

DESIGN OF AN EXPERIMENTAL SPRAYER FOR PESTICIDE APPLICATION STUDIES IN ORCHARDS

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An experimental orchard sprayer was fabricated for use in pesticide application studies. Its design features three independently controlled vane-axial fans, vertically stacked and driven hydraulically, three pesticide nozzle manifolds, and provision for altering the air outlet geometry. Use in experimental programs has confirmed its usefulness.

INTRODUCTION

Modern pest management programs demand reduced application rates and more precise placement of chemicals (Hagley et al. 1978). It is difficult to achieve insect and disease control in the top center of the tree canopy with many current sprayers, particularly when application rates are reduced (Fisher et al. 1976). A study of the factors affecting sprayer performance is needed. Commercially available spray machines are not suited for such a study because they have large pesticide tanks, fans and nozzle manifolds fixed in position, and air volume and release angle fixed within relatively narrow limits. For these reasons, an experimental orchard sprayer was designed and fabricated as reported here.

Design Requirements

A tree canopy, because of its shape, variable density, and height, is a difficult target to spray uniformly without overspraying to runoff or underspraying to the detriment of pest control. Laboratory studies have shown that the toxicity from residual deposits of pesticide can be optimized within narrow limits of deposit/cm² for European red mite (Fisher and Menzies 1973; Fisher et al. 1974), for Oriental fruit moth (Fisher and Menzies 1976; Fisher and Menzies 1978) and for codling moth (Fisher and Menzies 1978). It is, therefore, apparent that the density and uniformity of deposit within the tree canopy should be the criteria on which to judge a spray machine's performance, so long as the drift losses are kept to a minimum.

Several aspects of the sprayer's design and use should be considered. It has been shown that the volume-velocity relationship of the airstream is important for canopy penetration by the pesticide cloud (Randall 1971). Coverage has been enhanced by spraying laterally into the tree (McMechan 1972). It is reasonable to assume that if the pesticide cloud is released horizontally rather than at a large angle above the horizontal, the droplets are less likely to pass through the boundary layer above the canopy and drift out of the target area. Therefore, an experimental unit should have a variable air output, a fan or ducting such that the air outlet can be positioned at several heights above the ground, and some provision for changing the air outlet width.



Figure 1a. Experimental sprayer: (1) vane-axial fans; (2) guide vanes; (3) nozzle manifold; (4) nozzles.

It would also be advantageous to have the nozzle manifolds' positions adjustable with respect to the tree canopy, and to the airstream.

It has been noted that through a wide range of atmospheric conditions, droplets with diameters greater than 140 μm show little tendency to drift (Threadgill et al. 1971) and that droplets larger than 100 μm have high impingement efficiencies (Bainer et al. 1955). The droplet-size distribution from hydraulic nozzles has been modified in the laboratory by trajectory separation, thereby reducing the emission of droplets smaller than 100 μm in diameter (Menzies 1975). Incorporating this method in an orchard sprayer would, therefore, be of interest.

The pesticide tank should hold approximately 350 liters and have a high, narrow profile to lend more precision to volume measurement.

The design of this experimental machine is based on the above requirements.

Design

The characteristics of the machine's design are shown in Fig. 1a. Three 533-mm diam Buffalo Type MB direct drive vane-axial fans rated at 2.83 m³/s (0.25 kPa static

pressure, 1760 rev/min, 1.26 kW) supply the air requirements for conveying. Each is powered by a Hydreco Model 2M012 hydraulic motor and can be adjusted from 0 to 2.83 m³/s output. Each fan is connected to an 80° vane-elbow outlet by a round to rectangular transition duct (533 mm diam. to 610 × 152 mm). The elbows, vanes, and transition ducts are fabricated from 2.54-mm thick aluminum sheet. Three fans provide the versatility required in the airstream. Friction losses in an alternative multiple duct system would require higher power requirements. The fans are positioned with their axes 0.91, 1.84, and 2.75 m above the ground, with their intakes to the rear of the sprayer. Each fan is held in position with a circumferential clamping band around the fan and an axial pivot pin on the outlet duct. This arrangement allows the fan and outlet duct to be rotated $\pm 15^\circ$ from the horizontal.

Auxiliary ducts for the top and bottom fans provide an alternative outlet configuration with a maximum possible air output of 5.66 m³/s (Fig. 1b). The outlet width of these ducts is 50 mm and the nozzle manifolds are mounted on the leading face. The air patterns from the top and bottom fans converge 1.5 m from the outlet.

