EQUIPMENT FOR PRECISE PLACEMENT OF PESTICIDES ON SHADE TREES[1]

by Loren E. Bode

Spraying shade trees for insect and disease control requires thorough coverage of leaf, stem, and trunk surfaces. Much more energy is required than for ground spraying because of the greater distance the spray must be projected and the necessity for covering large surface areas.

Tree spraying is normally accomplished with either high-pressure, high-volume hydraulic sprayers or air-carrier sprayers. Hydraulic sprayers use pressure in the liquid system to impart sufficient velocity to the spray droplets to propel them from the point of release to the point of application. Air-carrier sprayers use an airstream to transport and distribute the spray droplets; they may use either high- or low-pressure liquid systems.

High-Pressure Hydraulic Sprayers

Hydraulic sprayers used for spraying shade trees generally have tanks, pumps, and control systems that can handle high volumes of spray materials at high pressures. Sprayers are available with tank capacities up to 1500 gallons and with pumps that can supply up to 60 gallons per minute at pressures up to 800 psi. Hand-operated spray guns are used to direct the spray onto the tree. To insure thorough coverage, liquid is applied to the point of runoff.

Positive displacement piston pumps are generally used to produce the high pressures required. Abrasion-resistant cylinder linings are desirable to prevent damage to the pump when spraying wettable powders. Piston pumps, however, produce a pulsating flow that can damage gages, valves, hose fittings, and even the pump itself. A surge tank should therefore be installed to absorb the pressure peaks. Air-chamber surge tanks are available for intermittent spraying at pressures up to 400 psi. Although the initial cost of a piston pump is high, its rugged construction, dependability, and long life make it economical for continuous, hard usage.

A relief valve is necessary to protect the system from excessive pressure and to control the pressure applied to the spray gun. Tension on the spring in the relief valve is adjusted so as to maintain a constant pressure in the system by bypassing some of the liquid to the supply tank. When the line to the hand gun is shut off, the entire output of the pump is bypassed to the tank. The relief valve must be sized to handle the desired flow rates and pressures. Some are available with two or more springs that make it possible to operate the spray system over a wide range of pressures. When the system is used at a low pressure only the more responsive low-pressure spring is energized.

When pressures of over 200 psi are to be used, the relief valve should be replaced with an unloader valve. This type of valve will decrease the pressure on the pump and the load on the engine when the spray valve is closed. It should be remembered that if an unloader valve is used in a system having hydraulic agitation, the agitation flow may be insufficient when the valve is unloading.

A pressure gage covering the range of pressures to be used should be installed in the supply line to assist in adjusting and monitoring the sprayer's operation. A damper is needed to protect the gage from the pump pulsations. All components of the system must be designed to withstand the high pressures produced by the pump. Figure 1 illustrates the basic connections for a spraying system utilizing a piston pump.

Centrifugal pumps can be used for high-volume applications at low pressures. They have excellent wear resistance and deliver much higher volumes than piston pumps, but single-stage types can produce pressures up to only about 60 psi. Multistage pumps can develop pressures up to about 200 psi but are much more expensive. When a centrifugal pump is used, a throttling valve

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can be substituted for the relief valve. Throttling valves achieve the desired pressure by simply restricting the flow.

Mechanical agitators are generally used on systems with piston pumps. Since centrifugal pumps provide high capacities, the amount of hydraulic agitation they produce is satisfactory to keep wettable powders in suspension. Hydraulic agitators should be connected to the high-pressure line ahead of the boom or handgun cutoff valve so that they will operate continuously.

Engines to drive spray pumps should be sized according to the flow rate and pressure required. When determining the horsepower needed for a system, a pump efficiency (Eff) of 50 to 60 percent should be assumed. The horsepower required to drive the pump can be estimated by the formula

$$\mathbf{Hp} = \frac{\mathbf{(gpm)(psi)}}{\mathbf{(1{,}714)(Eff)}}$$

Handguns that can handle pressures up to 1,000 psi are available. For optimum results the correct combination of nozzle flow rate and pressure must be selected. Figure 2 shows the effect of flow rate and pressure on the vertical reach of typical spray gun nozzles.

