscript is adapted from ARC-Apopka Research Report RH-75-7.

[2] Associate Plant Pathologist, Agricultural Research Center-Apopka.

ability to move so rapidly within the industry has been facilitated by sales of X. dieffenbachiae-infected P. oxycardium between growers. Early symptoms of infection within the lamina of the leaf are small water-soaked dots which turn yellow. With age, the center of the lesion often turns brown. The most common symptom, however, occurs as a yellowing along the leaf margin, with the earliest sign occurring at the pointed leaf tip. During the hot wet summer, the infected leaf margin becomes nectrotic and turns a reddish-brown, hence the name "red edge", given to it by the growers. As the disease progresses, the affected leaf turns yellow and drops from the stem, thus making the node useless as a propagative unit. Severe leaf drop within stock plantings severely limits the number of cuttings produced per area. Often diseased leaves appearing free or nearly free of disease are stuck into propagative beds and turn yellow and die during the first weeks of propagation. The disease is most active in the summer months and may be present, but not detected, during the cooler parts of the year.

Once established, the pathogen is difficult and costly to control.

If a new stock area is planned, plant only cuttings known to come from clean sources. Never establish clean stock in the same structure and preferably not on the same property with X. dieffenbachiae-infected cordatum or dieffenbachia. Take steps to prevent any recontamination of clean areas. Because the pathogen attacks only the leaves and needs wet foliage to gain entrance, any cultural change that will aid in keeping the foliage dry will assist greatly in controlling the disease. Where disease is present and chemical control is required, weekly applications of a combination of Kocide 101 86 WP (1 1/2 pounds in 100 gallons of water) and Dithane M-45 (1 1/2 pounds in 100 gallons of water) will give effective control. A spreader-sticker such as Plyas (Allied Chemical, Atlanta, GA), should be added to the preceding combination at the concentration of 2 ounces in 100 gallons of water to ensure proper coverage and retention of the protective bactericide combination. Streptomycin, recommended in the early attempts to control this pathogen, was found after repeated sprays to be ineffective because the pathogen developed resistance to this antibiotic. If streptomycin is used it should be employed only on a schedule alternating with the Kocide-Dithane M-45 combination and then never at a concentration above 200 parts per million active ingredient.

Another effect influencing control is the possibility of a plant's nutritional level affecting disease development. In research conducted under glasshouse conditions, disease severity was found to decrease with increasing levels of nitrogen. To date, however, this effect has not been adequately studied and shown to occur under field conditions.

II. ERWINIA BLIGHT OF FOLIAGE PLANTS

Pathogen: Erwinia chrysanthemi
Susceptible plants: Aglaonema spp. Dieffenbachia amoena, other Dieffenbachia spp., Philodendron panduraeforme, Philodendron selloum, other Philodendron spp., Syngonium spp. and many others.

Without question, Erwinia chrysanthemi is the single most important bacterial pathogen of tropical foliage plants. Although discovered on chrysanthemum, the pathogen is by no means restricted to this ornamental crop and recently has been found as an important pathogen on poinsettia as well as several other ornamental crops, many of them foliage plants.

The pathogen is by no means meek in its attacks on foliage plants. Symptoms of attack may result from internal (systemic) invasion, these being a foliar yellowing of new leaves often with an accompanying wilt followed by a mushy, foul-smelling stem rot. Infected Dieffenbachia, especially Dieffenbachia amoena, exhibit these symptoms. When aerially disseminated, the pathogen can cause folair infection, resulting in a rapid mushy leaf collapse similar to that produced on Philodendron panduraeforme and Philodendron x 'Florida', or definite leaf spots as seen on Syngonium podophyllum 'Green Gold'. With some foliage such as Philodendron selloum, the pathogen might produce all the preceding symptoms in addition to several others. With this latter plant, attack often results in death of the plant.

Aerial spread of the pathogen from diseased to healthy plants occurs most often in free water that results from rainfall or overhead irrigation. Fresh wounds in the plant's epidermis facilitate infection, but in many cases they are not necessary for infection to occur. Another important method of dissemination of the pathogen may occur during the normal vegetative propagation of foliage plants. During propagation, workers handling and cutting E. chrysanthemi-infected canes, cuttings or vines unknowingly contaminate their hands and tools. These same contaminated hands and tools often are then employed in cutting clean plant material, which in turn becomes contaminated in the process. Thus, an important phase of the pathogen's travels through the production cycle is maintained in the normal propagative process.

Erwinia chrysanthemi grows best in warm-to-hot, wet and humid environments. Under these conditions, common in Florida, the short period of time required by E. chrysanthemi to decimate a crop often is astounding. The pathogen appears to survive in infested propagative media, in stock bed areas (especially where overhead irrigation is used) and on and in infected plants, even during times when temperatures are adverse to its rapid development. Surveys of plant material for freedom from this pathogen must be made during periods of the year conducive to the pathogen's development and growth.

Although preventive streptomycin sprays (100 to 200 ppm active ingredient) to stock and production plants and 5 to 30 minute streptomycin dips (100 to 200 ppm active ingredient) to propagative cane units have been shown to have activity against E. chyrsanthemi, this approach alone is far from the answer for control of this pathogen. Growers are advised to seriously reevaluate any and all cultural procedures which induce and encourage either foliar wetting or condensation on the foliage. Whenever possible, changes necessary to keep the foliage dry at all times should be made.

When new areas for stock production are contemplated, they should be established under a permanent (glass, fiberglass, rigid plastic) structure. Plant in raised beds containing sterilized media. Employ a watering system that does not wet the foliage, and select the best stock available (known pathogen-free, when possible) for planting.

In established stock areas, maintain a constant vigilance for diseased plants. Remove and destroy all diseased plants. Keep the foliage dry at all times. When this is impossible, apply streptomycin sprays on a weekly basis during the wet, warm periods that are particularly conducive to disease development. Never use plant material that is exhibiting disease symptoms for propagation. Lastly, always sterilize propagative media between crops, especially following a severe case of cutting or cane decay caused by E. chrysanthemi.

III. BACTERIAL LEAF BLIGHT OF SYNGONIUM

Pathogen: Xanthomonas vitians
Susceptible plants: Syngonium spp., Aglaonema roebellinii, possibly other Aglaonema spp.

The pathogen causing bacterial leaf spot of syngonium was determined in 1969 to be identical to that described in 1918 as a pathogen of lettuce. Xanthomonas vitians, like its sister species, X. dieffenbachiae, abounds in warm-to-hot, wet and humid environments. Cultural practices like crowding of plants and overhead irrigation are particularly conducive to its development.

