# An Analysis of Spray Application Methodology for the Greenhouse: Air-Carrier, Electrostatic Sprayers

**(Proposal for continuation of project started in 1990)**

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A. Summary

Over the next 10 years, ornamental growers will face an uphill battle in the continued fight against insect and mite pests. Insecticide resistance has rendered many registered compounds ineffective; remaining pesticides are being taken off the market due to environmental and health concerns. Furthermore, there are few new materials corrting along the registration pathway to replace them and tougher rules and regulations make legal use of pesticides more difficult.

If current trends continue, IPM programs must be developed which rely on methods other than the use of pesticides or through the development of techniques which provide for more effective use of those materials which are currently registered. In California, legislation has been proposed which would potentially ban by 1996 as many as 70% of the pesticides currently used in the state's agriculture (Stimman & Ferguson 1990).

Part of the answer lies in the development and adoption of integrated pest management (IPM) strategies by individual growers. A second possible solution, which is compatible with the IPM approach, is the development and adoption of alternative methods of applying pesticides in the greenhouse. Flint (1990) indicated that in California two areas of critical research needs are development of new application technology and the practical use of biorational materials. This proposal focuses on these two vital areas of research.

We intend to examine the feasibility of using electrostatic, reduced-volume application of biorational materials. There are some distinct advantages to electrostatic spraying which include: 1) small droplet size which promotes improved foliage penetration and increased efficacy, 2) good deposition of spray on the underside of the leaves due to the small droplet size and electrical charge on the droplets, 3) no run-off after the application because of the low amount of water required, and, perhaps most importantly, 4) less active ingredient may be required per unit area.

Despite these advantages, there are researchable questions about reduced-volume sprayers which must be answered if this technology is to provide the type of control growers demand. The concerns can be classified as: 1) efficacy or "Does the technology dependably work?"; 2) regulatory or "Can legal reduced-volume applications be made"; and 3) operational or "Is it as fast and easy as conventional spraying". Our overall research program is investigating all these questions; this particular proposal will primarily investigate efficacy.

B. Detailed Proposal

1. Introduction and background information / 2. Review of significant literature

Conventional high volume application methods deposit between 25-50% of the spray on the plant surface and approximately 1% of this actually reaches the target pest (Metcalf 1980). High volume sprays generally produce a range of droplet sizes, but most of those produced are > 250 microns in diameter and these are very prone to run-off from a surface. Thus, high volume sprays are extremely wasteful of pesticide from an economic standpoint (most of the pesticide applied is not causing any insect mortality). In addition, this considerable pesticide run-off presents problems with possible groundwater and soil contamination. As we look to the future of pesticide use in the greenhouse and nursery, it makes sense to consider the viability of alternative application methods. Drs. Lindquist and Powell at Ohio State have led greenhouse research in this area and much of their work has concentrated on the thermal pulse-jet applicators (Lindquist and Powell 1981). However, they and others (Lake, 1977) have shown quite clearly that smaller droplets ( < 50 microns in diameter) remain on the leaf surface far better than larger droplets and provide the best control of many pests. This work has been duplicated using whiteflies as the target; it is clear that smaller droplet size provided the best efficacy (Mboob, 1975; Owens and Bennett, 1978; Scopes 1981). A problem with small droplet size is difficulty in spray penetration into a dense crop canopy (such as a bench of potted chrysanthemums or poinsettias) and coverage on the underside of leaves. Electrostatic spraying overcomes these inherent disadvantages of using smaller, charged droplets (Law and Lane 1981; Lake 1988).

Recent exciting work has been done using electrostatic spray application of the aphid specific fungus, Verticillium lecanii (Sopp et al. 1990). They have demonstrated better infection and efficacy using this fungus via electrostatic spray applications when compared to conventional full volume sprays. An important point is that this study used marketable chrysanthemum plants as one of the criteria for efficacy; in this regard, the electrostatic spray application was superior. While there is no registration for this fungus in the United States, we believe that registration will be forthcoming over the next few years. This fungus has gained broad registration (and acceptance) in glasshouses in Europe and there is definite interest in U.S. registration.