To reach the tops of trees, large drops are required, but the size of the drops emitted decreases with increasing pressure. Hence, there are limits to the amount that the pressure can be increased to extend the vertical range of a spray stream. Relatively large droplets are necessary to keep wind from dissipating or spreading the liquid stream. As can be seen in Figure 2, the vertical

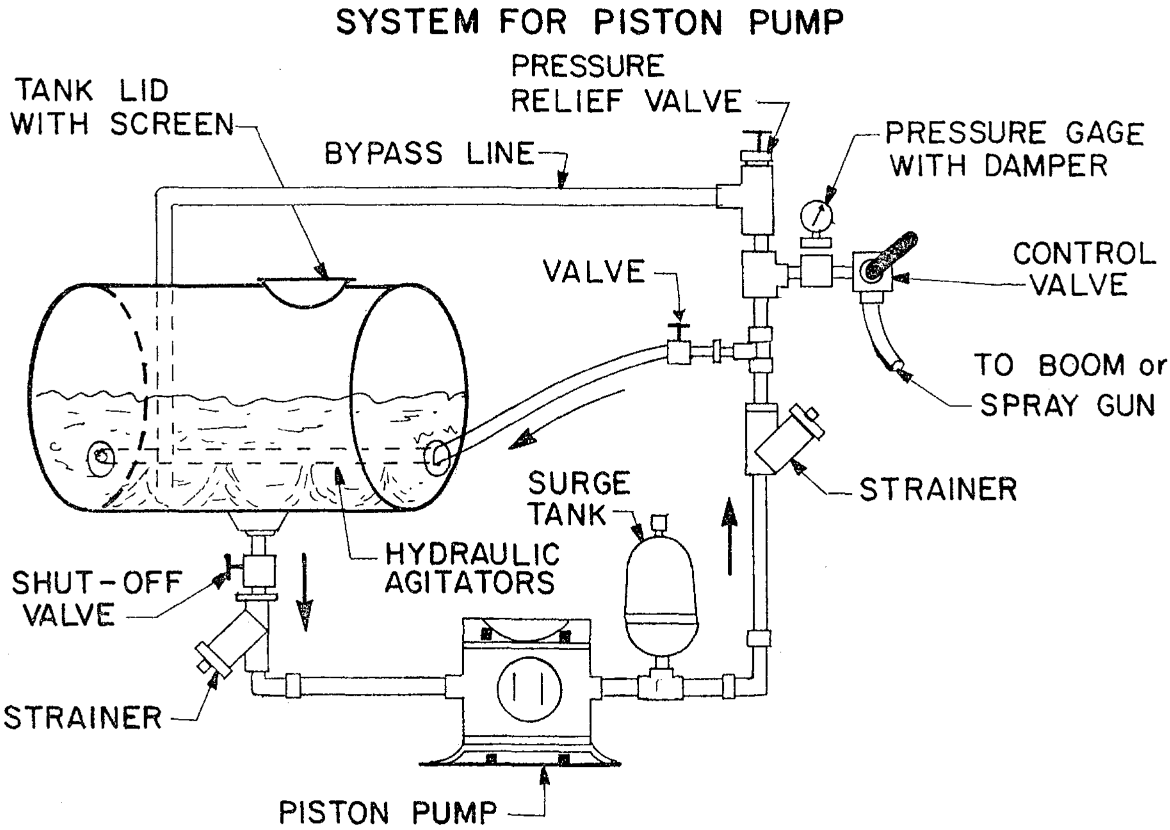

Fig. 1. Basic high-pressure sprayer system using a positive displacement piston pump.

reach increases only slightly for pressures above 400 psi.

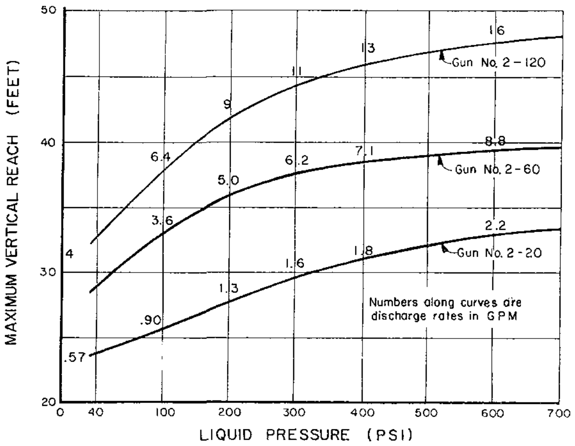

Fig. 2. Vertical reach of typical spray gun nozzles at various spray pressures.