The most characteristic symptom of infection on syngonium, which is the principle host plant, is the presence of water-soaked lesions along the leaf margin and leaf tip. The lesions may elongate and extend into the midrib of the leaf. Lesions are initially dark green, then turn yellow and eventually become brown and necrotic. The diseased area often is surrounded by a bright yellow zone that separates it from the apparently healthy portion of the leaf. On the undersurface of leaves with older lesions, white flakes of dried bacterial exudate (which in reality are billions of bacterial cells) often are visible to the unaided eye.

Along with attack of the leaves, the pathogen recently has been found to cause a cutting decay during propagation. Cuttings taken from vines showing severe leaf infection stand a good chance of rotting during propagation, especially in the warmer months.

Methods for control of this pathogen are similar to those used for the preceding pathogens. Clean stock, proper sanitation and production procedures that ensure dry foliage will aid a great deal in control. To date, bactericide applications have not been so effective in control of X. vitians as experienced in control of X. dieffenbachiae. If bactericides must be employed, however, the combination given earlier for the control of X. dieffenbachiae appears to be the most effective.

IV. RAPID DECAY OF POTHOS

Pathogen: Erwinia carotovora
Susceptible plants: Scindapsus aureus and several other foliage plants.

Rapid decay of S. aureus first was noted in 1961. The pathogen working alone or often in conjunction with Pythium splendens is a major reason for the failure of many growers to produce this foliage plant species successfully. The pathogen E. carotovora, is the same one that often causes a rapid, mushy foul-smelling rot of vegetables and ornamental tuber crops. It also plays a role in the propagative decays of foliage plants other than S. aureus and is widely present in the foliage plant industry.

The pathogen on S. aureus invades the leaves and petioles of potted plants and the stems, leaves and petioles of unrooted and rooted cuttings. The most severe disease development occurs under wet, warm-to-hot environments. Often during periods conducive to optimal disease development, young emerging shoots of propagative cuttings will be completely blighted, with the rot eventually progressing into the stems of the cuttings.

Infection can occur through intact plant tissue but is enhanced by wounds in the plant epidermis. Infected plant tissue appears initially as a discrete water-soak grayish-green area which rapidly enlarges, becomes mushy and turns brown to black, eventually resulting in the complete collapse of the affected plant unit. If during leaf infection the environmental conditions become excessively dry, leaf lesions will turn dry brownish-black, often with a yellow margin. Cuttings taken near the vine apex and those taken from rapidly growing vines are most susceptible to the pathogen. Infection of unrooted cuttings usually occurs through cut ends at the area where aerial roots have been removed, with the decay eventually progressing into the petiole and lamina of the parent leaf. Complete collapse of the cutting often can occur within two to four days. Parent leaves of cuttings attacked by E. carotovora often turn a bright yellow as a result of the stem infection.

Excellent control of this pathogen can be achieved by growing pothos under conditions which keep the foliage dry. Stock areas should be planted with the cleanest plants available. If a bactericide must be used in the stock areas, a weekly streptomycin spray (100 ppm active ingredient) will assist in control. Recent studies show that Dexon applied as a drench (1.0 pound in 100 gallons of water at the rate of one pint to a square foot) to beds prior to propagation, or as a 10-minute dip, aided in the control of E. carotovora. It is not suggested as a substitute for streptomycin, however, because the latter is superior as a bactericide. Rather, Dexon employed as a soil fungicide where pythium root and cutting decay occur will supply the added benefit of activity against E. carotovora. A 10-minute streptomycin dip (200 ppm active ingredient) of cuttings soon after cutting and prior to sticking will reduce disease resulting from transfer of the pathogen from diseased to healthy cuttings during the cutting process.

V. BACTERIAL LEAF SPOT OF DRACAENA SANDERIANA

Pathogen: Pseudomonas sp.
Susceptible plant: Dracaena sanderiana

This species of Pseudomonas can and has been shown to cause a serious disease of D. sanderiana. This disease is not, however, so common nor so economically important as those caused by the preceding members of the genera Erwinia and Xanthomonas.

Initial symptoms of infection usually are seen as circular to irregular water-soaked spots which can occur anywhere on the leaf blade. A thin, reddish-brown margin occasionally forms around the water-soaked centers, with diffuse chlorotic patterns developing around the lesions. The spots often enlarge, and the affected area may turn papery and dry. In severe cases, the affected area becomes brown and necrotic. Infection does not appear to progress into the cane.

The pathogen is capable of invading uninjured as well as injured plant tissue. Excessive moisture during propagation or foliar wetting to potted plants encourages disease development. Severely affected plants should be pulled and destroyed. Slightly infected plants can be saved by removing the affected leaves and spraying on a weekly interval with streptomycin (100 ppm active ingredient). Select cuttings carefully for propagation, and discard those showing infection. A 10-minute dip of streptomycin prior to planting may supply some protection, but its value is as yet undetermined. The best control of all, however, is employment of clean cuttings carried through propagation and finishing under the best sanitary and cultural practices possible.

VI. PSEUDOMONAS LEAF SPOT

Pathogen: Pseudomonas cichorii
Susceptible plants: Scindapsus spp., Philodendron panduraeforme, Aglaonema spp. and Monstera spp.

Little is known of P. cichorii's role in the production of foliage plants. Its presence first was noted in the middle '60s on Scindapsus aureus. As recently as 1972 P. cichorii was found causing a serious and new disease of gerberas at one of the largest foliage nurseries in Apopka, FL. This latter report further verifies the presence of the pathogen in the foliage growing areas.

Artificial inoculations of foliage plants produce a brownish-black lesion which takes 4 to 7 days to develop. With Scindapsus aureus, the formation of lighter and darker zones is quite noticeable. In inoculations to Monstera deliciosa, a yellow halo around the affected area is particularly prominent. The author has seen in foliage nurseries symptoms on S. aureus and monstera similar to those produced by artificial inoculations but cannot say with assurance that P. cichorii was the cause.

Pythium Control on Aglaonema

H. N. Miller [1]

Ninety tip cuttings of Aglaonema were stuck in 4-inch clay pots in new Canadian peat inoculated with millet seed cultures of Pythium splendens. The inoculum level was considerably higher than what would be encountered in nature under growing conditions.

The cuttings were divided into 9 groups of 10 plants each. Ten plants were used as an experimental unit and each treatment was replicated 3 times. Each replicate consisted of a different cultivar. The 3 cultivars used were A. modestum, A. treubii, and A. Pseudotracteatum.

