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New Pesticide Application Equipment and Techniques

Several new developments in equipment and techniques allow more efficient and precise application of pesticides. None will completely revolutionize and replace present practices, but each has potential in special applications. After extensive field tests, these techniques and equipment either will fade into oblivion or, if proved effective, will take their place in our arsenal of devices.

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0191-2917/81/01003205/$03.00/0

Controlling the Droplet Spectrum

Spray drift and target coverage depend largely on the range of droplet sizes produced by the atomizer. Small drops provide excellent coverage on the intended target but are highly susceptible to drift. Large drops are not as susceptible to drift but may result in inadequate spray coverage unless application volumes are increased to unrealistic levels. All commercially available agricultural spray nozzles produce sprays with a wide range of drop sizes. For each type of application, selecting a nozzle involves a compromise between obtaining adequate coverage and keeping the drift potential within acceptable limits.

Spray nozzle manufacturers have been active in designing nozzles that reduce the number of unwanted small drops. Delavan Corporation is marketing two designs of Raindrop® nozzles that rely on a secondary swirl chamber to absorb some of the energy in the liquid after it emits from the primary chamber. The spray leaves the secondary chamber at a lower velocity and produces a hollow-cone pattern made up of much larger drops than those emitted by standard nozzles. The RD Raindrop nozzle consists basically of a conventional disc-core hollow-cone nozzle to which a special cap has been added. The RA Raindrop nozzle (Fig. 1A) uses a right-angle swirl chamber and a Raindrop cap. According to Delavan, less than 1% of the spray volume from a Raindrop nozzle with a flow rate of 1.1 L/min is in drops smaller than 100 μm (0.004 in.) in diameter. In contrast, 16% of the spray produced by an equal-sized conventional hollow-cone nozzle is in drops that small or smaller.

