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PROPAGATION: FOG NOT MIST

TIMOTHY F. PRESS

Mee Industries, Inc.
1629 South Del Mar Avenue
San Gabriel, California 91776

Imagine a test tube environment the size of a greenhouse. An environment that guarantees zero transpiration loss, but that maintains a rooting medium that is light, fluffy, airy and not water-saturated. Recent improvements in fog system technology now make such an environment possible. The rooting zone is not overwet so there are much fewer disease problems and higher density planting is possible. Plants are not stressed, so they can tolerate more sunlight and higher temperatures and therefore root faster. But of more importance are the yields that can be achieved — virtually 100% yields with even hard-to-root species. Very large cuttings can be rooted without the need for air layering. This paper describes the hardware of one type of fog system, its applications in greenhouse microclimate control, and the difference between intermittent mist and continuous fog for use in propagation.

Description of Fog System. There are many methods of atomization, but very few are suitable for use in fog systems for greenhouse microclimate control. Spinning-type atomizers, for example, when rotated at high enough speeds, will produce droplets in the fog size range but the hardware becomes too expensive for any large scale application. Air jet atomizers are also capable of producing fog droplets but the energy requirements are 10 to 20 times greater than direct pressure atomizers.

Direct pressure mechanical atomization is the least energy consuming and the most practical in terms of hardware requirements for use on a large scale. Figure 1 shows a schematic which outlines the basic components of a fog system which utilizes this method for producing droplets in the desired size range.

At the heart of the system is the fog nozzle which is able to atomize water into microscopic water droplets. The nozzles operate under high pressure and the system therefore requires a high pressure pump. Due to the extremely small orifice size in the nozzle, extensive filtration is necessary to prevent possible nozzle clogging.

The fog nozzles are contained in PVC lines evenly spaced in the area to be fogged. A stream of water is forced to exit under high pressure from the small nozzle orifice. The high velocity stream impacts upon a pin placed over the center of the orifice and is shattered into extremely fine water droplets which make up the fog. The water droplets have a diameter about 1/10 that of a human hair. In terms of numbers, 95% of the droplets are less than 20 microns in diameter, almost identical to the drop sizes which occur in natural fog.

When the water source is not city water, it is treated with a small amount of chlorine to prevent slime-forming bacteria which could occur inside the nozzle orifices. Larger systems use a pre-filter, such as a sand filter, just downstream of the chlorine injection to trap any relatively large sediment or any particulates which may be formed when chlorine reacts with iron and other minerals in the water.

