CONTROLLED DROPLET APPLICATION TECHNOLOGY FOR ULTRA LOW VOLUME-OIL SPRAYING OF INSECTICIDES IN COTTON[1/]

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ABSTRACT

The development and application of controlled droplet application (CDA) technology in cotton insect pest management is reviewed. Focus is made on the use of the ultra low volume-oil technique with CDA equipment for applying insecticides to cotton from ground sprayers.

INTRODUCTION

"ULV-oil" describes a spraying technique combining the use of oil carriers (e.g. vegetable, petroleum, or blends of such oils) with low-volume (LV) or ultra-low-volume (ULV) application (Anonymous 1981, Anonymous 1982). LV and ULV without oil carriers have been shown to be effective for insect control in cotton (Awad et al. 1967, Wolfenbarger and McGarr 1971). In recent years the ULV-oil technique has become popular for applying insecticides for control of cotton insects (Reid 1981, Clower et al. 1982, Perantoni 1983, Crumby 1984).

With the advent of ULV-oil spraying, another technology has somewhat concurrently emerged on the agrichemical scene: controlled droplet application (CDA) spraying systems (Wiltse and Badey 1982, Freed 1982, Moore 1984). Crop producers in Texas and elsewhere have successfully used CDA equipment (especially with ground sprayers) for making ULV-oil applications of pesticides (Anonymous 1983, Pigg 1984, Anonymous 1986).

Much of the research and review of CDA technology has been conducted in Great Britain, the place of its origin. An overview of CDA spraying systems and their use in American settings is therefore appropriate. This paper reviews the basic principles and application of CDA technology, with a focus on its role in ULV-oil insecticide application in cotton.

INSECTICIDES AND COTTON INSECT PEST MANAGEMENT

The concepts and practices of pest management in cotton have been, and continue to be, developed and articulated (Bottrell and Adkisson 1977, Reynolds et al. 1982, Adkisson 1984). The short-season production scheme used throughout much of Texas provides an example of a successful integrated pest management strategy for cotton (Adkisson 1984, Walker 1984). Cotton pest management strategies in Texas can include some or all of the following tactics: 1) excape in time by means of short-season crop management, appropriate cultivars and manipulated planting dates; 2) post-harvest stalk destruction; 3) conservation of existing natural enemies by means of selective pesticides and selective use (e.g. timing,

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placement) of biocides; and 4) timely use of insecticides aimed at threshold-exceeding densities of pests (Bottrell and Adkisson 1977, Allen et al. 1985, Drees 1985).

The specific role of insecticides within effective pest management strategies has been extensively reviewed (Metcalf 1966, Knipling 1968, Smith 1970, Metcalf 1980, Metcalf 1982). In the context of pest management, insecticides should be used judiciously and selectively to maximize their advantages and limit their negative effects. To achieve this, Metcalf (1980) offered the following principles of insecticide management: 1) observe realistic economic thresholds, 2) improve timing of applications, 3) improve application methods, 4) reduce application rates, 5) use pesticides least toxic to important natural enemies, and 6) apply selective insecticides in lieu of broad spectrum biocides.

Some of these principles are already manifest in the pest management strategies for cotton insects in Texas (e.g. economic thresholds; carefully timed, early-season treatments for fleahoppers and overwintered boll weevils; recommended use of microbial insecticides). Chemical application methodology represents an area of possible improvement with subsequent potential for enhancement of control, reduction of rates, and reduction of environmental contamination. Our discussion now turns to focus on the role of application technology for effective insect suppression and management.

ASPECTS OF CHEMICAL APPLICATION IN CROPS

In treating cotton with insecticides, the widespread practice involves the application of broadcast sprays for the purpose of complete plant coverage. This method of application is typically made from high-clearance ground sprayers or aircraft (Newsom and Brazzell 1968).

Conventional insecticide application, as previously described, is characteristically inefficient (Joyce et al. 1977). Most insecticide sprays for crop protection result in the on-target deposition of 50% or less of the total spray material applied (McEwen and Stephenson 1979, Metcalf 1982). The remainder is lost due to drift beyond the target area ("exodrift") or deposition on the soil surface within the target area ("endodrift") (Himel 1974, Matthews 1979).

The problems of insecticide drift outside of the target area, or exodrift, has been the subject of much concern and investigation (Dean 1962, Akesson and Yates 1964, Ware et al. 1969a, 1969b, 1970a, 1970b, 1972a, 1972b). In general, physical drift of agricultural sprays is a product of meteorological conditions, height of release, spray formulation, and spray droplet size. Problems with ineffective depositon and/or distribution of pesticide sprays within the target crop are influenced by many of the same factors as in exodrift. Whereas small droplets are the major source of exodrift, it is the larger end of the droplet spectrum which makes up most endodrift (Matthews 1979). These droplets represent a large portion of the spray volume and frequently fail to reach or adhere to their intended targets. Large droplets that do deposit on target surfaces tie up large amounts of toxicant, creating a wastefully uneven distribution of chemical (Bals 1969).