When vertical reach becomes a problem, better results will be obtained by selecting a nozzle of larger capacity than by increasing the pressure. The greater the nozzle capacity and the narrower its spray pattern, the higher it will reach. Guns and nozzle kits are available to spray trees up to 100 feet tall at pressures between 350 to 450 psi. Ladders, elevated truck-mounted platforms, or gun extensions can also be used to gain the necessary height.

Disc-type nozzle orifices are usually numbered to represent the orifice diameter in 64ths of an inch. Table 1 shows the relationship between flow rate, pressure, and orifice size. At any given pressure, the flow rate will increase by a factor of four when the orifice diameter is doubled. Conversely, for any size orifice, the pressure must be increased by a factor of four to double the output.

Nozzles wear with use, particularly when they are used to spray abrasive materials such as wettable powders; as they wear, the orifice becomes larger and nozzle output increases. Because of the high stress on the nozzles, hardened stainless steel, chrome-plated brass, or ceramic nozzle components should be used. Discs are available with hard center cores that can be replaced when they become worn. Multiple nozzle arrangements with smaller nozzles may be used and tend to provide better coverage because they produce smaller droplets. However, drift increases and vertical reach decreases with smaller droplet sizes.

Air-Carrier Sprayers

Sprayers that blow the spray into the trees with a blast of air are equipped with powerful fans to generate the required air current. Nozzles dispense the spray droplets into the high-velocity air stream. Various combinations of air volume, air velocity, liquid volume, and liquid pressure are used in air sprayers to obtain uniform spray distribution.

To give thorough coverage, air sprayers must displace the air present in and around the tree, replacing it with spray-laden air. The volume of air delivered by the sprayer must be at least equal the volume of space between the sprayer and the far side of the tree. For example, if a shade tree is 50 feet tall and 25 feet in diameter, its volume can be considered as a cylinder:

$$V = \pi/4\, D^2 H = 3.14/4(25)^2 50 = 24{,}531 \text{ ft}^3$$

Therefore, approximately 25,000 cubic feet of air is required just to displace the air in the 50-foot-tall tree.

Since air sprayers use both air and water as diluents, they give full coverage with less water

Table 1. Spray-gun flow rate in gallons per minute for orifice discs of various sizes.

Orifice	Pressure (psi)					
disc no.	50	100	200	400	600	800
2	.3	.4	.5	.7	.9	1.0
4	.6	.9	1.2	1.6	2.1	2.4
6	1.3	1.8	2.5	3.4	4.1	4.6
8	2.1	3.0	4.3	6.0	7.1	8.0
10	3.1	4.4	6.2	8.7	10.5	12.0
12	4.4	6.2	8.7	12.0	14.2	16.0
16	7.4	10..0	13.8	18.9	22.6	25.8

than hydraulic sprayers. The use of a lower water-to-pesticide ratio with air sprayers is termed *concentrate* or *low-volume* spraying. With this technique, 3, 5, or even 10 times the amount of pesticide is used per 100 gallons of spray, but only 1/3, 1/5, or 1/10 as many gallons of spray are applied to the trees. In concentrate spraying, this rate is referred to as 3X, 5X, or 10X application. The resulting deposit of pesticide on leaves should be the same as with the dilute method. Table 2 shows the amount of spray required per tree for various degrees of concentrate spraying.

Basing the degree of concentration on the dilute application rate (spraying to the point of runoff) has caused considerable confusion. A 5X concentrate may mean 10 gallons per tree in one area but 8 gallons per tree in another area. The difference is that one operator using a handgun may require 50 gallons per tree to obtain satisfactory coverage while another operator may use only 40 gallons to treat the same tree. The degree of foliage, amount of runoff, timing, and spraying techniques are all reasons for this variance.