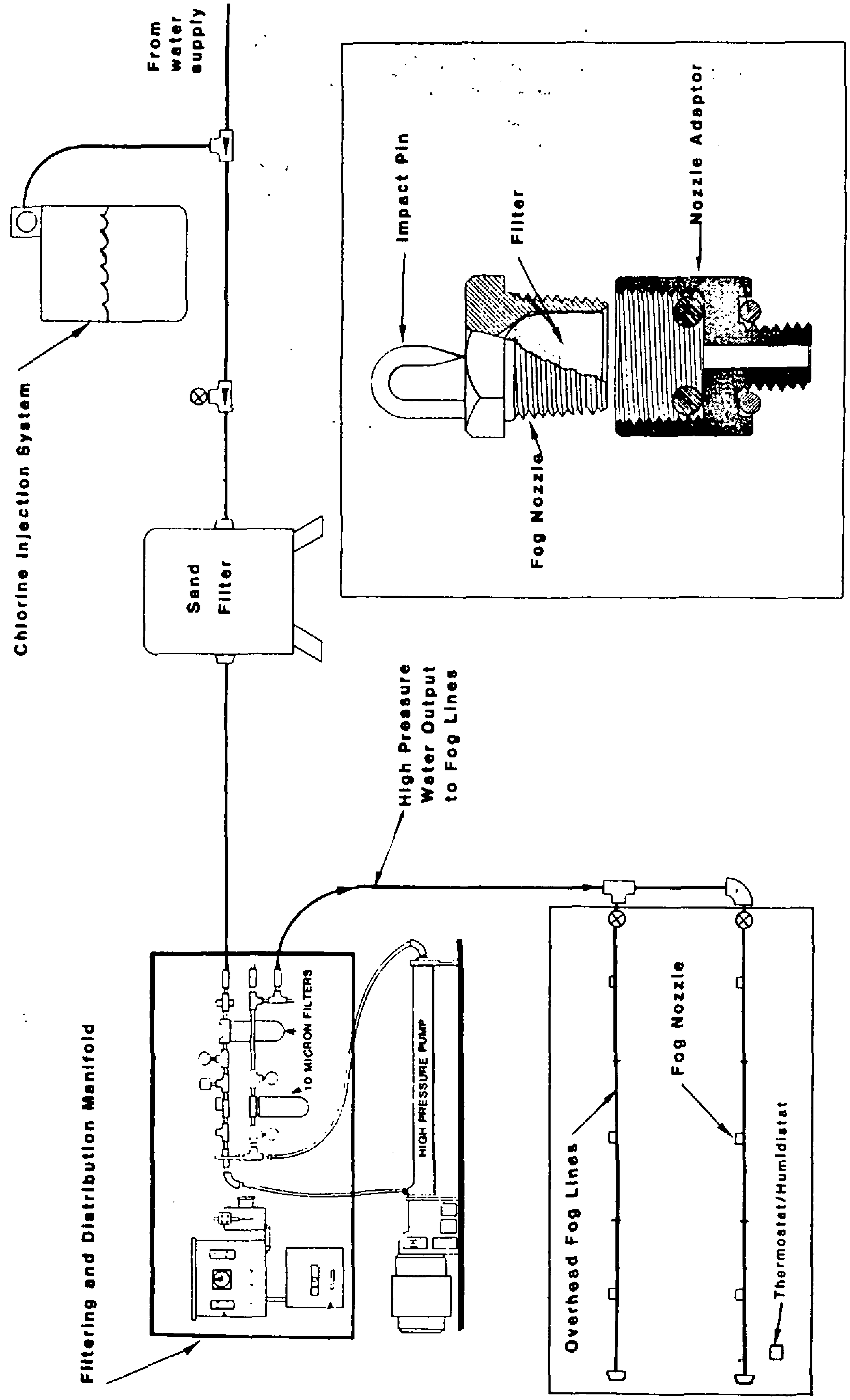


Figure 1. Fog system schematic.

The water is then routed to the main filtering and distribution manifold. It is filtered on the low pressure side of the manifold through a 10 micron cartridge-type filter after which it flows into the high pressure pump. The water exits the pump under a pressure of 600 psi and is filtered again through a high pressure cartridge filter. It is then sent through feedlines to the area to be fogged. The water is filtered one last time through a filter located at the back of each fog nozzle.

Fog vs. Mist in Propagation. Figure 2 compares the drop sizes produced by a high pressure mist system and by a fog system. Both views are enlarged approximately 150 times to show the individual droplets in the fog and in the mist. It should be noted that both systems were operated under the same pressure, about 550 psi, to achieve this comparison.