The concept of electrostatic spraying where droplets are charged as they move toward the target plant have been investigated in agricultural systems for more than 20 years (Moore 1973). In the United States, the potential of electrostatic spraying was emphasized in a Symposium at the national meetings of the Entomological Society of America held in Atlanta, Georgia, in 1980 (Law add Giles, 1980). Despite this excellent collection of papers and obvious interest in this application methodology, electrostatic spraying has been slow to gain acceptance in agriculture. This was especially true in greenhouses where a perception in popular horticultural literature held that electrostatic spraying was not feasible because of the lack of electrical grounding of spray targets (i.e., plastic pots, wooden benches, etc.). However, recent work (Law and Cooper 1989) has shown that electrostatic spraying in the greenhouse was not limited as previously thought. In fact, Giles and Law (1990) and Giles et al. (1991), demonstrated that the presence of non-conductive surfaces (for example, plastic mulch) near target plants could actually improve charged spray deposition on the plants.

Adoption of agricultural sprayer using electrostatic technology has been slow due to a number of non-technical reasons. The fundamentals of charged droplet technology are somewhat different than those of conventional technology. Manufacturers of agricultural nozzles have not, in the past, developed systems which were optimally designed. Few commercial organizations serving the agricultural market have had the necessary expe- rience and expertise for development of electrostatic spraying products. In late 1988, the first commercially-available sprayer based on the University of Georgia charging nozzle was introduced.

We have worked with and will continue to work with the system manufactured by Electrostatic Spraying Systems (ESS), 1880 Commerce Road, Suite 107, Athens, Georgia 30607 (404 353-0695). ESS is the exclusive licensee of the patents held by the University of Georgia. One of us, Dr. Giles, while located at the University of Georgia, was involved in the development of some of the technology that went into this sprayer. We are therefore very familiar with the design and operation of the system. We have executed successful field trials under funding by this project and other industry groups.

There are some very real problems that greenhouse electrostatic spraying must overcome before widespread adoption; some of these are unique to the electrostatic sprayer and some affect all low or ultra low volume (LV and ULV) applications of pesticides. As pointed out by Dr. Lindquist (1988), equipment isn't lacking for the application of low or ultra low volume amounts of material into a greenhouse, the problem is finding pesticides registered for use in this equipment and determining how the materials should best be used with the new technology. Most pesticide labels specify an exact amount of material in a specified amount of water (usually 100 gallons) which is to be sprayed. Often however, the amount of spray liquid to be used per unit area of greenhouse is not specified. Ironically, such label instructions can be interpreted as a virtually unlimited legal rate of active ingredient. Yet, many regulatory agencies view concentrated LV and ULV applications to be a breach of the label, and therefore illegal. Any deviation from the label can be viewed as a violation; making up solutions of highly concentrated pesticides and applying only a few gallons per acre could be considered an infraction. In fact, federal statute (FIFRA Sec.

2 {ee}) explicitly prohibits application "at a dilution less than label dosage". Similarly, California regulations prohibit "an increase in the concentration of the mixture applied" unless "it corresponds with the current published recommendations of the University of California".

There are several following approaches that can be taken to circumvent this problem and we are working on all of these. 1) Modify labels so that this 'new' type of application is covered in the wording (many labels have such statements as "The product can be used in concentrate sprays" or "with sufficient water for thorough coverage"). This may be possible as the reregistration process continues, however, research with these pesticides through this equipment must be done. This is critical because the new 'reregistered' labels will be -very specific and must be followed to the letter. 2) Work with the University of California and the CDFA (or other universities and state agencies) to have specific recommendations for the use of pesticides in LV or ULV equipment. This must be based on work done in that particular state. 3) Develop data showing that this type of application is not inherently more dangerous to the applicator or the environment than conventional high volume sprays.