Treatment 1. The soil was drenched with Nurelle (0.5 lbs ai/gal) at the rate of 5.3 ml/gal of water (100 ppm) 100 ml of the solution were used per pot.

Treatment 2. Drenched with Truban 30 wp at the rate of 1.3 gm/gal (100 ppm). 100 ml were used per pot.

Treatment 3. Control - No fungicide applied.

The soil, and plant roots, were drenched at the time of sticking and twice more at 21-day intervals for a total of 3 applications of the fungicides.

Two and one half months after planting all plants were carefully washed from the soil and read for plant growth and root infection. Data are given in Table 1.

[1] Plant Pathologist, Plant Pathology Department, IFAS, Gainesville, Florida, 32611.

Table 1. Control of Pythium root and cane rot of Aglaonema with fungicidal soil drenches.

Treatment	Weight of 30 plants (grams)	Percent root and cane infection	Degree of infection
1. Nurelle	1420.5	10	Abundant root system but most plants showed some root discoloration in form of root rot or root infections (isolations confirmed presence of pythium).
2. Truban	1656.0	1	Abundant white root systems on all plants. Two plants only had 2 to 4 infected root tips.
3. Check	885.0	95	Three plants had died from rotted roots and stems; on most plants the roots had rotted and slaughed off. Some of the cane tips were rotted. Five plants had fair root systems but showed abundant infection.

Conclusions: There appeared to be no difference in cultivar susceptibility to Pythium splendens consequently the data were combined for all replications. Under the conditions of this test, Truban appeared to be slightly more effective in disease control than did Nurelle, however, the systemic nature of Nurelle would indicate that it may have been more efficacious if it had been sprayed on the plant foliage after the initial soil drench.

When using soils heavily infested with Pythium splendens, Truban, in our experience, has been more effective in the control of pythium root rot of Aglaonema than Nurelle. However, under normal conditions of lower inoculum levels and proper application of Nurelle as a soil drench or foliar application, Nurelle would probably be the most effective of the 2 compounds.

FOLIAGE PLANT DISEASE CONTROL

J. F. Knauss & R. W. Henley

Foliage plant disease control is necessary to produce quality foliage plants. Environmental conditions in greenhouses which promotes rapid plant growth also favors rapid plant disease development.

The fungicides and bacterialcides listed in this guide are only suggestions for controlling diseases. These materials have been found to be effective in tests at the Agricultural Research Center - Apopka.

To simplify information it is sometimes necessary to use trade names of products. No endorsement of named products is intended nor is criticism implied of similar products which are not mentioned.

IMPORTANT NOTICE TO GROWERS: The Federal Environmental Pest Control Act makes it unlawful to apply a pesticide in any manner except as stated on the container label. Read the entire label carefully for correct dosage rates, application directions and precautions concerning the disease on your crop and under your growing conditions.

Name of pathogen and disease	Plants attacked	Chemical	Amount needed per 100 gallons	Amount needed per 1 gallon
	FUNGAL PATHOGENS ATTACKING LEAVES			
Alternaria actinophylla	Brassaia actinophylla (Schefflera)	Zineb 75 WP	1 1/2 lb	1 Tbsp
		or		
		Dithane M-45 (Fore) 80 WP	1 1/2 lb	2 1/4 tsp
		or		
		Manzate D	1 1/2 lb	1 Tbsp
Ascochyta necans	Polystichum adiantiforme (Leatherleaf fern)	Daconil 75 WP	1 1/2 lb	1 Tbsp
Cephalosporium spp. "Shotgun"	Dieffenbachia spp.	Daconil 75 WP	1 1/2 lb	1 Tbsp
		or		
	Syngonium spp. (Nephthytis)	Dithane M-45 (Fore) 80 WP	1 1/2 lb	2 1/4 tsp
		or		
		Benlate 50 WP*	1/2 lb	1 1/2 tsp
Cercospora spp.	Peperomia spp.	Daconil 75 WP	1 1/2 lb	1 Tbsp
		or		
	Ficus spp.	Dithane M-45 (Fore) 80 WP	1 1/2 lb	2 1/4 tsp
		or		
	Brassaia actinophylla (Schefflera)	Benlate 50 WP*	1/2 lb	1 1/2 tsp
	Cordyline spp.			

* Always alternate Benlate with one of the other suggested fungicides.

Name of pathogen and disease	Plants attacked	Chemical	Amount needed per 100 gallons	Amount needed per 1 gallon
Rhizoctonia spp.	Nephrolepis exaltata (cultivars)	Benlate 50 WP*	1/2 lb	1 1/2 tsp
		or		
	Polystichum adiantiforme (Leatherleaf fern)	Daconil 75 WP	1 1/2 lb	1 Tbsp
	Other ferns			

FUNGAL PATHOGENS ATTACKING STEMS AND ROOTS

Name of pathogen and disease	Plants attacked	Chemical	Amount needed per 100 gallons	Amount needed per 1 gallon
Phytophthora spp.	Dieffenbachia spp.	(Soil Drench)		
		Truban 30 WP	8 to 12 fl oz	1 1/2 to 2 1/4 tsp
	Peperomia spp.	or		
		Truban 25 EC**	4 to 8 fl oz	1/4 to 1/2 tsp
	Zygocactus spp.	or		
		Dithane M-45(Fore) 80 WP	2 lb	1 Tbsp
	Many others			
Pythium spp.	Philodendron spp.	(Soil Drench)		
	Aglaonema spp.	Truban 30 WP	8 to 12 fl oz	1 1/2 to 2 1/4 tsp
	Maranta spp.	or		
	Dieffenbachia spp.	Truban 25 EC**	4 to 8 fl oz	1/4 to 1/2 tsp
	Brassaia actinophylla (Schefflera)			
	Many others			