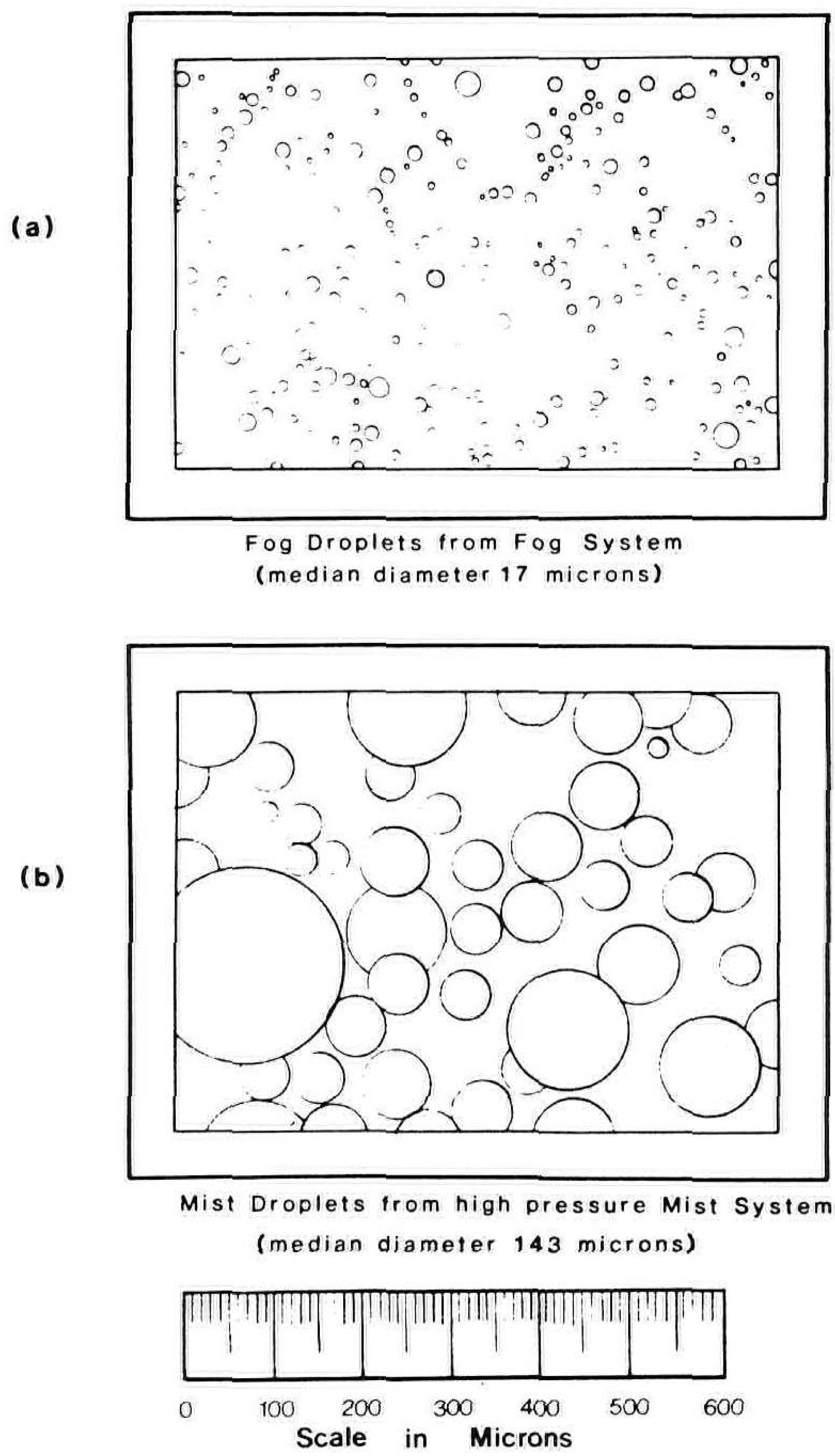


Figure 2. Fog droplets vs. mist droplets.

It is obvious from the figure that the droplets in the fog are many times smaller than those in the high pressure mist. The significance of the particle size is quite simple to see. Any droplet larger than about 35 microns will settle out and cause overwetting of the rooting medium. This may mean rotting, leaching of nutrients, and lack of sufficient oxygen reaching the roots; all factors which lower yields. On the scale at the bottom of Figure 2, 35 microns is but 3½ of the tiny divisions, and almost all of the mist particles are considerably larger than this.

All of the fog droplets are smaller than 35 microns, in fact most of them are smaller than 10 microns. Fog droplets float indefinitely and do not settle out. It takes only 10 sec for a 100 micron particle to reach the ground from 10 feet. By comparison, in still air, a 10 micron fog droplet would take 17 min to fall this distance. In practice, any slight air movements will keep the fog droplets suspended.

