Pesticide Formulations and Application Systems

Fifth Volume

Spicer/Kaneko
editors

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Foreword

The Fifth Symposium on Pesticide Formulations and Application Systems was held in Kansas City, Missouri, on 7–8 November 1984. ASTM Committee E-35 on Pesticides sponsored the event. Larry D. Spicer, Rhone-Poulenc Chemical Company, served as symposium chairman, and Thomas M. Kaneko, BASF Wyandotte Corporation (retired), served as symposium co-chairman. Both men have edited this publication.

Related ASTM Publications

Pesticide Formulations and Application Systems: Fourth Symposium, STP 875 (1985), 04-875000-48

Pesticide Formulations and Application Systems: Third Symposium, STP 828 (1983), 04-828000-48

Pesticide Formulations and Application Systems: Second Conference, STP 795 (1983), 04-795000-48

Pesticide Tank Mix Applications: First Conference, STP 764 (1982), 04-764000-48

A Note of Appreciation to Reviewers

The quality of the papers that appear in this publication reflects not only the obvious efforts of the authors but also the unheralded, though essential, work of the reviewers. On behalf of ASTM we acknowledge with appreciation their dedication to high professional standards and their sacrifice of time and effort.

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Overview

The Fifth Symposium on Pesticide Formulations and Application Systems was held on 7–8 November 1984 in Kansas City, Missouri. Like the previous four symposia in this series, it was sponsored by ASTM Committee E-35 on Pesticides and organized by Subcommittee E35.22 on Pesticide Formulations and Application Systems. The goals of this series are as follows:

1. Provide an open forum for presentations, discussions, and state-of-the-art review, covering the area of pesticide formulations, application systems, and related topics.
2. Allow for exchanges of ideas and discussions of problems confronted by manufacturers, shippers, applicators, and regulatory agencies.
3. Include a wide variety of topics in each symposium, such as formulating and testing procedures, container selection, storage stability, equipment and application techniques, and their relationships to pest control efficiency.
4. Discuss advances in overall techniques to improve the quality and yield of crops.

Of the 29 papers given at the symposium, 15 are presented in this volume. These are divided into two sections: General Topics and Use of Spray Drop Size Analyzers.

As was done for earlier symposia, the program was designed to appeal to the entire audience, which consisted of representatives of industry, academia, regulatory agencies, and research institutions.

This Special Technical Publication gives the reader a state-of-the-art overview of pesticide formulations and application systems. The subject matter covered by the papers reported herein indicates the broad scope of the symposium. This volume is expected to serve as a useful reference for anyone involved in the formulation, manufacture, distribution, and application of pesticides.

Contents

General Topics

Michael E. Kotz[1]

Functional Formulation for Prescription Performance

REFERENCE: Kotz, M. E., **"Functional Formulation for Prescription Performance,"** *Pesticide Formulations and Application Systems: Fifth Volume, ASTM STP 915*, L. D. Spicer and T. M. Kaneko, Eds., American Society for Testing and Materials, Philadelphia, 1986, pp. 3-12.

ABSTRACT: Pesticide formulations generally comprise three objectives: convenience of physical properties, ease of application, and biological activity. Economic necessity frequently dictates that a fourth objective, maximum utility (i.e., the fewest formulations for the greatest number of proposed uses), be considered. An overemphasis of the latter can result in significant reductions of overall pesticide performance, particularly in specialized applications. Several case histories of formulations are presented that demonstrate the advantages of proper definition and prioritization of the compromising criteria before initiation of formulation development.

KEY WORDS: granular carriers, granular pesticides, pesticides, pesticide application, pesticide exposure, pesticide formulations

A basic objective of a pesticide formulation is to provide an end-use product capable of producing a desired biological response on a target organism. A speciality formulation may be differentiated as one which stresses the functionalism of the end product for a more restrictive number of proposed uses.

In a speciality formulation, emphasis is placed on specific adaptation of a pesticide, frequently for a single site, pest, or use pattern which may make application of the product impractical or economically unacceptable for other uses. Utility may be sacrificed to achieve a performance advantage in a narrow and well defined set of conditions. While a formulator, in this situation, may be less restricted in his approach to designing a product, care must be taken not to eliminate desirable characteristics of the active ingredient itself or to overlook the preferred features of existing formulations which may be incorporated into the new product.

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The examples which follow are presented to demonstrate the modification of pesticide performance that is possible when the restriction of maximum universality is disregarded for a specialized application.