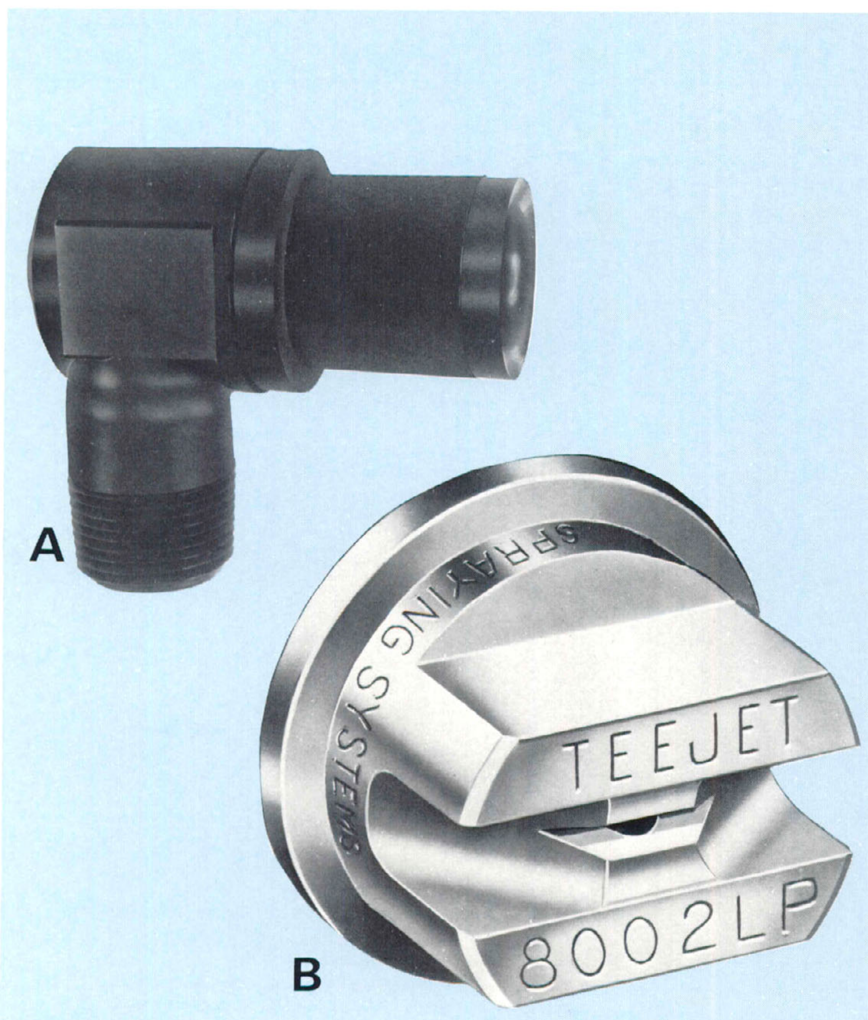

Fig. 1. Spray nozzles designed to reduce drift: (A) RA Raindrop and (B) LP flat-fan.

Spraying Systems Company has wide-angle full-cone nozzles that can be used with a premetering orifice to decrease nozzle exit pressure and increase spray droplet size. Spraying Systems also has developed the LP (low-pressure) flat-fan nozzle (Fig. 1B). The nozzle orifice is machined so that an LP tip at 15 psi produces a flow rate, spray pattern, and fan angle quite similar to those of a regular flat-fan tip at 40 psi. Consequently, an LP nozzle producing the same output as a regular flat-fan nozzle has a larger orifice, a lower sheet velocity, and a spectrum of considerably larger drops. Measurements at the University of Illinois and Texas A&M University have verified that drift deposits are less for the LP and Raindrop nozzles than for conventional nozzles.

Methods to completely control the droplet size spectrum with uniform-sized spray drops are being studied. The premise is that eliminating droplets

Fig. 2. Micromax sprayer for controlled droplet application.

smaller than 150 μm will reduce off-target drift and eliminating droplets larger than 300 μm will allow good coverage with low application volumes. For example, a spray containing only 200-μm drops applied at only 9.4 L/ha would result in a coverage of 23 drops/cm^2 of soil surface. This size drop should deposit well and provide sufficient coverage for most pesticide applications. The advantages of such an application over conventional hydraulic nozzles include less drift and less water used.

Many different ways have been found to generate uniform spray drops. One method uses a magnetostrictive device, piezoelectric crystal, air horn, or wave generator to apply a controlled frequency pulse to the liquid either at or above a small (usually less than 400 μm) hole in the nozzle. The number of droplets produced per second with this technique is much smaller than that produced with a hydraulic nozzle.

Although development work has been considerable, no commercially successful field application has resulted. Problems include producing accurate multiple-orifice plates, adequately filtering spray liquids to prevent clogging, and preventing formed drops from coalescing. A multicapillary jet unit on the market, the Micro-Foil, relies on the natural frequency of the liquid jet to form fairly uniform large drops and is used primarily on helicopters for spraying at speeds less than 80 km/hr.

Rotary atomizers have been used for many years to apply pesticides, with some success. Spinning disks, cups, and perforated screens use centrifugal force to produce a narrow spectrum of drop sizes. In recent years, researchers in the United Kingdom have extensively examined the concept of controlled droplet application (CDA). In developing countries, hand-held units are being used commercially on crops. White fly on cotton has been controlled, for example, with rates as low as 1 L/ha; drop sizes approximately 40 μm result in 300 drops/cm^2 of soil surface and about 80 drops/cm^2 of leaf surface.

The most widely used sprayer for controlled droplet application, produced by Micron Sprayers of Bromyard, England, is a spinning cup with small radial grooves up the inside. Several models are available but most are driven by a small DC motor at speeds of 2,000–5,000 rpm. Fairly uniform droplets are produced with volume median diameters ($D_{V.5}$) from 40 to 250 μm, depending on cup diameter, speed, and flow rate. The Herbi model, for applying herbicides, generates 220–260 μm droplets that are deposited in a 1.2-m circular pattern. The ULVA model produces 70–90 μm droplets suitable for many insecticides and fungicides, and the ULVAFAN model is for applying pesticides in enclosed areas.