The primary advantages of using concentrated sprays are that they require less labor, water, and time than applying dilute mixtures. Concentrate spraying has several limitations that must be clearly understood by anyone considering a change from dilute to concentrate spraying:

1. The greatest savings in time and labor costs occur when one converts from dilute sprays to those of about 10X concentration. The savings are negligible when one switches from a 10X to a 20X or 30X concentration. Most air sprayers can be set up to give good coverage at concentrations up to 10X; however, the higher the concentration, the greater the effect of improper application. Changes from dilute to concentrate spraying should be made gradually and carefully.
2. As the water volume is decreased the air capacity should be increased to maintain even distribution and thorough coverage. This principle is violated by the present trend toward using smaller fans in high-concentrate sprayers.
3. The evaporation and drift of pesticides is increased because concentrate spraying requires smaller drops to maintain adequate coverage. Small drops are much more affected by humidity and wind than large ones. The range of climatic conditions suitable for spraying are more restrictive for concentrate spraying. Because of drift and evaporation losses, the ideal time to apply concentrates sprays is at night.
4. There is no runoff with concentrate spraying, making it impossible to tell the degree of coverage achieved during application. The spray pattern is almost invisible, which means that the operator must be well-trained and experienced.

For precise application of pesticides to a tree, the nozzle type, flow rate, and pressure must be coordinated with the velocity and volume of the airstream. Researchers do not agree on the ideal range of drop sizes for most effective coverage. The drops must be small enough to provide good coverage, yet large enough to impinge on the foliage and not be highly susceptible to evapora-

Table 2. Gallons of concentrate spray required per tree.

Concentrate to be applied	Dilute spray (gallons per tree)					
	5	8	10	15	20	50
1X	5.0	8.0	10.0	15.0	20.0	50.0
2X	2.5	4.0	5.0	7.5	10.0	25.0
3X	1.7	2.7	3.8	5.0	6.7	16.7
4X	1.3	2.0	2.5	3.8	5.0	12.5
5X	1.0	1.6	2.0	3.0	4.0	10.0
6X	.8	1.3	1.7	2.5	3.3	8.3
8X	.6	1.0	1.3	1.9	2.5	6.3
10X	.5	.8	1.0	1.5	2.0	5.0
15X	.3	.5	.7	1.0	1.3	3.3
20X	—	.4	.5	.8	1.0	2.5
30X	—	—	.3	.5	.7	1.7

tion and wind currents. Several scientists suggest that droplets in the 30- to 80-micron range would give maximum coverge with any given amount of spray material. Droplet size is a function of nozzle type and size, the viscosity and surface tension of the liquid, nozzle pressure, and the relative velocities of the droplet and the air. Spray drops will shatter when subjected to high-velocity air.

Higher air velocity at the nozzle means better spray atomization but higher evaporative losses because of the greater difference in velocity between the droplet and the carrier air. The ideal situation is to use a nozzle and pressure that results in a liquid discharge velocity equal to the air discharge velocity. For example, at 200 psi the liquid discharge velocity is 105 miles per hour (MPH), and it is 91 MPH at 150 psi.

Research has shown that to obtain uniform coverage of an entire tree it is necessary to direct considerably more spray toward the top of the tree than toward the lower portions. The reason is that the larger drops, which contain most of the spray's volume, settle out of the airstream very rapidly.

The airflow rate and velocity of the airstream are critical to placing the spray material in the top of a tree. The airstream must be strong enough to drive the spray into the tree and impinge the drops onto the foliage even when light winds are present. Studies have been conducted to determine the best ratio of air velocity to airflow rate. Figure 3 shows a comparison of the air velocities for two sprayers with the same fan horsepower but with different discharge velocities and airflow rates. One sprayer delivers 70,000 cfm at 80 MPH and the other delivers 31,000 cfm at a 50% higher velocity (120 MPH). Tests show that typical airstreams lose 70 to 75% of their velocity in the first 20 to 25 feet after leaving the sprayer (Figure 3). Airstreams from low-volume fans lose their velocity sooner than airstreams from high-volume fans. For a discharge velocity of 120 MPH, the velocity 25 feet from the discharge port is only about 30 MPH. At 50 feet it is 15 MPH or less. In research tests a sprayer delivering a higher airflow rate but lower velocity deposited the pesticide much more uniformly and applied more in the top of the tree.