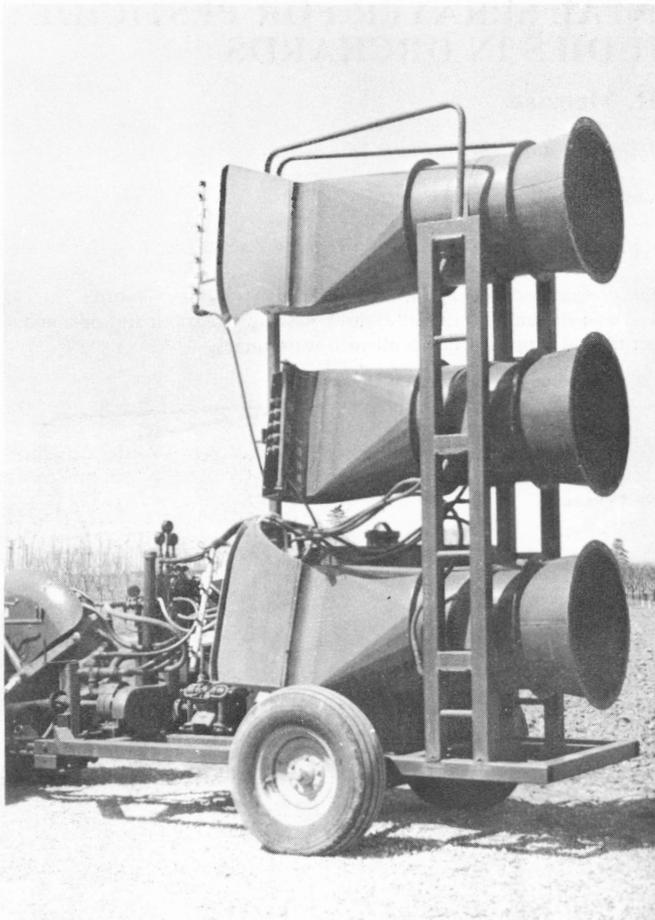


Figure 1b. Experimental sprayer with two auxiliary ducts attached.

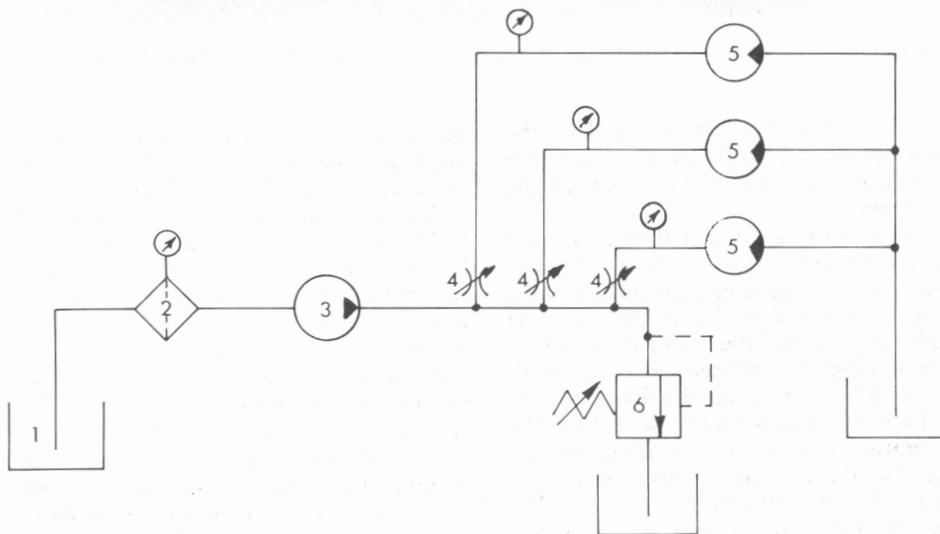


Figure 2. Schematic diagram of hydraulic system for fan control: (1) tank; (2) filter; (3) gear pump; (4) flow control valves; (5) fan motors; (6) pressure relief valve.

Oil is supplied to the hydraulic drive motors by a Gresen RJM 2000 gear pump which is driven from the PTO powered implement shaft through a roller chain drive. Three flow control valves on the pressure-regulated manifold control the speed of the fan motors (Fig. 2). The filter is

located in the suction line to the pump. The 136 L oil reservoir has three baffles to insure good circulation for cooling. Calibration curves were established that relate air output to fan motor inlet pressure so that operating conditions can easily be set in the orchard.