The most recent CDA model, the Micromax, is tool-bar mounted for broadcast applications (Fig. 2). The sprayer can be driven at 2,000 or 5,000 rpm by choice of pulleys on a belt drive using a DC motor and 12-V tractor electrical system. At 5,000 rpm with a flow rate of 200 ml/min, the sprayer produces a fairly narrow drop spectrum, with a $D_{V.5}$ of about 100 μm; at 2,000 rpm with a flow rate of 1,000 ml/min, 250-μm droplets are produced. At spacings of 200 cm, application rates of 20–100 L/ha can be achieved at reasonable field speeds.

Worldwide interest in CDA application is considerable. Development work is continuing not only on field units but also on units for use on grapes, hops, and fruit trees. Controlling droplet size of sprays may well result in much lower spray volumes with significantly less drift.

Modification of such spray liquid properties as viscosity is another means of shifting the droplet size spectrum upward. Because viscosity modifiers, such as Vistik, Dacagin, Norbak, and invert emulsions, are generally non-Newtonian and pseudoplastic in behavior, high concentrations must be used in the spray tank so the liquid emitting from the nozzle will be a few times more viscous than water. The new polyvinyl thickening products, such as Nalco-Trol, Lo-Drift, and Target, are effective in lesser amounts and easier to use. These products, which are seeing limited use, not only increase spray viscosity but also have other viscoelastic properties that reduce the number of fine droplets produced. Tests indicate that Nalco-Trol is essentially Newtonian under shear, is less salt-sensitive than most of the other thickeners, and reduces the evaporation rate of droplets by about 30%. Field research at the University of Illinois, Texas A&M University, and the University of California indicates that drift deposits can be reduced by as much as 80% with Nalco-Trol concentrations of less than 0.05%.

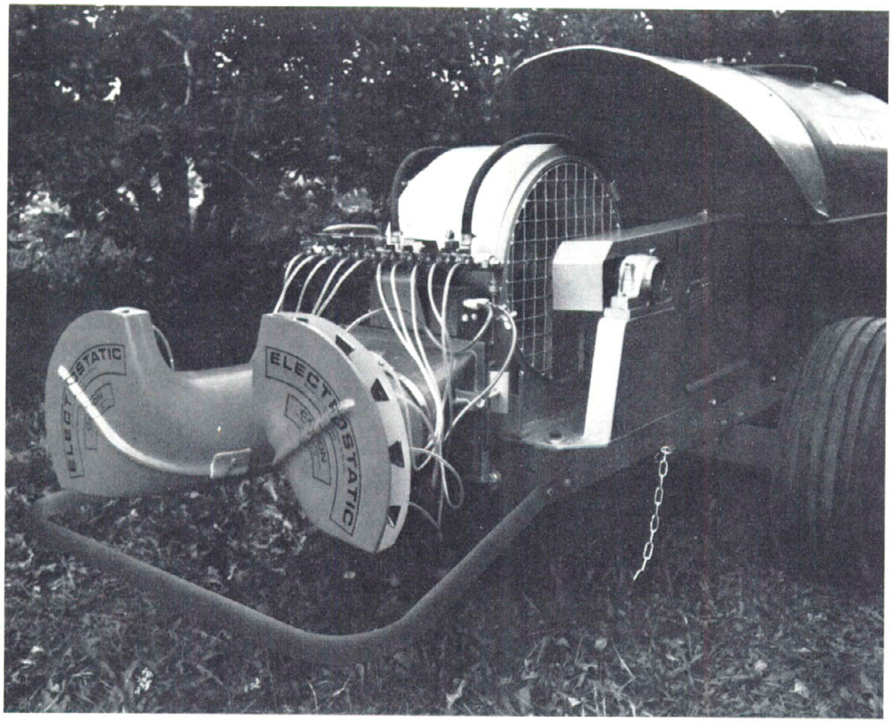

Fig. 3. With the E ± SPRAY electrostatic sprayer, the pesticide solution passes through specially designed spray nozzles containing electrodes and takes on a high electrical charge.

Fig. 4. Spray rate monitor with speed and flow rate sensors. (Inset) Controller.

