Disease and insect pest management will include many different components. Pesticides certainly are important parts of most pest management programs for ornamental plants. Choosing the correct product for the job is very important to the success of a pest management program. However, another very important part of pest management is the equipment (and application technique) used to apply the pesticide. The purpose of this article is to discuss major aspects of pesticide application equipment, and to provide information concerning the advantages and disadvantages of the different equipment types available for use on greenhouse crops. Emphasis will be on low-volume and ultra-low volume sprayers.

High Volume Sprayers. If a greenhouse operator has only one type of sprayer it should be a high-volume (HV) sprayer. This is the most versatile method of applying pesticides in greenhouses. HV sprays are generally believed to be inefficient for several reasons, including drop sizes produced (many too large or too small), incorrect dosage, and improper application technique. Other problems include the time required to make an application and potential groundwater contamination from excessive run-off. A common problem is even in defining what constitutes "run off".

Done properly, however, high-volume sprays remain excellent general-purpose methods of applying pesticides, despite the potential problems mentioned above. The equipment is widely available, relatively inexpensive, and remains the only legal method to apply some pesticides. Many pesticide labels for ornamental plant uses are written to effectively prevent using materials at the higher concentrations required by low-volume sprayers discussed below, even though less total pesticide may be applied in low-volume sprays. A further advantage of HV sprays is they are adaptable to pest and disease management programs requiring occasional localized or "spot" applications.

Low-Volume Sprayers. Low-volume and ultra-low-volume (LV &ULV, separated based on the amount of spray volume applied) applications utilize specialized equipment, including Total Release® aerosol products, thermal pulse-jet foggers, coldfoggers, rotary atomizers, mechanical aerosol generators, and air-assisted electrostatic sprayers. LV and ULV sprays are supposed to eliminate many disadvantages of conventional HV applications. They generally take less time to apply than HV sprays. Further, they use less water or oil to dilute, result in little or no pesticide run-off, often use less pesticide, and produce most of the spray volume in small drops. Small drops are more efficient at delivering the pesticide to certain targets.

LV and ULV sprays are not new. Various types of specialized equipment have been in use for decades. Smoke generators, ready-to-use aerosols, and mist blowers, as well as the equipment previously mentioned, have been used. All can be useful and effective in many situations, but will not totally replace the need for HV sprays. The following summarizes some of the advantages and limitations of using certain types of presently available LV equipment.
Ready-to-use aerosols. (Figure 1). These formulations, called Total ReleaseÒ aerosols, are actually prepackaged LV sprayers containing technical insecticide plus a propellant to disperse the pesticide when released. Total ReleaseÒ aerosols can be used to treat small and large greenhouses. Several insecticide formulations are available, but no fungicides. The air movement system used in the greenhouse can be used to help distribute the pesticide. Our experiments have demonstrated that pesticide deposition occurs on both upper and lower leaf surfaces in an approximate 60% upper to 40% lower ratio.

Thermal Pulse-Jet Foggers. (Figure 2). Thermal foggers have been in use for more than 35 years. Some pesticides are specially formulated for use in foggers. However, thermal foggers also can apply contact and residual pesticides, sometimes depositing as much pesticide as with an HV application. A liquid dispersal agent may be specified by the manufacturer to assist in dispersing the pesticide and reducing spray drop evaporation.

Thermal foggers are generally used to treat large areas, but can be used to rapidly treat individual smaller greenhouses. The area treated will depend on the fogger capacity and whether a vapor active or non vapor-active wettable or liquid formulation is applied. Foggers generate very small drops, usually less than 10 to 50 microns in diameter, that are able to move long distances from the applicator. With some of the larger models, spray drops will travel more than 200 feet. Liquid flow rates also vary with the unit size. For example, a small model will disperse 10 liters (approximately 2.5 gallons) in 30 minutes, and a larger model will disperse 20 liters (approximately 5 gallons) in 30 minutes. The area covered with these spray volumes will depend on whether a wettable or liquid formulation is applied. Two and one-half gallons will cover approximately 50,000 square feet with a wettable powder and 76,000 square feet with a liquid formulation.

Proper application technique is essential. When using foggers to apply wettable powder formulations, it is very important to use the proper application technique of aiming the spray over the crop at about a 30° angle. If this is not done, there may be heavy deposition in areas immediately in front of the fogger, causing excessive dosage and possible plant injury, and less deposition in other areas resulting in poor pest control. The amount of moving around required by the person doing the application will depend on the size of the fogger plus greenhouse size and configuration.

The main limitation of thermal foggers is that the distribution of contact and residual pesticides within the plant canopy and deposition on undersides of leaves may be poor. Much depends on greenhouse air movement. Therefore, using thermal foggers with certain pesticide/pest combinations may not be successful. Vapor active pesticides applied with thermal foggers can be very effective.

Mechanical Aerosol Generators. (Figure 3). These devices use air-atomizing nozzles with air supplied by an air compressor to disperse the spray liquid into small drops. Air also is the main method of moving the spray around the greenhouse and onto the foliage. Much of the spray movement is accomplished by the greenhouse air movement system, e.g., horizontal air flow (HAF) fans. These sprayers are operated unattended from a single position in the greenhouse. The spray mixture can be placed in the tank, with a timer set to begin the application later. As with thermal foggers mechanical aerosol generators are used to treat large areas. The amount of greenhouse area that can be treated with a single unit ranges from 10,000 square feet to 70,000 square feet, depending on the unit size and air flow within the greenhouse. The liquid flow rate is less than 2 fluid ounces per minute, and the total spray volume applied is about 14 liters (3.5 gallons) per acre. The pesticides are normally mixed in water, without special additives. Both liquid and wettable powder formulations can be applied, but there have been some problems with nozzles clogging with wettable powders and oily liquid formulations.