Commercial Application of Preemergent Turf Herbicides

Oxadiazon [2-*tert*-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)-Δ^2-1,3,4-oxadiazolin-5-one] is an oxadiazole herbicide active as a pre-emergent control on a broad spectrum of annual grasses and broadleaf weeds. The active ingredient has a low water solubility (about 0.0007 g/L), negligible vapor pressure (about 10^{-6} mm Hg at 20°C), is resistant to degradation by ultraviolet light, binds rapidly and strongly to soil colloids, and has limited downward and almost no lateral movement in the soil. Persistence is good, with a half life of 2 to 6 months under normal field conditions [*1*]. These properties make oxadiazon desirable as a preemergent herbicide for the control of crabgrass, goosegrass, and some phenoxy-resistant dicotyledons in commercially maintained turf. However, oxadiazon is absorbed through the aerial portions of the plant (leaves as well as emerging shoots) [*2*] and even tolerant, desirable turfgrass species may be thinned or removed by applications that allow prolonged contact of the active ingredient with the foliage. Standard sprayable formulations (wettable powders, emulsifiable concentrates, and flowables) designed for use as directed sprays or pre-emergent application in food crops produce unacceptably foliar burn on turfgrass.

Benefin [*N*-butyl-*N*-ethyl-a,a,a,-trifluoro-2,6-dinitro-*p*-toluidine] is a preemergent herbicide used for control of annual grasses in lettuce, peanuts, tobacco, some forage crops, and turfgrasses. Benefin is susceptible to decomposition by ultraviolet irradiation and, with a comparatively high vapor pressure (7.8×10^{-5} mm Hg at 25°C), loss of activity can be rapid when the herbicide is exposed to direct sunlight and high temperatures. Use in agricultural crops requires soil incorporation within 4 to 8 h of application [*1*].

The performances of these two herbicides as standard sprayable formulations limited uses on turfgrass to straight granular or heavyweight fertilizer combination formulations. These types of granular products prevent interception of the active ingredient by the turfgrass foliage.

The speciality formulation developed for these chemicals utilized the concept of clay-based mini-granules of the active ingredient dispersed in a matrix of dry soluble fertilizer to aid in spray tank dispersion. Adjuvants were selected to minimize adherence of the materials to plant foliage. The completed formula is then agglomerated with a briquetter, pellet mill, or similar equipment to reduce airborne dust and produce homogeneity.[2] When added to wa-

[2]U.S. Patent 4,563,344.

ter or a fertilizer solution, the soluble portions of the formulation dissolve, wetting the mini-granules. The preparation of a pre-mix or slurry common to wettable powders is eliminated.

Plot work with the oxadiazon formulation has consistently shown an almost complete elimination of the foliar burn characteristic of previous sprayable formulations (Table 1). Data support a reduced rate of herbicide per acre because of increased deposition of the active ingredient at the soil surface.

The analogous benefin formulation has been commercially available in the midwestern states since 1981. Based on acreage figures supplied by the Elanco Products Division of Eli Lilly and Company, basic producers of benefin, benefin now accounts for approximately 20% of the total pre-emergent herbicide sprayed by commercial applicators to turf in the United States. Despite limited distribution, it is estimated that the speciality formulation (Pel-Tech® Benefin Concentrates) constitutes 65 to 70% of that total [3].

Although the use of this type of formulation is not feasible in many conventional spray tank systems, the equipment common to much of the liquid lawn care industry utilizes strong mechanical or bypass agitation, or both. This high level of agitation, uncommon with most agricultural-type spray systems, aids in maintaining the suspension of the mini-granules.

Granular Mosquito Larviciding

In the application of products for mosquito larvae control, the use of diluted liquid toxicants can be a problem in areas where vegetation provides a

TABLE 1—*Comparative performance of Oxadiazon formulations on turfgrass.*

		Site 1 Ames, Iowa Kentucky Bluegrass		Site 2 Kingston, Rhode Island Fine Red Fescue	
Formulation	Rate (AI kg/ha)	Phytotoxic Damage[a]	% Crabgrass Control	Phytotoxic Damage[b]	% Crabgrass Control
Wettable powder	2.24	3.0	96.6	3.6	99
Wettable powder	3.36	3.0	100.0	4.1	100
Wettable powder	4.48	3.0	98.9	6.4	100
Sprayable mini-granule	1.12	1	78.6	0.6	58
Sprayable mini-granule	1.68	1	95.5	0.6	91
Sprayable mini-granule	2.24	1	97.7	0.9	96
Sprayable mini-granule	3.36	1	93.2	0.9	98
Sprayable mini-granule	4.48	1	100.0	0.9	98

[a]Rating of 3 or higher unacceptable; 7-day rating.
[b]Rating of 3 or higher unacceptable; composite rating May to September.

protective canopy above or around the breeding habitat. Heavyweight granular formulations normally offer an efficient mechanism for delivering larvicide in these circumstances; however, in the case of the toxicant *Bacillus thuringiensis israelensis* (BTI), the mode of activity compounds the problem.