Typically, mist systems are operated under pressures of about 125 psi or less and the droplets are even larger than those shown in Figure 2(b).

Many advantages of fog over mist result from the fact that fog will remain suspended in the air while mist will not. For use in propagation, a fog system produces a visible fog in the area surrounding the propagating benches. This keeps the relative humidity of the propagating environment right at 100%, meaning that the air is saturated with water vapor and there can be no evaporation. The transpiration loss from the cuttings is virtually eliminated.

Equally as important is the fact that while maintaining a 100% relative humidity condition, the fog does not overwet the leaves or the rooting medium. Fog nozzles use about 25 times less water than mist nozzles and thus the rooting medium and the root zone in a fog house remain relatively dry and oxygen is readily available for root development. This produces an ideal environment for propagation of cuttings, as well as seedlings and tissue culture.

An interesting point to note is that although a dense fog is visible in the house, it does not act as a shade in any way. Light intensities at the crop level have been shown to be the same with or without fog present.

The result of eliminating loss of moisture through the leaves, while allowing oxygen to freely flow in the root zone, is that the cuttings are under much less stress. Growers have reported rooting times shortened, larger cuttings started without leaf loss, less disease, and increases in yields of rooted cuttings from 40% under mist to 99% under fog in some species.

Other Applications. In addition to providing an optimum propagating environment, a fog system can be used for complete climate control in greenhouses and shadehouses. It can be used for cooling, for foliar feeding, for fungicide/insecticide applications, for supplemental heating, and for freeze protection.

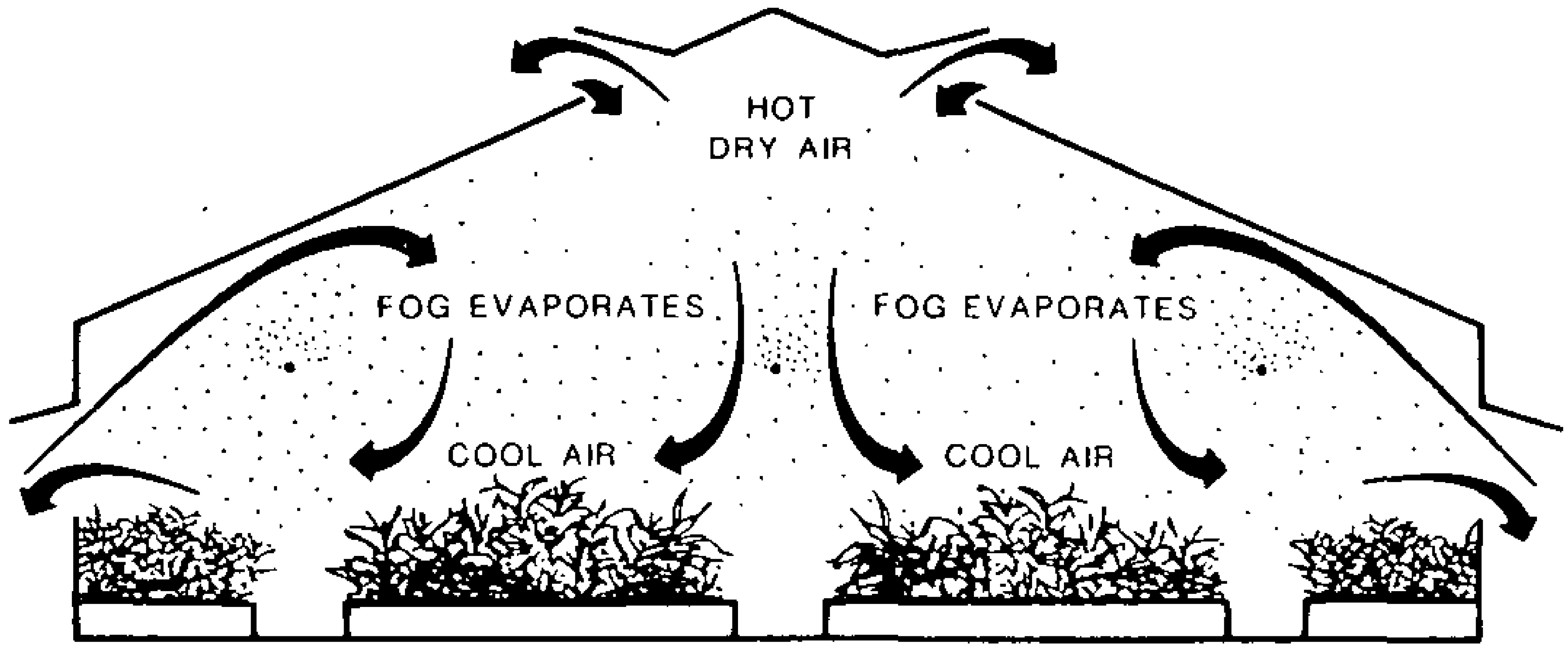
Foliar feeds, provided they are liquid or water soluble, can be put directly through the fog system. With the entire house sealed off, the solution containing the foliar feed will form a dense fog. The fog penetrates the foliage resulting in an even application throughout each plant, the undersides as well as the top. Liquid fungicides or insecticides can also be applied directly through the system.