**Should be tried on a small scale until determined safe if not used on crop previously.

Name of pathogen and disease	Plants attacked	Chemical	Amount needed per 100 gallons	1 gallon
Cylindrocladium pteris	Polystichum adiantiforme (Leatherleaf fern)	Daconil 75 WP	1 1/2 lb	1 Tbsp
		or		
Cylindrocladium spp.		Benlate 50 WP*	1/2 lb	1 1/2 tsp
Dactylaria humicola	Philodendron oxycardium	Daconil 75 WP	1 1/2 lb	1 Tbsp
		or		
	Philodendron spp.	Benlate 50 WP*	1/2 lb	1 1/2 tsp
		or		
		Dithane M-45 (Fore) 80 WP	1 1/2 lb	2 1/4 tsp
		or		
		Orthocide (Captan) 50 WP	1 1/2 lb	1 Tbsp
Fusarium moniliforme	Dracaena spp.	Daconil 75 WP	1 1/2 lb	1 Tbsp
		or		
	Pleomele spp.	Dithane M-45 (Fore) 80 WP	1 1/2 lb	2 1/2 tsp
		or		
	Sansevieria spp.	Benlate 50 WP*	1/2 lb	1 1/2 tsp
Leptosphaeria spp. "Brown Leaf Spot"	Dieffenbachia spp.	Dithane M-45 (Fore) 80 WP	1 1/2 lb	2 1/4 tsp
Phyllosticta draconis	Dracaena spp.	Daconil 75 WP	1 1/2 lb	1 Tbsp
		or		
	Cordyline spp.	Dithane M-45 (Fore) 80 WP	1 1/2 lb	2 1/4 tsp
Phytophthora spp.	Philodendron oxycardium	Daconil 75 WP	1 1/2 lb	1 Tbsp
		or		
		Dithane M-45 (Fore) 80 WP	1 1/2 lb	2 1/4 tsp

Name of pathogen and disease	Plants attacked	Chemical	Amount needed per 100 gallons	Amount needed per 1 gallon
Rhizoctonia spp.	*Brassaia actinophylla* (Schefflera)	(Soil Drench)		
	Scindapsus spp.	Benlate 50 WP	3/4 to 1 lb	3/4 to 1 Tbsp
	Dieffenbachia spp.	or		
	Philodendron spp.	Terraclor 75 WP	1 to 1 1/2 lb	1 1/2 to 2 1/4 tsp
	Hoya spp.			
	Many others			
Sclerotinia sclerotiorum	*Scindapsus* spp.	(Soil Drench)		
	Syngonium spp. (Nephthytis)	Benlate 50 WP	3/4 to 1 lb	2 1/2 to 3 tsp
	Many others			
Sclerotium rolfsii "Southern Blight"	*Philodendron* spp.	(Soil Drench)		
	Syngonium spp. (Nephthytis)	Terraclor 75 WP	1 to 1 1/2 lb	1 1/2 to 2 1/4 tsp
	Dracaena spp.	or		
	Peperomia spp.	Ferbam (Fermate) 76 WP	2 to 3 lb	2 1/3 to 3 1/2 Tbsp
	Many others			

Name of pathogen and disease	Plants attacked	Chemical	Amount needed per 100 gallons	Amount needed per 1 gallon
	BACTERIAL PATHOGENS ATTACKING LEAVES AND STEMS			
Erwinia chrysanthemi "Erwinia Blight"	Philodendron spp.	Keep foliage as dry as possible		
Erwinia spp.	Syngonium spp. (Nephthytis)	Streptomycin	100 to 200 ppm	
Leaf and stem rot	Scindapsus spp.	Agri Strep 17 sp	1/2 to 1 lb	1 to 2 tsp
	Aglaonema spp.	Agrimycin 17	1/2 to 1 lb	3/4 to 1 1/2 tsp
Erwinia dieffenbachiae	Dieffenbachia spp.	(Cane section dip for 30 min) Streptomycin	100 ppm	
		m Agri Strep 17 sp		1 tsp
		Agrimycin 17 plus Keep foliage dry plus Foliar spray to clean plants		3/4 tsp
		(use streptomycin) plus Clean tools and rubber gloves in LF-10 (1:100) for 5 min.	100 ppm	
Xanthomonas dieffenbachiae "Red Edge"	Philodendron oxycardium	Combination Kocide 101 86 WP plus	1 1/2 lb	3/3/4 tsp
		Dithane M-45 (Fore) 80 WP	1 1/2 lb	2 1/4 tsp
Xanthomonas vitians "Bacterial leaf spot"	Syngonium spp. (Nephthytis)	Kocide 101 86 WP plus	1 1/2 lb	3 3/4 tsp
		Dithane M-45 (Fore) 80 WP	1 1/2 lb	2 1/4 tsp.

METHODS OF PROPAGATING FOLIAGE PLANTS

C. A. Conover & R. T. Poole

Foliage growers and other interested horticulturists frequently ask how some of the most popular foliage plants can be propagated. Actual propagation methods vary according to growers, but use of cuttings is probably most popular. Foliage plants are also frequently propagated from seed, air layers, division, and spores.

Key - To Propagation Methods

A - Air layers
B - Cane cuttings
C - Division or offsets
D - Leaf cuttings
E - Seed
F - Single and double-eye cuttings
G - Spores
H - Tip cuttings

Botanical Name	Common Name	Method of Propagation	Remarks
Adiantum spp.	Maidenhair fern	C, G	Plants from spores take 2 to 3 years to reach saleable size.
Aglaonema spp.	Aglaonema	A, B, H	Air layers rarely made in commercial operations.
Aphelandra squarrosa	Zebra-plant	F, H	Grows well from single eye cutting with one-half of stem section.
Aralia spp.	Aralia	B. E. H	A. elegantissima is one of the best.
Araucaria excelsa	Australian-pine	E, H	Rarely grown from cuttings
Ardisia crenata	Coral Ardisia	E, H	Rarely grown from cuttings
Begonia spp.	Rex begonia	D	
Brassaia actinophylla	Schefflera	A, E, H	Only larger specimens grown from cuttings or layers.
Calathea spp.	Calathea	C, H	Usually grown from cuttings.
Codieum variegatum	Croton	A, F, H	Air layers maintain best leaf size.
Coffea arabica	Coffee	E	
Collinia elegans	Parlor-palm	E	
Cordyline terminalis	Ti	B, H	Some seed is also available.
Crassula spp.	Jade-plant	D, H	
Dieffenbachia spp.	Dieffenbachia	A, B, H	Some varieties also produce offsets which can be divided.
Dracaena fragrans	Dracena	B, H	Woody cane is usually rooted directly in pots for larger standards.
Dracaena godseffiana	Dracena	H	The cultivar 'Florida Beauty' is most attractive.
Dracaena marginata	Marginata	B, H	Propagations by tip cuttings are best.
Dracaena sanderiana	Sanderiana	H	