This toxicant is a naturally occurring bacterium which produces a protein endotoxin highly specific in its activity against black fly and mosquito larvae. Activated by the alkaline gut of these target pests, the protein must be ingested by the organism to be effective. Although the majority of mosquito larvae are filter feeders randomly ingesting particulate matter, differentiation does occur in the preference of different species to feed at various distances from the water surface.

The family Culicidae are primarily bottom feeders and include a host of nuisance mosquitos as well as the common vectors for yellow fever and various arborviruses such as California Viral Encephalitis. The genus *Anopheles* tend to feed at the water surface and includes the primary vectors for malaria.

The difference in feeding behavior of mosquito larvae can influence the performance of a larvicide [*4*]. Various researchers have concluded that the availability and persistence of an ingested toxicant in the primary feeding zone would provide increased efficacy [*5–7*]. It has also been proposed that increasing the feeding rate of larvae through phagostimulants or similar means would increase efficacy more than increases in the amount of active ingredient applied [*8*]. Ideally, a granular formulation of BTI should be capable of penetrating vegetative growth, durable enough to withstand the abuse of typical application equipment, provide toxin in both primary larva feeding zones, and stimulate feeding.

The formulation developed for this application utilized a ground organic component which had demonstrated an ability to arrest or attract swimming mosquito larvae. This component could also serve as a food source and was readily consumed by the larvae (Fig. 1).

The finished product, a dense pellet approximately 3.2 mm in diameter, begins to disintegrate upon contact with water, releasing some toxin near the surface for ingestion by surface-feeding species. The remainder of the active ingredient is carried along with the carrier particle to the bottom. There, bottom-browsing larvae consume the endotoxin crystals along with the organic component food source.[2]

Field trials and laboratory experiments conducted with artificial pools containing mixed populations of *Culicine* and *Anopheline* larvae confirmed efficacy in both larvae feeding zones (Tables 2 and 3). While this formulation does not have the flexibility of the wettable powder and liquids in systems such as continuous application to irrigated rice or for black fly control in streams, it is capable of providing excellent control of mosquito larva in habitats difficult to treat with more conventional materials.

Structural Pest Control

The use of toxicants in and around residential and commercial properties to control insect pests presents some unique problems. Property owners and tenants typically require a high level of efficacy while demanding treatments which are unobtrusive and pose little threat to nontarget organisms or property.

Granular formulations have had limited acceptance by the professional pest control operator (PCO), accounting for only 3 to 4% of the total pesticide usage in this market [*9*]. While the active ingredient used in the granule may be a standard control measure for the pest, the granular formulations frequently provide less than acceptable performance.

During 1983, special PCO granular formulations were prepared at the request of Dow Chemical and Whitmire Research Laboratories. The formulations were designed specifically for use on cockroaches and ants, and compromises to increase utility for applications on agricultural crops, nursery, ornamental stock, and other flora were disregarded.

Chlorpyrifos [0,0-diethyl-0-(3,5,6-trichloro-2-pyridyl) phosphorothioate], an organophosphate demonstrating insecticidal activity by both contact and ingestion with an ability to bind with organic matter, thus increasing residual activity, was the toxicant used. This insecticide is registered for PCO applications and is routinely applied against ant and roach species.

Efficacy against the target pests was improved compared with standard treatments. In one study, a residential structure infested with Oriental cockroaches was treated with 170 g of the 2.5% chlorpyrifos (Dursban®) PCO granule. The general test site was irrigated by an automatic sprinkling system which delivered 1.3 cm of water each day. Relative humidity ranged from 45 to 88%; air temperature ranged from a low of 18°C to a high of 40.5°C. Previously, standard perimeter treatments of 5% diazinon granules, chlorpyrifos 4EC, and Knox Out® 2FM had been used but provided only limited control. The first inspection of the site at four days post-treatment revealed dead roaches. By Day 11, the property owner commented on the level of control and reduced roach sightings.

Although subjective evaluations such as this leave much to be desired from the standpoint of statistical analysis, they do provide an indication of the potential level of customer acceptance. In a more traditional test, ten sites infected with harvester ants were treated with the special formulation of chlorpyrifos at a rate of 25 granules per mound. Within 120 h of treatment, ant activity at all sites was nonexistent. Based on an average density of 25 to 37 mounds per hectare, this equates to 57.5 to 92.5 *milligrams* of active ingredient per hectare. The label rate for general ant control is approximately 1.12 kg/ha of chlorpyrifos when applied as standard emulsifiable concentrates.

Additional studies on Argentine ants (Table 4) and American cockroaches