Methods Using Electrical Energy

Electrostatic spraying is making a comeback as a means to obtain more efficient applications of pesticides. In electrostatic spraying, the pesticide solution passes through specially designed spray nozzles containing electrodes and takes on a high electrical charge. The spray cloud induces an opposite charge on the plants, which are at ground potential, causing an electrical attraction between the cloud and the plants. At the same time, the negatively charged drops in the cloud repel each other so that the cloud expands outward and is drawn to any surface connected to the ground. Thus, pesticide distribution is greater on the underside of interior leaves and stems and the deposit on the entire plant is more uniform than with uncharged sprays.

The only electrostatic unit commercially available is the E±SPRAY (Fig. 3), introduced by Marwald, Ltd. The unit is used on Kinkelder's low-volume air-shear orchard sprayer equipped with a nonmetallic head. The E±SPRAY unit is currently used on fruit, nuts, grapes, and ornamentals, and units for vegetables and row crops are being developed.

Two other institutions have electrostatic sprayers in the development stage. Ed Law of the University of Georgia has designed and patented an electrostatic system that uses compressed air to atomize and carry the spray material into the crop. A calibration monitoring system keeps the spray cloud at the optimum charge. Evaluations of prototype units have shown excellent pest control when one-half the recommended pesticide rate is applied in 8 L of water per hectare. ICI of Great Britain also is working with electrostatics. Their Electrodyn system combines electrostatics with controlled droplet application and has no moving parts. Spray material flows by gravity to the nozzle and is charged and atomized by electrodes. Droplets range in size from 40 to 200 μm, depending on the voltage applied. ICI plans to introduce the Electrodyn into certain developing countries.

Lasco, Inc., has developed a selective weed control system called EDS (electrical discharge system) that delivers high voltage to a metal bar, which passes a current through any plant contacted. The plant's electrolytic solution boils and ruptures cell walls, killing the plant. The EDS is powered by a generator operated from a tractor, and energy requirements are high.

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Electronic Sensors, Monitors, and Control Systems

Advances in electronics are having an impact on pesticide application techniques. At least two types of monitors with sensors to indicate clogged or partially clogged nozzles are available. One uses a mechanical system to complete an electrical circuit through the spray sheet. In the other, a sonic sensor molded into the nozzle body activates an alarm buzzer when the nozzle becomes partially plugged.

Several companies make spray rate monitors (Fig. 4). Each system has a meter to sense total flow to the spray boom, a transducer to sense travel speed, a control to dial in the effective width sprayed, and a panel that continuously displays the spray rate during operation. Some units have such additional features as displays of nozzle flow, travel speed, area covered, total volume sprayed, and amount of solution remaining in the tank. Initial problems with flowmeters have been solved by the manufacturers, and most monitors are maintaining good reliability in the field. Spray rate monitors have the potential of eliminating many of the current errors in application accuracy.

Some manufacturers add a controller (Fig. 4, inset) system to their spray rate monitors. A microprocessor-controlled servovalve assembly automatically regulates the flow in proportion to travel speed to maintain a constant spray rate. Several control systems have such features as alarm systems, manual overrides, and individual boom controls. The factor limiting the operating range of any control system is the spray nozzle. All currently used nozzles must be operated within a narrow range of pressures to obtain a good spray pattern while controlling droplet sizes. With all automatic calibration systems, nozzle pressure must change in proportion to travel speed. Pressure varies as the square of the speed and must increase fourfold when speed is doubled. This is more variation than most nozzle types can utilize and still obtain quality atomization. Basic research is under way to develop nozzles that will maintain good atomization characteristics over a wide range of flow rates. Bypass nozzles, developed by Delavan Corporation, that return unneeded spray solution to the supply tank are being considered for use with automatic control systems.

Studies are also being conducted to develop sensors that continuously monitor soil organic matter content during field application of pesticides. In the research studies, reflected light passes through optical interference filters into phototransistors, which transform the reflected light into an electrical signal proportional to soil organic matter content. An on-board microprocessor delivers the properly amplified signal to a stepping motor for automatic control of application rate. The concept needs a great deal more development before becoming commercially available.

Marking swaths is a major problem when applying pesticides, especially with high-speed sprayers that have wide booms. Overlaps and skips could be reduced with accurate swath-marking systems. Current research activities are aimed at utilizing such electronic advances as light sensing, rotating lasers, and radio-controlled guidance systems. One commercially available system, the Ag-Nav, uses radio signals that an on-board processor converts to a series of relative locations to track and guide the operator by means of a continuous display on the dashboard. The system can handle swath widths from 0.5 to 30 m at distances up to 1,500 m.