Three pesticide nozzle-manifolds are

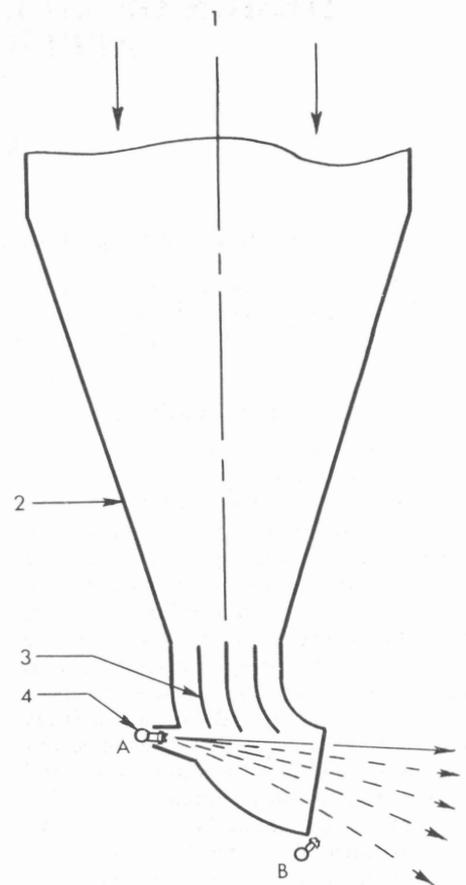


Figure 3. Schematic plan view of air duct: (1) air flow direction; (2) transition duct; (3) guide vanes; (4) nozzle manifold. (A) nozzle position for separation (B) conventional position.

mounted, one to each air outlet elbow, so that the spray can be injected across the airstreams (Fig. 3). The manifolds can be rotated on their support brackets to the alternative position B where either flat fan, hollow cone, or full cone nozzles can be used. Five nozzle-bodies are attached by ball valves and swivel connectors to each manifold. The pesticide is pumped from the 341 L hydraulically agitated tank by a Comet P100 diaphragm pump to a pressure-regulated manifold (Fig. 4). Three lines, with hand-operated ball-valves, control the on-off flow to the nozzle manifolds.

The machine frame and vertical fan supports are fabricated from 76-mm square section steel tube. The axle is attached to the frame through drag links and is cushioned with 108 × 108 × 45 mm-thick rubber shock pads. The aluminum pesticide tank is positioned with its center of gravity as close as possible to the axle (307 mm) to minimize load variations on the drawbar. The sprayer is supported on two 241 × 381 mm ribbed implement tires.

Design Flexibility

The flexibility of the machine's configuration is important for application studies related to machine parameters. The design of this unit fulfills this requirement as follows:

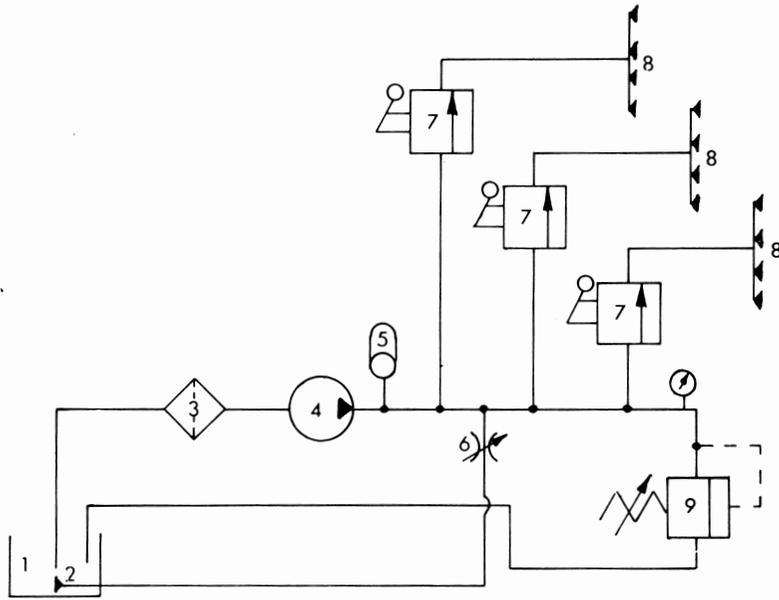


Figure 4. Schematic diagram of pesticide system: (1) tank; (2) agitation nozzle; (3) filter; (4) pump; (5) surge tank; (6) flow control valve (agitation); (7) ball valves for nozzle manifolds; (8) nozzle manifolds; (9) pressure regulator.

The air volume output can be varied from 0 to 8.5 m³/s from one side of the machine. If this is limited to the range from 0 to 2.83 m³/s, its source can be located at 0.91, 1.84, or 2.75 m above the ground permitting spraying upwards, horizontally or downwards into the canopy (for semi-dwarf and dwarf trees), or combinations of these configurations if more than one fan is used. Speed controls for each fan provide further flexibility in air output. The auxiliary ducts provide a change in the volume-velocity ratio of the air output.

The nozzle manifolds can be located in

the outlet ducts to utilize trajectory separation or can be located external to the duct for testing a variety of nozzle types and numbers. Changes in nozzle numbers and orientation can be made rapidly with individual shutoff valves and swivels on each nozzle.

The machine has been used in experimental programs for several years; the results will be published in the near future.

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