Summary

During his address as incoming president for 1984 at the Annual Meeting of the Weed Science Society of America, Dr. C. G. McWhorter stated that in 1983 the total cost attributable to noxious weeds that affected production of food and fiber crops amounted to 20.0 billion dollars. The breakdown of this sum was 3.1 billion for herbicides, 4.1 billion for tillage, and 12.8 billion for losses in crop yields. Since Dr. McWhorter's audience consisted largely of those interested specifically in weed science, it is understandable that he omitted mentioning the tremendous costs attributable to other pests such as insects and fungi. Nevertheless, in spite of these staggering costs, the American agricultural industry has achieved production of such huge surpluses of crops year after year that food exports have contributed significantly to keeping our foreign trade imbalance from getting completely out of hand. These surpluses also maintain our enviable image of benevolent supplier of food to needy countries throughout the world. Much of this success is due not only to our fortunate abundance of land and raw materials but also to the skill and efforts of the entire agricultural community. Researchers in industry, academia, and government have increased crop yield and improved quality by maximizing pesticide efficacy and improving techniques and equipment for pesticide application. The widespread activity in these efforts is reflected by the papers in this volume.

This ASTM Special Technical Publication groups the papers of the Fourth Symposium on Pesticide Formulations and Application Systems into three categories: (1) Formulations, (2) Applications, and (3) Granules. The following sections summarize the papers from each of the three groups.

Formulations

Widely different aspects of pesticide formulation and evaluation technology are covered in the first group of papers. *Sheridan* explains how the choice of phosphorylating agent affects the composition, properties, and performances of the resulting phosphated nonionic surfactant. He shows that phosphate esters prepared using phosphorus pentoxide (P_2O_5) are suited as emulsifiers and dispersants for emulsifiable concentrates, wettable powders, and suspension concentrates, which are otherwise known as liquid flowables, while those prepared using tetraphosphoric acid are particularly suited as compatibility agents and stabilizers for pesticide-fertilizer mixtures. The his-

toric background of developments in seed treatment formulations and equipment is presented by *Halliday*. He lists the overall characteristics of a desirable formulation and describes evaluation methods for its chemical, physical, and biological properties.

Tank mix compatibility testings were studied by *Brenner et al* by applying regression analysis to construct a model for predicting success or failure of planned experiments for the laboratory evaluation of mixes of two formulations each of a liquid flowable and an emulsifiable concentrate. Extensive work was performed in systematizing and studying the results of numerous complex interactions. The authors are candid in their concluding remarks: "The farmer/user, by means of a simple jar test, can make as good or better an assessment of this [compatibility] as a well-equipped laboratory. To deduce that failure is *unlikely* under field conditions requires what is, most probably, an uneconomical level of effort to cover the possible interactions."

A much less complex system, without the many interactions of independent variables confronted in the preceding paper, was chosen by *Lohr*. He succeeded in modelling a situation, by use of computer regression analysis, to predict experimental outcome in the evaluation of the stabilities of emulsions produced at various dilution ratios and water hardnesses. His method for emulsion optimization is limited to the use of one anionic and two nonionic surfactants, with xylene as the oil component. *Frank et al* describe a small-scale laboratory apparatus for evaluating potential defoamers for pesticides, using an emulsifiable concentrate and three [liquid] flowables as examples. Their simplified laboratory system is described as allowing easy and efficient comparative evaluations of defoamers and defoamer behavior under realistic conditions.

Applications

Of the nine papers covered in the second section, seven deal with the evaluation of spraying techniques and/or low and ultra low volume (ULV) applications employing oil carriers, one with subsurface drip irrigation, and one with evaluation of plant growth regulators. *Hall and Reichard* describe a high-speed photographic technique for studying the effects of such factors as droplet size and velocity, electrostatic charge, and type and concentration of surfactant upon the rebound of spray droplets from various types of leaves. The authors use the data obtained by these studies to improve the deposition efficiency of sprays. In field studies, to determine the efficacy of insecticides applied as ULV vegetable oil sprays, *Luttrell* obtained results showing that such sprays are just as efficacious as standard volume-water sprays in terms of controlling major cotton insects.

Bode et al explain the potential of low volume application of pesticides using vegetable oils as carriers, citing the development of practical rotary atomizers and electrostatic sprayers that made such techniques economically feasi-

ble. Their studies included the effects of viscosity of pesticide/vegetable oil mixtures over a wide range of temperatures upon spray patterns of several nozzle types. Concerning the control of the spruce budworm, *Shafer* describes the development of Matacil flowable, an aminocarb insecticide that is dilutable with either oil or water, for satisfying a variety of use conditions, including ULV spraying from aircraft. Test results for suspension and resuspension of flowable dilutions as well as for environmental impact and biological efficacy are given.

The application of systemic insecticides and fungicides, N-P-K fertilizers, and chelated micronutrients by injection into drip irrigation systems is described by *Tollefson*. The necessary equipment for proper filtering and flow control is discussed. A system for maintaining clean drip emitters and for decreasing the accumulation of salts at the surface of the irrigated soil is also described. *Schneider* explains the low-volume application of Roundup, an aqueous solution of glyphosate herbicide, in field tests using several types of spray equipment and nozzles. He shows how herbicide cost per acre is reduced for the farmer, while maintaining optimum weed control.

Evaluation of plant growth regulators, such as plant growth retardants (PGR), for various turfgrasses is described by *Armstrong*. As the result of this investigation, he recommended that uniform standards be developed by PGR researchers to allow faster data analysis and more efficient decision making. *Krueger and Reichard* reported their studies of the effects of distribution across the spray swath upon the effectiveness of the applied pesticide, using various types of hydraulic atomizing nozzles for water and emulsions at different pressures. The authors also studied the effects of composition of spray mixture, type of nozzle, and operating pressure upon the optimum distances between nozzles. A new interdisciplinary approach for solving problems involving pesticide application is described by *Hall*. He outlines a methodology for investigating pesticide delivery, target impingement, and efficacy with the purpose of effecting optimization of pesticide usage.

Granules

The four papers dealing with granules are grouped in this section to emphasize the rapidly growing interest of formulators and applicators in granule technology. *Banks et al* report that of more than 4400 chemicals tested for control of field populations of fire ants, only three primary toxicants demonstrated promise. Most of their latest studies show Amdro fire ant bait and Prodrone insect growth regulator, solubilized in soybean oil and absorbed onto a granular carrier such as Pregel (defatted corn grit), as giving effective fire ant control. Described by *Holley* is the process development and required equipment for agglomerating pesticide formulations into water dispersible granules. Details of operating the suggested equipment are also given.

Gandrud and Haugen describe field evaluations of the dry application of

dry flowable formulations in low volume use of various herbicide granular products. Rates as low as a fifth of a pound per acre can be metered and distributed uniformly by using a new metering and distribution system. The paper by *Sawyer and Purcell* explains test results of several methods for determining liquid holding capacity (LHC) or sorptivity of a number of powdered and granular carriers used in making pesticide granules. The effects of absorbent type, particle size distribution, heat treatment, moisture content, temperature of testing, and contact time are shown. The authors conclude that the dry end point LHC test method is the most feasible.

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