Pesticide Injection Systems and Selective Placement

Work is again being conducted on developing a spraying system that injects undiluted pesticide directly into a conventional sprayer applying only carrier solution. Pesticides are metered at rates directly proportional to travel speed using adjustable displacement metering pumps. Errors in application can result if the pesticide is injected into the carrier at the pump, then is delayed in reaching the nozzle; improper mixing may occur if the pesticide is injected directly into the nozzle. Handling of wettable powders is also a problem. No units are commercially available, but several state universities and commercial firms have systems in development. If the major problems can be overcome, induction sprayers have the potential for eliminating some of the environmental and human hazards of using pesticides. Operators do not have to handle the concentrated pesticides during mixing and loading, there are no surplus mixtures requiring disposal, and the supply tank does not have to be cleaned to prevent contamination.

Efficiency of application can be improved by spraying only the target pest. Tests have shown that shutting off the spray between each plant reduces the pesticide amount by 25–80%, with no loss of pest control. Some intermittent sprayers use mechanical feelers to trigger the spray. Others have photoelectric sensors for activating the system; when the light beam is interrupted by a plant, a solenoid valve opens and pesticide flows to the spray nozzles. Timers allow for various lengths of spray. Easy Hoe, Inc., has a commercial unit designed for herbicide application that activates when weeds trigger a mechanical switch.

Many devices for selective application of pesticides have become available during the past few years, including directed nozzles, shielded nozzles, wax bars, burlap-wrapped booms, foam-rubber wipers, and recirculating sprayers. Acceptance of the selective application concept was limited somewhat by the scarcity of suitable pesticides, but interest

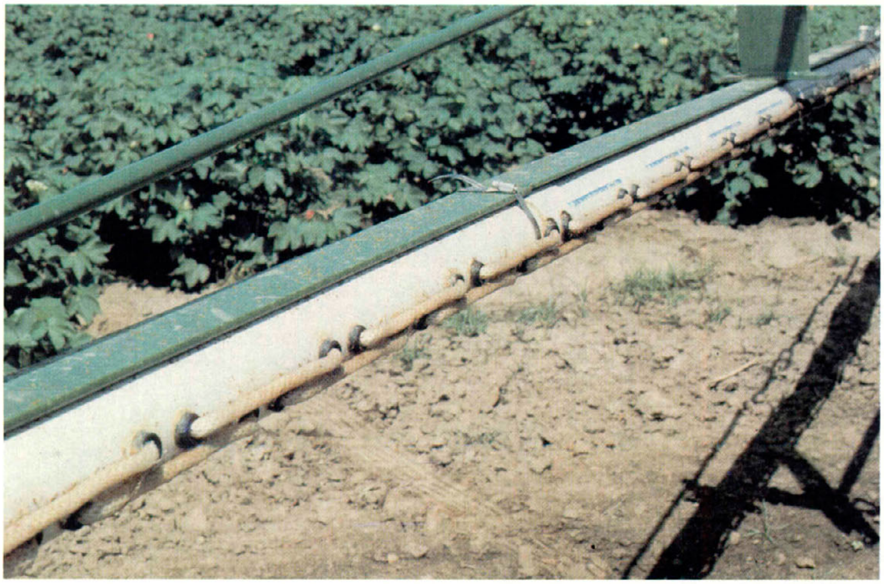

Fig. 5. Ropewick applicator; the chemical is drawn from the reservoir into the rope by capillary or wick action, then wiped onto the target.