Botanical Name	Common Name	Method of Propagation	Remarks
Ficus, elastica	Rubber plant	A, H	Rooting percentage on tip cuttings is very low.
Ficus, Lyrata	Fiddle-leaf fig	A	Usually only grown for large specimens.
Hoya, carnosa	Wax plant	F, H	
Kalanchoe, spp.	Kalanchoe	D, H	Also grows from leaf-margin plantlets.
Maranta, spp.	Prayer-plant	H	
Monstera deliciosa	Monstera	A, F, H	(Philodendron pertusum) most plants are now grown from tip cuttings.
Nephrolepis exaltata	Boston fern	C	Almost all commercial plants come from runner offsets.
Peperomia spp.	Peperomia	F, H	
Philodendron florida	Florida philodendron	A, F, H	Usually grown from cuttings.
Philodendron hastatum	Hastatum	A, F, H	Usually grown from cuttings.
Philodendron micans	Micans	F, H	Mostly grown from single-eye cuttings.
Philodendron oxycardium	Heart-leafed philodendron	F	
Philodendron panduraeforme	Panduraeforme	F, H	
Philodendron selloum	Selloum	E	
Pilea, codierei	Aluminum plant	H	
Platycerium spp.	Staghorn-fern	C, G	Plants from spores take 2 to 3 years to reach saleable size.
Podocarpus macrophylla	Podocarpus	E, H	Can be grown from cuttings but this is not common in foliage nurseries.
Pteris spp.	Pteris fern	G	Plants from spores take 2 to 3 years to reach saleable size.

Botanical Name	Common Name	Method of Propagation	Remarks
Sansevieria hahnii	Hahnii sansevieria	C, D	Gold striped variety will not come true to form from leaf cuttings.
Sansevieria trifasciata		C, D	
Sansevieria trifasciata 'laurentii'		D	Will not come true to form from leaf cuttings.
Saintpaulia spp.	African violet	D	
Scindapsus spp.	Pothos	F	
Spathiphyllum spp.	Spathiphyllum	C, E	
Syngonium spp.	Nephthytis	E, F	Emerald gem plants from seed are disease free - many cuttings are lost due to a bacterium.
Zygocactus, spp.	Christmas cactus	H	

FOLIAGE PLANT PROPAGATION

C.A. Conover & R.T. Poole

Factors affecting propagation of foliage plants are of major importance to foliage growers because sales of seedlings or small, recently rooted plants account for a significant portion of sales. Propagation practices which control quality, percentage and speed of rooting cuttings are thus of major importance to growers.

Foliage plants are propagated by cuttings, seed, air layers, division and spores. Of all methods mentioned, propagation by cuttage is most popular. Plants propagated from cuttings and seed are usually rooted or germinated in flats or benches, but there is a recent trend toward direct potting. Seed propagation is becoming more important in foliage production and is the only way to produce many foliage types.

Major problems of foliage plant propagation include sanitation, propagation media, environmental conditions and fertilization.

METHODS OF PROPAGATION

Cuttings - The types of cuttings most frequently used include tip, single or double eye, leaf and cane. Foliage plants grown from cuttings usually reflect growing conditions of stock plants and therefore, should be obtained from healthy, disease and insect free stock plants with no nutritional deficiencies. Such cuttings will root faster, be of higher quality, produce more roots and growth in a shorter time and require less maintenance than poor cutting materials. Rooting hormones generally are not utilized, except with a few difficult-to-root types and cane cuttings.

Tip cuttings - are a popular way of producing some Dracaena, Aglaonema, Peperomia and Dieffenbachia varieties. Cuttings should be 4 to 6 inches long, although larger specimen material can be rooted. Small cuttings root faster with less loss of lower foliage and require less space. Only enough lower foliage should be removed to allow sticking of the cuttings.

Single and Double-eye leaf-bud cuttings - are the best way to produce most vinetype foliage plants such as Philodendron oxycardium (cordatum) and Scindapsus aureus (pothos). Single-eye cuttings consist of a short stem section with an attached leaf. Stem sections about 2 inches long root better than longer or (turn to page two for continuation).

shorter lengths and those from the tip or base of vines are slow to root. Cuttings should be stuck into the rooting media until the eye is slightly below or at the surface, since new roots arise from that point. Double-eye leaf bud cuttings are sometimes used to plant totem poles, as they grow at a more rapid rate than single-eye cuttings.

Leaf cuttings - are utilized to propagate plants such as Rex begonias, violets and species of sansevieria that do not have chimeras. This method of propagation supplies the most plants from the least propagating material. Sanitation is very important when using leaf cuttings or segments, as detached parts are easily attacked by disease organisms.

Cane cuttings - provide an economical method of propagating *Dieffenbachia* and *Dracaena* such as *Dracaena fragrans*. Soft cane of *Dieffenbachia* is usually cut with one eye per section, while stem sections of one to four feet are used for *Dracaena*. *Dieffenbachia* cuttings of large diameter taken from the upper part of stems and planted shallow produce largest plants. Research on requirements for best rooting of hard cane of dracaena has just begun, and presently cane is either potted directly and maintained under high humidity or set vertically on a rooting medium until roots initiate.

Seed - A number of popular foliage plants, including *Podocarpus*, coffee, palms, schefflera and others, are grown from seed. Unlike many woody temperate species, seed of tropical and subtropical foliage plants should be planted as soon as they are ripe or germination will be reduced. Seed propagation does not require maintenance of stock blocks and reduces transmission of a number of disease organisms that are transmitted with vegetative plant parts. A good example is a bacterial disease of *Syngonium podophyllum* 'Emerald Gem' (nephthytis) that is almost always present in vegetatively propagated cuttings, but not in seedlings.

Air layers - This propagation method utilizes the parent plant as a source of water and nutrients during the rooting process and is most used with *Ficus* species. However, crotons, schefflera, philodendron and Dieffenbachia of specimen size are also propagated in this manner. Major benefits of air layers include the large plant-sized cuttings which can be rooted and the minimum reduction in leaf area necessary.

Factors of importance in the layering process include type of cut and amount of sphagnum moss used around the cut. Two types of cuts are used to make air layers. A slanting cut upward at a 45 degree angle about one-half way through the stem is most popular and least expensive. A wedge is placed in the cut, or the knife is twisted to spread the cut and prevent cambiums from reuniting before root formation. The other method consists of removal of a ring of bark about one inch long which is better, but more time consuming and requires more labor. The amount of moist sphagnum moss used to wrap the cut helps determine size of root systems that will develop, and therefore a large handful should be used for each layer. A covering of aluminum foil over the moss is better than plastic and should be applied with a collar around the top to catch moisture from rain or irrigation.