Mechanical aerosol generators generally provide good-to-excellent pesticide distribution and deposition, particularly on upper leaf surfaces. Deposition on leaf undersides has been variable, depending on the crop type, foliage canopy thickness, and plant location within the greenhouse. As might be expected, air currents within the greenhouse can significantly alter pesticide distribution.

Coldfoggers. (Figure 4). Coldfoggers use high pressure to produce small spray drops. The Pulsfog "Coldfogger" is one such applicator. A high-pressure pump is used to disperse the liquid into small drops
Coldfoggers are used to treat large or small areas. The spray stream has a range of 10 to 12 feet, and applications are made by walking through the area and aiming the spray, produced by a single nozzle, ahead and down into the crop. A liquid sheen is usually visible on the foliage following an application. These applicators produce a drop size with a volume median diameter of approximately 30 microns, and they have a flow rate of 80 liters per hour (20 gallons per hour). About 100 to 400 liters (20 to 80 gallons) of spray are applied per acre, depending on crop size. Pesticides are normally mixed in water without additional additives. Both wettable powder and liquid formulations can be applied when labels permit.

Pest control success with coldfoggers has been variable. If the pest or pathogen occurs primarily on upper leaf surfaces and on upper parts of plants, control has been quite good. Coverage on leaf undersides has been erratic, so pests such as spider mites and whitefly nymphs may not be controlled effectively. Deposition on leaf undersides depends on the plant type, plant spacing and how easily leaves can be moved in the spray stream.

Air Assisted Electrostatic Sprayers. **(Figure 5)** Several sprayers that utilize electrical charging of spray drops have been developed in the past. Research has shown that the sprayers with air assistance have been the most effective. The air assistance combined with charged spray drops produces the best (but not perfect) balance of good pesticide distribution and deposition within plant canopies. The only air-assisted electrostatic sprayers now on the market in the United States for greenhouse use are produced by Electrostatic Spraying Systems (ESS). Both handheld and unattended (similar to mechanical aerosol generators) models are available. The handheld models can be used to treat both large and small areas. Approximately 16 to 64 liters (4 to 16 gallons) are applied per acre, depending on crop size and walking speed. One acre can be treated in 1 to 4 hours. At higher spray volumes, there is a noticeable liquid sheen on leaves following an application.

Studies of electrostatic sprays using fluorescent tracers, pesticide residue analyses, and insect and pathogen bioassays have shown increased spray deposition on plants with less spray drift compared with other LV and HV sprays. Effectiveness will vary with the pesticide, crop, spray volume, and person doing the application. Some of the variation in pesticide deposition and distribution can be reduced with proper application techniques. Deposition on leaf undersides can be increased and foliage canopy penetration improved by increasing the spray volume; i.e. from 4 to 16 gallons per acre. Of course, this also increases application time.

Air-assisted rotary mist applicators. **(Figure 6)** Two basic types of these sprayers, the Turbair and Ulvafan, both manufactured in England, are now more widely available in the United States. Both are distributed by the Dramm Corporation. Both produce good pesticide deposition on all foliage surfaces with proper application technique.

Rotary atomizers are hand-held sprayers that can be used to treat large and small areas. The pesticide and water mixture flows onto a rapidly spinning disk, which throws the liquid off in a relatively narrow drop size range (10 to 80 microns). A fan behind the disk propels the spray forward in a turbulent airstream. The spray volume ranges from 8.5 to 17 quarts per acre (20 to 40 liters per hectare). When treating larger areas the 1-liter bottle containing the spray mixture will need to be refilled relatively frequently.

Turbair models have a more powerful fan, and the sprayer is aimed ahead about 10 feet, angled toward the crop, and moved from side to side. Ulvafans are more "drift" sprayers, with a less powerful fan, with a coverage area of about 6 feet. They are moved slowly up and down while walking among the crop. Practice and experience will help determine the best technique to use for each type of rotary mist applicator.

Summary. Low-volume sprays are useful tools to use in an integrated crop health management program. The best type of sprayer to use will depend on several factors, including greenhouse size and configuration, crops produced, and major pest and disease problems. No LV or ULV sprayer will be perfect in all cases. Remember, the pesticide and application interval are as important as the spray equipment.
Figure 1. Total Release Aerosol applicator among greenhouse plants. The cans are sometimes placed on elevated platforms above the plant canopy.
Figure 2. Thermal fog application in a greenhouse. The pesticide is usually mixed with a carrier solution to facilitate application. An agent is also added to make the fog visible.
Figure 3. A mechanical aerosol generator. An air compressor provides air pressure and a fan behind the spray nozzle helps distribute the pesticide.
Figure 4. A coldfog applicator.
Figure 5. An electrostatic sprayer. Newer models have a different nozzle design that is supposed to improve pest control.
Figure 6. Rotary atomizer models. Turbair models are on the left and right. An Ulvafan is in the center.