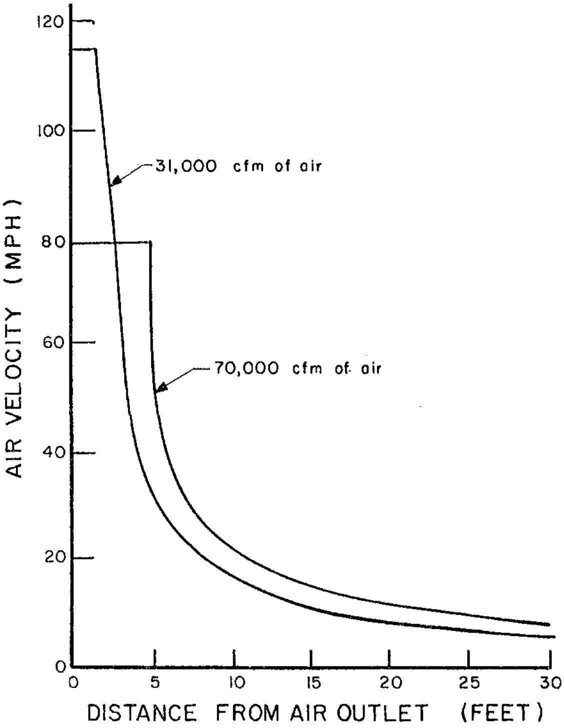

Fig. 3. Comparison of the decrease in air velocity with distance from the air outlet of two sprayers having different airflow rates.

A certain minimum air velocity is needed to convey and impinge the spray drops. There are no known data that show with certainty the velocity needed to make various sizes of droplets impinge on a leaf in an airstream. Several researchers have shown that large spray droplets produce higher deposition efficiencies than do small droplets. More research is needed to determine the air velocities needed to produce high deposition efficiencies under conditions encountered with air sprayers.

Electrostatic Spraying

Electrostatic spraying has the potential to produce increased deposition and coverage on trees. Newly designed systems have overcome the problems of earlier electrostatic machines and are giving consistent results. The basic principle of such systems is to charge the drops by electrostatic induction and to transport the drops to the tree in an airstream. As spray droplets are generated within the nozzle in the presence of a high-voltage electric field, they take on a negative charge and are then carried outward to the tree in the airstream. The cloud of negatively charged spray droplets drives negative ions out of the tree into the ground, leaving the tree with a positive charge. The negatively charged drops are then drawn to the positively charged plant, resulting in greater pesticide coverage on the underside of leaves and stems than can be achieved with uncharged sprays. Prototype electrostatic sprayers are being evaluated and the results to date are very promising.

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ABSTRACTS

Bramble, William. 1980. **Sound right-of-way program must include plant ecology.** Weeds Trees & Turf 19(1): 16-18.

Plant ecology is the science which treats of relations between plants and their environment — a reciprocal relationship. An understanding of these ecological relationships is basic to sound ROW management. To simplify and make something useful and understandable out of the complex ROW situation is the most difficult task in application of ecology to management. One of the leading tenets in an ecological approach to ROW management is the stability of shrub communities. The concept is that pure shrub patches on ROWs, once established and trees removed from them, are stable and resist tree invasion. The sequence of events which takes place after a ROW is cleared through a forest has some very interesting ecological aspects which are also a key to what occurs in older ROWs.

Thimann, Kenneth. 1980. **Scientist defends use of 2,4-D**. Agrichemical Age 24(2): 29.

2,4-D is the most generally useful of all herbicides. Its discovery arose from the work on natural plant hormones, to which it is related. It is harmless to man, it is rapidly destroyed by bacteria in the soil (and to nontoxic breakdown products), and lastly it has the special ability to kill broadleaved plants (technically dicotyledons) without harming the narrowleaved group (monocotyledons), a group that includes the grasses, wheat, barley, corn, rice, etc. It has been in regular use throughout Europe and North America since about 1948, i.e., for 31 years, and in that time the only damage to human ascribed to it, as far as I know, was to a few who deliverately drank it for suicidal purposes. Now some pesticides are indeed toxic to humans. When EPA made the mistake of banning the insecticide DDT, farmers and others resorted to malathion and other organophosphates which are toxic, and those have accounted for over 60% of the hospitalized cases of pesticide poisoning in 1976-77.