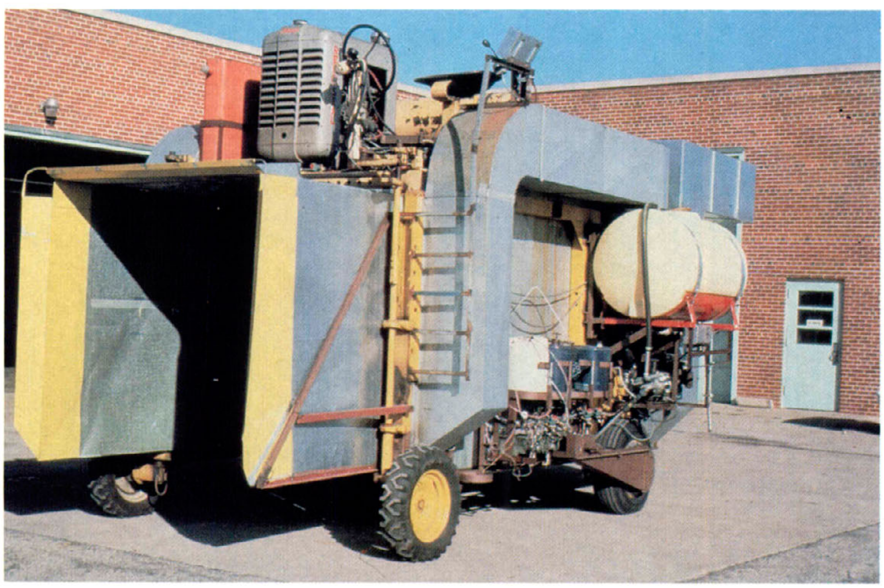

Fig. 6. Experimental air-blast sprayer; a pesticide mist is injected under the shield over the crop in a stream of air.

has been revived and expanded by development of the herbicide glyphosate. The recirculating sprayer applies the chemical over the top of the crop, and the portion not intercepted by tall weeds is collected and reused. Depending on how many weeds are in the field, herbicide requirements are reduced 80% or more from what would be used for a broadcast application. Several types of recirculating sprayers are now manufactured by as many as 20 companies.

Also available are applicators that use a hydraulic-driven, continuously turning roller covered with carpet and saturated with pesticide. An electronic device senses the amount of pesticide on the roller and activates spray nozzles to wet the roller when it becomes too dry.

The newest development for selective application that has gained wide acceptance is the ropewick applicator (Fig. 5). The chemical is drawn from the reservoir into the rope by capillary or wick action, then wiped onto the target when the rope is placed in contact with the weeds. Much of the method's popularity lies in the fact that functional models can be easily constructed from inexpensive materials; several companies also manufacture the applicator. Work is continuing on devising new wick materials and configurations to improve contact with weeds.

Shielded air-blast and air-cushion sprayers are being studied as a way to obtain good plant coverage with spray mists while protecting the environment from drift damage. Work is being done in North Dakota on an air-blast band sprayer that injects a pesticide mist under a shield over the crop in a stream of air (Fig. 6); coverage and placement of the pesticide are good, with a minimum of drift. Canadian researchers are developing an air-cushion spray boom; pesticide is sprayed into an air-supported canvas shield that contains the spray until deposited on the target surfaces.

Several other concepts are being evaluated for improving application efficiency. These include equipment for applying biological control agents, pesticide encapsulation, ultralow-volume sprayers, irrigation application, automatic self-leveling booms, and electronic sensors for maintaining proper boom heights.

Research Support Declines While Need Increases

Despite the many new approaches and concepts, development of equipment has not kept pace with development and knowledge of pesticides. In terms of the total pesticide industry, only a relatively small amount of research is being conducted on improving the efficiency of application equipment.

Much of the engineering research on application techniques in past years has been supported by federal and state institutions, with about 1.5% of total pest control funds directed into equipment research. There are strong indications that such activity is going to be decreased in the future and that engineers in private industry will be expected to do the research and development. Most equipment companies are quite small and cannot support large research programs, so if such research is done by private industry the pesticide manufacturers will have to be the sponsors. While government support of engineering research declines, other government agencies are actually increasing the need for such research through current and proposed regulations.

Spraying systems of the future will have to be more precise, placing more of the material on the desired target with less drift. The use of electronics will continue to increase, with the operator able to easily monitor and control more of the parameters. The potential for improving application efficiency is good, provided the resource level is expanded.

Acknowledgments

I thank all the individuals who furnished information and illustrations for this paper and apologize to those developing application equipment and techniques I am not aware of and therefore did not report.

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