Fog has been used extensively for its cooling properties, both in fan ventilated and naturally ventilated houses. In the cooling mode, the fog application rate is controlled so that all the fog evaporates. This differs from the propagation mode in which a visible fog is present in the house.

The amount of cooling which can be achieved depends on the relative humidity of the outside air. Up to 40 degrees of cooling has been demonstrated with outside air temperatures of 115°F and 10% relative humidity. Undoubtedly, this is an extreme case. For typical summer conditions, 20 degrees of cooling is common.

Fog System Design. The mode of operation for the system, such as propagating, cooling, etc., determines the on and off cycles for the fog nozzles. For example, in the propagating mode, the nozzles would operate about 90% of the time during a sunny afternoon in order to maintain a 100% relative humidity condition. At night the nozzles may operate only 5% of the time for the same effect. Thermostat/humidistat controls and repeat cycle timers allow a wide range of versatility to achieve the desired fogging effect.

In naturally ventilated houses, fog lines are usually placed over the aisles, spanning the length of the house. In a house with roof vents and side vents, the fog produced by each fog nozzle evaporates, cooling and humidifying the air, which, as a result of its increased density, falls downward into the growing zone. The air can then exit through the side vents. This sets up a circulation which draws outside air in through the roof vents, as shown in Figure 3.



AS HOT, DRY AIR ENTERS THE GREENHOUSE IT IS COOLED AND HUMIDIFIED BY EVAPORATION OF MICROSCOPIC FOG DROPLETS. THIS COOL, MOIST AIR FLOWS DOWN INTO THE GROWING AREA, FORCING WARM AIR TO RISE AND ESCAPE. COOLING AND HUMIDIFYING IS UNIFORM THROUGHOUT THE HOUSE.

Figure 3. Cooling and humidifying without fans using a fog system.

For proper ventilation in propagating, the naturally vented house should have openable vent space equivalent to at least 10% of the total floor space in the house.

A fog system is also very efficient for achieving an ideal propagating environment in a fan ventilated house; however, the design is slightly different from that of a naturally vented house. In the fan ventilated design, a dense array of fog nozzles is placed at the end of the house opposite the exhaust fans, i.e. the intake end of the house. The purpose of these intake fog lines is to initially cool and humidify the outside air as it enters the house. The intake fog lines provide the bulk of the humidification, but in addition, fog nozzles are placed in overhead lines which run down the aisles, spanning the length of the house. The purpose of these overhead lines is to prevent drying of the air as it is drawn through the house by the exhaust fans.