We have made good progress in several of these areas. First, the University of California's spray recommendation system (called IMPACT on the UC IPM computer) has been modified (by M. P. Parrella) to include recommendations for low and ultralow volume application for specific pesticides. This has come from experimental data collected in California over the past 10 years. Moreover, the issue of increasing hazard is greatest with more the toxic chemical pesticides. As biorational materials come into use, the exposure problem, and regulatory concerns with reduced volume application may diminish.

Also, in collaboration with the California Department of Food and Agriculture and the California Strawberry Advisory board, data have been collected (Giles and Blewett, 1991) on dislodgeable residues in field situations using the electrostatic sprayer. Results are very promising and there appears to be no unmanageable personnel hazards associated with insecticide/acaricide use with these types of application. While similar work has not been done in the greenhouse, the research methods have been successfully developed and there is clearly overlap to any situation where this new spray technology is used. Recently, project funding was been approved for study of applicator and re-entry worker exposure during and after conventional and electrostatic pesticide application.

Finally, use statements on individual pesticide labels can be written in such a way as to accommodate low or ultralow volume application. Several pesticides already have the necessary wording. One in particular, Enstar (kinoprene from Sandoz Crop Protection) states that the applicator should "follow the equipment manufacturer's specifications". Preliminary studies by the manufacturer (ESS) have indicated that electrostatic applications of kinoprene against whitefly on poinsettias resulted in significantly less pupal emergence than from full wet spray applications (Personal Communication with Steve Cooper, ESS). Dr. M. P. Parrella has recently begun efficacy investigations with the material in cooperation with Sandoz Crop Protection.

3. Objectives of Proposed Research

The objectives of this proposal are two-fold. First, to evaluate on a practical scale the efficacy of Enstar applied through a reduced-volume, electrostatic spray system. Second, to continue laboratory and field studies of pesticide and tracer deposition from the electrostatic system. Floral Endowment funds will completely support the efficacy work and partially support deposition work.

The specific objectives are:

1) Determine the efficacy of Enstar against whitefly on poinsettia when applied at 50X concentration using the ESS electrostatic spraying system. Further, to compare the efficacy to conventional (wet spray) application.

2) Continue studies of pesticide deposition, degradation and ease of dislodgement from plant surfaces with specific emphasis on comparison of full dilute sprays versus reduced- volume application methods.

4. Materials and Methods

Enstar will be used on a preventative program for whitefly (greenhouse and sweetpotato) on poinsettias. A randomized complete block design with 4 replications will be used to position 20 ft X 20 ft plots in a greenhouse. The test will be conducted simultaneously with a conventional application method, Enstar rate trial under the direction of Dr. Parrella. Enstar 5EC will be applied conventionally at rates of 5 to 12.5 oz per 100 gal. of water and approximately 100 gal. of tank mix per 15,000 ft2. Enstar 5EC will be applied electrostatically (with and without charging) at 10 oz per 15,000 ft2 and at a 50X concentration or 2 gal. of tank mix per 15,000 ft2. Two, preferably 3, applications will be made. Efficacy of treatments will be determined by pre- and post-treatment counts of viable nymph, pupae and adults. Phytotoxicity will be monitored throughout the tests.

In-greenhouse and laboratory studies of pesticide deposition and degradation from conventional and reduced-volume applications will be conducted using techniques recently developed. Pesticide will be applied at the same rate of active ingredient per unit of bench area using wet spray and reduced-volume systems. Concentration of the tank mix will be adjusted so that the equal time is spent spraying each bench regardless of application method. After application, the dislodgeable foliar residue (pesticide deposition) on the plant surface is determined by chemical analysis of leaf punch samples. Sampling is continued over 14 days. The pesticide deposition versus time data are then used to estimate the initial deposit and decay rate of the pesticide and statistical comparisons of treatment techniques are made.

5. Facilities and Equipment Available

While there are several electrostatic sprayers and prototypes available, we will continue to use the sprayer produced by ESS. The nozzle is a molded air-atomizing induction charging type with a turbulent full cone pattern. It delivers a 40 micron droplet size at a distance of 20 feet and has an 0.08 gal/min flow rate.