Division - This propagation method is not commonly used in foliage plant production, but is used for some sansevieria species that have chimeras, since they will not reproduce true-to-type from leaf cuttings. Propagation of some ferns and a few Dieffenbachia varieties are also partly obtained by division from parent plants.

Spores - Some ferns are grown from divisions or offsets, but many must be propagated from spores. Production of saleable fern plants from spores requires 1 to 2 years, but is not difficult.

Spores may be germinated on sterilized milled sphagnum (ground sphagnum peat) in 80 to 85 percent shade (2000 foot-candles of light). Spores should be dusted on the surface of the peat and not covered. However, since surface of the medium will dry rapidly, spores should be misted to maintain surface moisture or covered with clear glass or plastic. Germination is slow and 3 to 4 months will lapse before small plants can be noticed.

PROPAGATION MEDIA

Any medium selected should be readily available, uniform and available in quantity so the plant propagator can repeatedly use a similar material. The medium must be firm enough to support cuttings without necessity of placing a large portion of the cutting into the media and of a consistency that will allow a cutting to be placed into it easily and removed easily when they have adequate root systems. Lastly, any medium selected should be attractive, easy for potters to handle and odorless.

A pH of 5.5 - 6.5 will allow satisfactory rooting of most foliage plants. Most imported and native peats have a pH of 3.5 - 5.0 and five to ten pounds of dolomite per cubic yard are necessary to raise pH as well as supply magnesium and calcium to rooted cuttings.

The medium used should have adequate water holding capacity so that frequent irrigations will be unnecessary when a mist system is not used. A water holding capacity of 50-100% by volume or 200-400% by weight is acceptable. If plants are to be watered frequently, high water holding capacity of the medium is not necessary. Water conductivity should be rapid, particularly when cuttings are watered heavily. Water should pass through the soil at 4 inches/hour, so it will not become water-logged. Aeration is important, especially when the medium is watered heavily. Fifteen to 25% air space will allow water to flow through and insure an exchange of gases that will keep an oxygen supply around the rooting surface.

Because of large water volumes applied to cuttings and low amounts of fertilizer applied, cation exchange capacity (CEC) is not as important in a propagation medium as potting media. However, a high CEC is desirable so fertilizer can be held after cuttings have initiated roots and watering reduced. Soluble salt readings should be low or cuttings will have difficulty absorbing water.

Shrinkage and rate of decomposition of propagation media is important, particularly if the medium is to be used for a long time. Weight or bulk density of propagating media are relatively unimportant as long as they perform as required and are not used for direct rooting.

Peat is a satisfactory medium for propagation of foliage plants. Imported and domestic peats may be used, but domestic peat should be sterilized for weed, disease and nematode control. Highly decomposed native peats or peats from vegetable fields should be avoided. Since native peats do not have physical properties equal to imported peats, they can be mixed to obtain a satisfactory peat at lower cost. Calcined clay, bark, wood shavings, rice hulls, perlite, vermiculite, bagasse, sphagnum moss and sand can be mixed with peat, each other or used singly. There are several products on the market that can be bought as individual blocks for sticking of cuttings, but they are too expensive for rooting low priced plants. Products made of compressed peat, treated wood fiber or a synthetic produce such as styrofoam are available. All media should be completely moist before sticking of cuttings.

Aerated steam sterilization is the best method of preparing contaminated media for plant propagation, but conventional steam sterilization, heat or chemicals are satisfactory.

Many media may be used to propagate foliage crops and left in benches for 1-2 years. If there has been any indication of disease in propagating beds, the medium should be sterilized or discarded to prevent disease spread to the new crop. Preferably, the medium should be leached with water to remove excess salts and sterilized before new cuttings are stuck.

LIGHT

Light is a major factor in success of rooting cuttings. Cuttings rooted under low light intensities (less than 2000 foot-candles) take longer to root and are lower quality than those rooted under higher light levels. Optimum light requirement varies between foliage plants and, therefore, a level must be selected for the propagating house that will allow maximum carbohydrate production without injury to cuttings. Light levels near 3000 foot-candles (70 percent shade) provide best average light intensity for foliage propagation benches, although some genera require higher or lower levels. The higher light intensity allows cuttings to produce carbohydrates necessary for rooting without utilization of reserves and aids in reducing time required to root. High light intensity also aids in bud break and decreases time in the propagation bench for vine-types to reach the 3 to 5 leaf stage. When mist systems are not utilized in propagation houses, light intensity should be lowered to 2000 to 2500 foot-candles.

Light intensities of 2500 to 3000 foot-candles are also satisfactory for propagation from seed as long as the surface layer is not allowed to dry, but some species must be moved to higher light for growing. Light intensity for germination of fern spores must be slightly reduced over that suggested for cutting and seed propagation. Light intensity in houses used for germination of fern spores should be near 2000 foot-candles (80 percent shade).

HUMIDITY CONTROL

Mist systems and their use in propagation of foliage plants is usually beneficial. However, frequency and amount of water applied per application should be considerably reduced over systems in full sun locations used for propagation of woody ornamentals.

The most critical factor in designing mist systems is evenness of application. Timing of mist application varies according to air movement, temperature, humidity and light intensity, but at a light intensity of 300 foot-candles should average not more than 15 seconds every 15 minutes. Mist application during hours of darkness is not necessary and will increase possibility of disease. After the first week, the mist interval should be increased so that at the time of pulling no mist is being applied.

Frequently uneven mist application is a problem on foliage propagating benches due to improperly spaced or partially clogged nozzles. Uneven mist application causes cuttings to root and grow at different rates causing uneven quality. Usually, when cuttings are pulled at the proper time for most advanced cuttings, those that have not received sufficient moisture will be in the lowest grade. On the other hand, application of excessive mist causes foliar leaching of nutrients and an increase in disease problems. This can be partially offset by fertilization after roots have formed, but is best controlled by adjusting mist application.

Many foliage plants can be grown without use of mist systems. Under these conditions, cuttings should be syringed two or more times per day to maintain turgidity and rooted under a light intensity of about 200 foot-candles.

TEMPERATURE

Day air temperatures of 80-90 degrees F. and night temperatures of 70 degrees F. are satisfactory for propagation of most foliage plants. The growing medium temperature at these air temperatures will be 10-20 degrees lower except during hot summer months. During the winter, within the propagating medium temperatures may fall as low as 65 degrees during the night and early morning or after watering and rise no higher than 70 degrees during the day. Use of heating cables or steam pipes under propagation benches can reduce propagating time of many foliage plants by 50% during cool months of the year if the propagating medium is maintained at 75-80 degrees F. An economical way of heating propagating beds is to support them with steam lines and trap heat with plastic drop-cloths on the sides. Air temperature can be reduced 5-10 degrees if the propagating medium is heated.