Figure 4 shows a comparison between a greenhouse which was cooled and humidified by a fog system and one which was cooled and humidified by a wet pad and fan system. The measurements were taken simultaneously on a dry summer day in the Arizona desert. The pad and fan system cooled the air from 115°F to 95°F as measured just inside the pad. The relative humidity was increased from 10% outside to 32% just inside the pads. The temperature, however, increased as the air was drawn toward the fans. The air temperature had risen to 110°F after the air had traversed the house, due to the solar reheating.

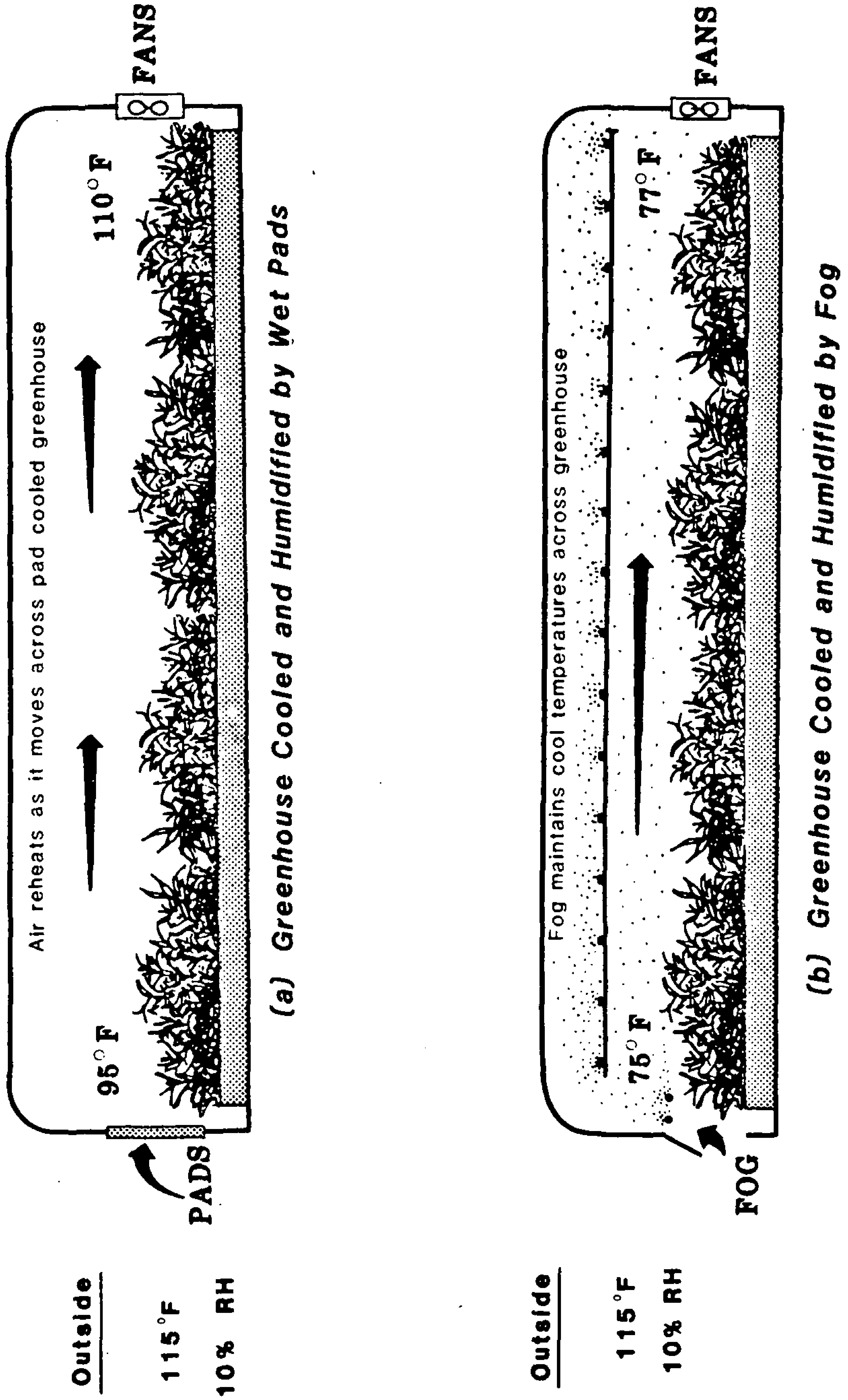


Figure 4. Greenhouse environment control: wet pads vs. fog.