We actually have two of these nozzles, one is located with the full ESS GPS-5 sprayer (as commercially available), the other is mounted in the laboratory where controlled studies of spray deposition and plant canopy penetration are being conducted.

With techniques developed in the first years of the project, we are able to precisely measure pressure and flow rate through the nozzle in addition to the air pattern and velocity and charge on the individual spray particles. By positioning a leaf in the path of the spray, different spray deposition rates can be obtained. These can be detected, quantified, and analyzed using tracer material. Spray deposition can be quantified using elemental metal tracers. Fluorometric tracers will be used for visual assessment of spray deposition and can be used for quantitative measurement of spray deposit (Giles and Law, 1985). Elemental metals (formulated as foliar nutrients such as cooper, iron, manganese and zinc) can be added to spray solutions, applied to foliage and then analyzed by atomic absorption techniques to determine mass of spray deposit. The suc- cessful use of this technique for spray application method comparisons has been reported by Travis et al. 1985.

As discussed above, we currently have the hardware for evaluation (the fun ESS GPS-5 sprayer in addition to another nozzle). Dr. Giles has in his laboratory mounted sprayer/nozzle evaluation hardware as well as a spray simulator. For engineering measurements of system performance, a complete, modern test facility with instrumentation exists within the UC-Davis Department of Agricultural Engineering. The lab is equipped with precision bourdon-tube gauges and lab grade rotameters for measurement of air and liquid flow rate and pressure as supplied to the ESS nozzle. Air- carrier velocity and turbulence (both within the spray pattern and the target plant canopies) is measured using a four channel hot-film anemometer system which is interfaced to a high speed digital data collection system. The air velocity instrumentation will be calibrated in a miniature wind tunnel which is traceable to the National Bureau of Standards. Electrical current in the spray cloud (which indicates the level of charging) will be measured using an ionization probe and a precision picoarnmeter. The picoammeter and probe are portable and will also be used at the cooperating grower applications to verify proper charging operation during efficacy trials. Leaf area will be measured nondestructively using an electronic planimeter. The Agricultural Engineering Department's Agricultural Chemical Lab is also equipped with a fluorometer for tracer measurement, atomic absorption instruments and general gc and hplc systems for quantitative chemistry. Dr. Parrella has initiated colonies of both western flower thrips, sweetpotato whiteflies, melon aphids, and green peach aphids. These pests should be available in large numbers for efficacy evaluations. Plant material is available from cooperating growers.

6. Literature Cited

Flint, M.L. 1990. The research imperatives: knowledge to reduce the use of broadly toxic pesticides. Calif. Agric. 44: 20-22.

Giles, D. K. and S. E. Law. 1985. Space charge deposition of pesticide sprays onto cylindrical target arrays. Trans. of ASAE, 28(3):658-664.

Giles, D. K. and S. E. Law. 1990. Dielectric boundary effects on electrostatic crop spraying. Trans. of ASAE 33(1): 2-7.

Giles, D. K. 1990. Pesticide application: engineering and biological response with aerodynamic delivery of charged sprays. pp. 89-97. In (M. P. Parrella & J. Hall, eds.). Proceedings of the Sixth Conference on Insect and Disease Management on Ornamentals. The Society of American Florists, Alexandria, Va.

Giles, D.K., Y. Dai and S.E. Law. 1991. Enhancement of spray electrodeposition by active precharging of a dielectric boundary. Proceedings of Electrostatics '91, International Conference on Electrostatics, Oxford. Institute of Physics, London (In Press).

Giles, D.K. and T.C. Blewett. 1991. Effects of conventional and reduced-volume, charged spray application techniques on dislodgeable foliar residue of captan on strawberries. J. Agric. Food Chemistry (In Press).