CARBON DIOXIDE

Additional carbon dioxide (CO_2), up to 1500 ppm, will increase plant growth and decrease time required to propagate foliage plants. The atmospheric content of CO2 is normally 300 ppm, but in enclosed greenhouses the level may drop to 100 ppm or less during daylight hours. CO_2 addition is helpful only during daylight hours when vents are closed and for maximum growth, fertilizer, water and temperature should be increased.

Some growers vent the exhaust air from heaters into their greenhouses in an effort to increase CO_2. This is not recommended because of the possibility of emission of harmful gases, primarily ethylene. An inefficient burner can cause the loss of an entire crop.

There are several Liquid Gas CO_2 generators available that will safely increase CO_2 in the greenhouses and detectors to measure CO_2 and ethylene can also be purchased.

SPACING

Spacing of cuttings varies with size and type of plant material and size of the root ball to be produced. Single eye cuttings with leaves such as those taken for *Philodendron* should be spaced approximately 2" x 2". Small tip cuttings should also be stuck at 2" x 2". Larger tip cuttings, such as some Dieffenbachias should be placed 3" x 3". Sufficient space should be maintained between plants so that light will be available to leaves and to permit air movement between plants. Sufficient space should also be allowed so rooted plants can be removed without damaging roots.

FERTILIZATION

Foliage plants in propagating benches are generally fertilized as soon as they start to produce roots. This practice aids in stimulating bud break, speeds new growth and is especially useful with vine-type cuttings such as philodendron, pothos and nephthytis.

Fertilizer rate depends on whether CO injection is used and amount of misting with higher levels of nutrition provided when CO_2 or mist is used. Two methods of fertilization can be used separately or together - chemical liquid fertilizers applied overhead or slow release fertilizer mixed in the propagating medium.

The type of liquid fertilizer program to follow depends on how the propagating medium was amended, at time of mixing. When calcium, magnesium, phosphorus and micro elements are mixed into media, a combination of ammonium nitrate and potassium nitrate or 20-2-20 without micro elements can be used. If only calcium and magnesium were premixed into the medium use 20-20-20 plus micro elements. Table 1 provides information on a complete program.

When slow release fertilizer programs are used, fertilizers should be premixed into propagating media at the time initial applications of calcium, magnesium and micro elements are incorporated. Only one application of slow release fertilizer should be applied per crop. If a liquid program is used in conjunction with slow release fertilizer one-half the normal rate of each should be used. Table 1 contains additional information on rates and timing.

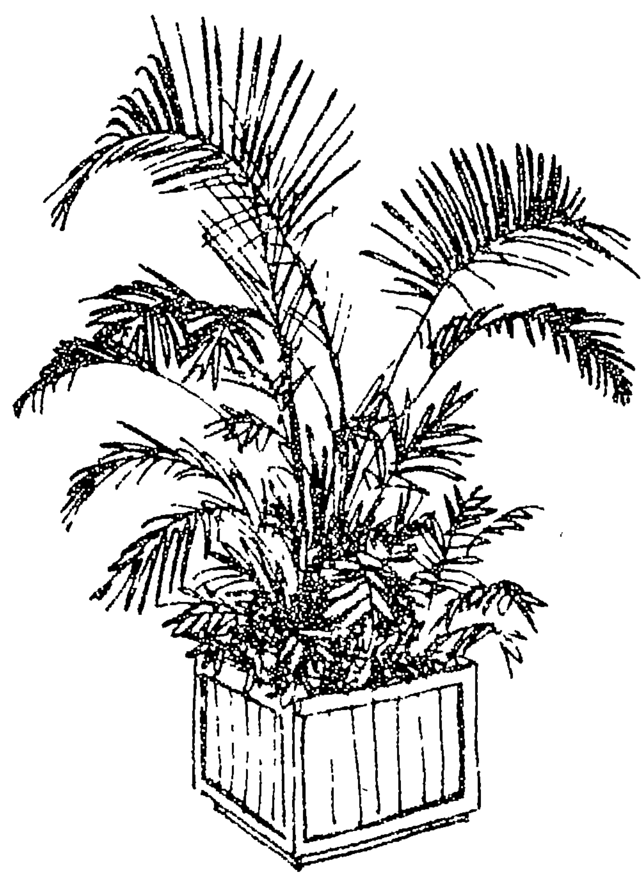

Table 1. Liquid and slow release fertilizer programs for foliage plant propagating beds.

Type of amendment used in propagating beds/cu.yd.	Type fertilizer to use	Amount to use[1] on 400 sq.ft.	Frequency of application
1. 5 to 10 lbs. dolomite, 3 lbs. superphosphate 3 lbs. Perk	20-2-20[2] or 20-0-20[2] or Ammonium nitrate plus Potassium nitrate	2 1/2 lbs. / 2 1/2 lbs. / 1 1/4 lbs. ea.	Apply in 50 to 100 gallons of water every 2 weeks.
2. 5 to 10 lbs. dolomite, 3 lbs. Perk	20-20-20[2] or ammonium mitrate plus potassium nitrate	2 1/2 lbs. / 1 1/4 lbs. ea.	Apply in 50 to 100 gallons of water every 2 weeks.
or Slow release 14-14-14[2]		20 lbs.	Incorporate into propagating medium once each 3 months.
3. 5 to 10 lbs. dolomite	20-20-20[3]	2 1/2 lbs.	Apply in 50 to 100 gallons of water every 2 weeks.

[1]Levels should be approximately 20 percent higher when using CO_2 injection or mist.

[2]Without a micro element supplement.

[3]With a micro element supplement.

Fertilizer retention ability of peats and other organic materials used in propagating benches is very high, and will cause a buildup of soluble salts if benches are not leached periodically. Therefore, benches should be heavily leached between crops or monthly if salts are a problem.

DISEASE CONTROL

Control of diseases in propagating benches is difficult and precautions should be taken to prevent entry of disease-causing organisms. Thorough sterilization of media is essential. Many media used are sterile when received and do not require sterilization, although if there is any question of contamination, the media should be sterilized prior to use by the propagator. Disease free cuttings should be used whenever possible, and any tools or clippers used in the operation should be disinfected or sterilized to make them disease free.