In the fog cooled greenhouse, the microscopic fog droplets proved much more efficient as an evaporative cooling system and were able to cool the air down to within a few degrees of the outside wetbulb temperature. The incoming air was cooled from 115°F to 75°F at the intake end of the house and the relative humidity was increased from 10% outside to 85% inside.

Unlike the wet pad system, the air in the fog cooled greenhouse reheated very little as it was drawn through the house, since overhead fog nozzles were situated down the entire length. As the air was drawn through the house, the humidity increased further — up to 100%. The air was able to reheat only 2 degrees between the intake end and the fan end, in comparison with 15 degrees of reheating in the pad and fan house.

A further point worth considering is the fan ventilation rate in the pad-cooled house versus the fog cooled house. Typical pad and fan systems are designed for an air flow rate of 1 air change per minute, meaning that the volume of air in the house is completely replaced with outside air (pulled through by the exhaust fans) after 1 minute. The fog system is typically designed for 1 air change per 2 minutes, only half the ventilation rate required in a pad and fan system. Thus in a house requiring 2 fans for a pad and fan system, only 1 of these fans need be run if a fog system is installed.

Supplemental Heating and Freeze Protection. Fog is a very good reflector of heat energy and growers and horticulturists have long recognized that a cloud cover throughout the course of a night will keep minimum temperatures higher than would be the case if no clouds were present. For this reason, another application of the fog system is in supplemental heating and freeze protection of crops during winter months.

Fog acts in precisely the same way as a natural cloud since fog is nothing more than a cloud at ground level. A visible fog covering the growing benches in a greenhouse will trap in and evenly distribute the heat supplied by any heating system. Without fog, most of the heat produced by heaters rises to the top of the house and is lost by conduction through the roof.

Another advantage with fog is that thermostats can be set at the same temperature as the minimum desired plant temperatures; they need not be set 5° to 10° above this temperature, as is sometimes done in practice. The reason for this is that in a fog house, the temperature of the air is also the dewpoint temperature. If a leaf or plant tissue begins to cool below this temperature, condensation takes place on the plant, and a large amount of heat is released (known as the latent heat of condensation). The result is that the plant temperature will not cool below the dewpoint, which is the same as the air temperature in the house. Fog is also a much better conductor of heat than is dry air. In effect, for a given thermostat setting, the plant temperatures will remain 5° to 10° warmer in a house filled with fog than in one with no fog.

Inherent in using fog as a supplement to heaters is the fact that the relative humidity is kept at 100%. In a house heated without fog, the relative humidity drops substantially as the temperature rises.

For use in cold protection, the fog need not be used in conjunction with heaters, for the system will work alone as a freeze protection mechanism in greenhouses, shadehouses, and outdoor areas. By running the system continuously throughout the night, a dense blanket of fog can be formed and maintained even in an outdoor area. The fog acts as a reflector of the infra-red heat radiation which normally escapes from the ground and all solid objects during the night. The blanket of fog traps the heat and keeps temperatures from cooling as rapidly as they would during a clear sky condition. Up to 11°F protection has been shown in an outdoor application, e.g., the ambient air temperatures dropped to 21°F while leaf temperatures inside the fog area remained at 32°F. Even more protection can be expected in greenhouses and shadehouses due to easier containment of the fog in the desired area.

CONCLUSION

Fog systems differ considerably from mist systems. A fog system produces droplets small enough to remain suspended in the air, resulting in a 100% relative humidity environment assuring zero transpiration loss, but without overwetting the plants or the rooting medium.

The optimum propagating environment of ample root zone aeration and zero transpiration loss causes much less stress on the young plantlets. Increased yields, less disease, larger cuttings rooted, and shorter rooting times have been reported by growers propagating in a fog environment.