Kisha, J. S. A. 1986. Comparison of electrodynamic spraying with use of knapsack sprayer for control of whitefly on tomato the Sudan Gezira. Tests of Agrochemicals and Cultivars 7. Supplement to Ann. Appl. Biol., 108:36-37.

Lake, J. R. 1977. The effect of drop size and velocity on the performance of agricultural sprays. Pest. Sci., 8:515-520.

Lake, J. R. 1988. The deposition of electrostatically charged sprays-on parts of targets shaded from the spray. J. Agric. Engr. Res., 39:9-18.

Law, S.E. and S.C. Cooper. 1989. Target grounding requirements for electrostatic depositions of pesticide sprays. Trans. of ASAE 32(4):1169-1172.

Law, S. E. and D. K. Giles. 1980. Electrostatic pesticide spraying: Insect-control efficacy evaluations. Special publication. Proceedings of an Entomol. Soc. Am. p; Symposium, Atlanta, GA. Nov. 30-Dec. 4. 60 pages.

Law, S. E. and M. D. Lane. 1981. Electrostatic deposition of pesticide sprays onto foliar targets of varying morphology. Trans. of the ASAE, 24(6):1441-1445, 1448.

Lindquist, R. K. and C. C. Powell, Jr. 1981. The effect of formulation, structure type, and environmental conditions on the behavior and fate of selected pesticides applied through pulse-jet applicators. Proc. BCPC-Pests and Diseases, pp. 147- 156.

Lindquist, R. K. 1988. Whitefly control and pesticide application methods. Proc. Fourth Conference on Insect and Disease Management, Soc. Am. Florists, Alexandria, Va. pp.172-173

Mboob, S. S. 1975. Preliminary assessment of the effectiveness of two droplet sizes of insecticides for the control of the glasshouse whitefly, Trialeurodes vaporariorum (Westwood). Pathol., 24:158-162.

Metcalf, R. L. 1980. Changing role of insecticides in crop protection. Ann. Rev. Entom., 25:219-256.

Moore, A. D. 1973. Electrostatics and its application. New York, New York: Wiley Interscience.

Owens, J. M. and G. W. Bennett. 1978. Spray particle size distribution in greenhouse ULV applications to poinsettia. J. Econ. Entom., 71(2):353-357.

Scopes, N. E. A. 1981. Some factors affecting the efficiency of small pesticide droplets. Proc. 1981 BCPC-Pests and Diseases, pp. 875-882.

Sopp, P.I., A.T. Gillespie and A. Palmer. 1990. Comparison of ultra-low volume electrostatic and high-volume hydraulic application of Verticillium lecanii for aphid control on chrysanthemums. Crop Protection 9:177-184.

Stimman, M. W., & M. P. Ferguson. 1990. Potential pesticide use cancellations in California. Calif. Agric. 44: 12-16

Travis, J. W., T. B. Sutton and W. A. Skroch. 1985. A technique for determining the deposition of heavy metals in pesticides and foliar nutrients on apple leaves. Phytopathology, 75:783-785.

7. Detailed Budget

Salaries and benefits for Research Associates and Graduate Student Assistant $ 7,000 Pesticide application, deposition measurement and efficacy counts

Supplies for laboratory and field studies 3,500 Plant material, pesticide, insect colony maintenance, sprayer test laboratory

Travel expenses for field studies 1,500 Personnel travel, equipment shipment

TOTAL REQUEST $ 12,000

C. Project Leader Qualifications

D. Ken Giles is an assistant professor of agricultural engineering at the University of California-Davis with research specialization in pesticide application systems. He holds 2 patents and has 1 pending on computer-controlled application equipment. Since 1987, he has published 15 articles related to engineering aspects of pesticide application. Current research is focused on pest control efficacy, potential worker exposure and operational logistics of reduced-volume pesticide application in ornamental and small- fruit production.

Michael P. Parrella is professor and chairman of the Department of Entomology at the University of California-Davis. His research emphasis is pest control in ornamental production. His accomplishments and knowledge in the field are internationally recognized and he is a regular contributor to industry publications.