Tools and clippers may be disinfected by flaming in alcohol, soaking in either a 10% chlorox solution or a 1:100 LF-10 solution for 5 minutes. Hands should be washed and may be rinsed in 1:200 LF-10.

Sanitation measures must be thoroughly enforced throughout the propagating period so that no disease organisms are introduced into the beds. If disease symptoms do appear, the infected and surrounding plants should be carefully removed in a manner which allows minimum soil contamination of clean areas. The removed plants should be destroyed and watering reduced as much as possible.

Use of fungicides may be beneficial, however, they should be used cautiously as many fungicides are toxic to young roots or cuttings. Drenching treatment of infected areas with terrachlor, 1 lb/100 gal. at the rate of 1 pint/sq. ft. will control Rhizoctonia, Sclerotinia, and Botrytis. Terrachlor, however, should be applied only once. Captan and Dexon, 1 lb/100 gal. applied at the same rate are useful in reducing and controlling Pythium incited diseases. All three mentioned chemicals may be applied as total bench treatments at the mentioned concentration to cover an area of 800 sq. ft.

A combination fungicide - growth hormone may help control diseases and promote rooting.

INSECT CONTROL

Insect control in propagating beds under mist is difficult since pesticides are washed from foliage before they can effectively control pests. The best control is to use only insect and mite free seed, cuttings and air layers for propagation.

When insecticides are used in mist areas they should be applied during late afternoon so they will remain on foliage for longest possible periods. Aphids, thrips, mealybugs and scale can be controlled with Dimethoate, Meta-Systox-R or Malathion if they become a problem. Spider mites rarely become a problem in misted propagation beds, but they can be controlled with Chlorobenzilate, Tedion or Kelthane. Aerosols are also a good method of insect control in propagating houses.

Slugs and snails frequently are troublesome in propagating areas because of high moisture and low light levels, but can be controlled with Metaldehyde dust or bait.

To simplify information, it is sometimes necessary to use trade names of products, equipment, and firms. No endorsement of named products is intended nor is criticism implied of similar products which are not mentioned.

USE OF GROWTH REGULATORS ON TROPICAL FOLIAGE PLANTS

R.W. Henley & R.T. Poole

Foliage plants with compact growth habits are preferred by consumers to those which have been grown under low light levels or have been held for extended periods in retail displays or terrariums without sufficient light. Plants handled in this manner develop excessively long internodes creating a spindly appearance. For several years commercial flower growers have used chemical growth regulators to modify crop growth. However, until recently little attention has been given potentials of growth regulators to improve appearance of foliage plants.

The activity of both chlormequat (Cycocel) and SADH (B-Nine or Alar) have been widely reported on floricultural crops. Chlormequat effectively reduces internode elongation on azaleas, geraniums and poinsettias while SADH is commonly used to produce compact chrysanthemums and bedding plants.

An early report of growth regulators used on foliage indicated a limited dwarfing response by Philodendron oxycardium, Scindapsus aureus and Syngonium podophyllum to foliar sprays of SADH at 10,000 ppm. Scindapsus aureus internode elongation was reduced by 33% over the controls with 8 weekly foliar sprays of 1 ppm ancymidol. Ancymidol (A-Rest) has been reported to effectively reduce therate ot stem elongation of several species of ornamental plants including both monocots and dicots.

This study was initiated to establish the influence of 3 growth regulators on growth habits of 11 foliage plants.

An effort was made to select small potted plants which grow relatively fast and elongate excessively under reduced light levels. Species used were: Coral Ardisia (Ardisia crispa), Umbrella Tree (Brassaia actinophylla), Teddy-Bear Vine, (Cyanotis kewensis), Purple Passion Vine (Gynura sarmentosa), Satin Pellionia (Pellionia pulchra), Heartleaf Philodendron (Philodendron oxycardium) Aluminum Plant (Pilea carierei), Panamiga (Pilea involucrata), Artillary Plant (Pilea microphylla), Yew Pine (Podocarpus macrophyllus) and African Evergreen (Syngonium podophyllum).

Growth regulators were applied March 20. 1974 at which time stem length was determined. Treatments - 50 ppm ancymidol, 3,000 ppm chlormequat and 10,000 ppm SADH - were applied as foliar sprays to the point of runoff. Plants were maintained in a glasshouse under 70% shade, 80° F days, 70° F nights and 2 lb. of 20-20-20 fertilizer/100 gal/400 ft^2 weekly. April 30, 1974, the experiment was terminated and final stem length measurements were collected.

Ancymidol was most effective in reducing elongation of Brassaia, Gynura and Pilea involucrata stems; and Ancymidol and SADH were similar in their dwarfing ability of Cyanotis (Table 1).

Stem length of Philodendron in this study was not controlled with SADH as previously reported. Increased response in this experiment may have been noted if more time had elapsed between treatment and final measurement.

Chloromequat used at 3,000 ppm caused severe chlorosis of young leaves of Cyanotis, Pellionia, Philodendron, Pilea cadierei, Pilea involucrata and Podocarpus. There are numerous reports of phytotoxicity to floricultural crops when chlormequat was applied as a spray. Data collected in this study indicate that chlormequat, 3,000 ppm, is not a suitable growth retardant treatment for a number of foliage plants. Possibly less concentrated chlormequat applications would reduce stem elongation on some species without phytotoxic effects.

Of the compounds evaluated, ancymidol displayed the widest spectrum of activity at the level used. Although soil applications of ancymidol have been reported to be more effective than foliar sprays, ease of application to plants in different size containers and reduced quantity of material, make foliar sprays more feasible for commercial growers.

Table 1. Stem growth (inches) of foliage plants 6 weeks after foliar sprays with growth regulators.

	Treatment (ppm)			
Botanical Name	Control	Ancymidol 50	Chlormequat 3000	SADH 10,000
Ardisia crispa	0.2	0.9	0.4	0.2
Brassaia actinophylla	4.2	1.1	3.6	4.8
Cyanotis kewensis	3.9	3.0	1.0	2.7
Gynura sarmentosa	11.8	3.9	14.5	12.6
Pellionia pulchra	3.7	3.4	1.4	2.0
Philodendron oxycardium	6.5	6.4	6.0	5.8
Pilea cadierei	2.8	2.0	1.3	2.4
Pilea involucrata	3.5	2.2	3.2	2.9
Pilea microphylla	4.3	3.7	3.9	4.0
Podocarpus macrophyllus	0.6	0.8	1.0	0.6
Syngonium podophyllum	2.2	1.8	2.4	2.7

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