The inefficiency inherent in conventional spray application gives rise to overdosing to ensure adequate coverage. For example, the typical application rate of most insecticides is many hundreds of times larger than theoretically needed to kill pests (Brown 1951). More accurate depositon and more even distribution of spray materials would restrict non-target area contamination and also preclude the need for inflated insecticide rates. This in turn would save money and material, help minimize the risk of resistance development, and selectively spare more beneficials (Ripper 1956, van den Bosch and Stern 1962, Watson 1975).

Many of the factors affecting uniform spray distribution, endodrift, and exodrift are functions of the spraying systems employed. Manipulation of parameters such as droplet size, release height, and spray formulation should be a possible means of increasing efficiency of insecticide applications.

Most conventional spraying systems generate droplets by using hydraulic pressure to force liquid through a standard pattern nozzle (e.g. hollow cone, etc.). This characterizes the type of spraying systems that have been used to apply insecticides to cotton (Wilkes et al. 1962). However, the range of droplet sizes produced by such systems is difficult to regulate and is typically wide (Matthews 1979). Chemical application technology requires innovation at this point to achieve the potential for better insecticide use and better pest management. The remainder of this discussion will examine a particular spraying technology and its possible utility for the future.

CONTROLLED DROPLET APPLICATION: THEORY AND PRACTICE

Controlled droplet application is a comparatively new spray application technology. CDA can be defined as a method of spray application whereby the spray droplets emitted are of a relatively uniform size. The development of CDA sprayers is associated with studies of rotary atomization of liquids.

The principle behind rotary atomization and CDA is fairly simple. Liquid is metered onto the center of a spinning disk or cone (Fig. 1 A), producing an evenly distributed sheet. As the disk rotates, centrifugal force overcomes the surface tension of the liquid at the edge of the disk (Fig. 1 B) causing the release of uniformly sized droplets (Bals 1969, Frost 1978).

The size of droplets emitted from rotary atomizers is determined by the diameter and angular velocity of the rotating disk, the surface tension of the liquid, and by specific gravity. A relatively uniform droplet size can thus be obtained when these previous factors are held constant. In addition, a specifically desired droplet size can be ordered by simply manipulating the speed of the rotating disk (Bals 1969).

CDA spraying systems have been designed using the concepts of rotary atomization. These systems have a high potential for efficiency in spraying. The fairly uniform droplet size spectrum from a CDA system theoretically allows for an even distribution of toxicant during spraying. Waste and environmental contamination could also be reduced by restricting the production of inappropriately sized droplets. The latter include small, drift-prone droplets as well as wasteful, oversized droplets.

Because of its properties, CDA systems can be variously adapted. Many CDA systems are designed for LV or ULV output. This is possible because of the low flow rate requirements of many rotary atomizers (Frost 1978). Given the increased potential for spray efficiency, CDA systems are realistic candidates for use in delivering ULV applications since the latter require an even distribution of a relatively small spray volume. This same reasoning is offered to promote the idea of using reduced rates of pesticides through CDA (Bals 1978).

CDA technology is also amenable to the use of oil carriers. In situations where a smaller droplet size is desired, oil carriers provide a means for preserving droplet integrity from evaporation (Bals 1969, Crumby 1984). Further, the use of certain oils through CDA equipment has been shown to reduce the opportunity for small droplets to drift (Wodageneh and Matthews 1981).

In addition to the potential for uniformity in spraying, CDA equipment is attractive because of the benefits of ULV application in general. Reduced volume spraying requires less carrier. This represents an advantage to spray applicators in the form of reduced expenditures of power, time and labor from fewer refilling times or smaller loads.

CDA SPRAYING SYSTEMS IN AGRICULTURE

The first CDA spraying equipment was developed in Great Britain in the early 1950's by E.J. Bals (Freed 1982). Early hand-held units proved successful in tropical countries for delivery of undiluted concentrate formulations of pesticides (Matthews 1978). In 1977 a popular hand-held model was introduced in the U.S. by Micron Corp., the company founded by Bals. Micron then developed and patented a tractor mounted CDA unit which was introduced commercially in the U.S. in 1980 (Wiltsey and Badey 1982, Freed 1982, Moore 1984). A number of companies are currently marketing boom-mounted CDA equipment in the U.S., making use of either the Micron design or redesigned rotary disks. Some of the commercial models (and their manufacturers) include the Micromax® (Micron Corp.), the Rotamizer® (Farm Fans, Inc.), the Turbo Rotary Atomizer® (Sprayrite Manufacturing Co.), and the Girojet® (Spraying Systems, Inc.). Commercial CDA equipment also exists for aerial systems, but these will not be discussed in this paper.

The application of CDA technology in American agriculture has gained in popularity since its introduction. U.S. farmers have used CDA equipment to successfully apply a wide range of agrichemicals including fungicides, herbicides, insecticides, plant growth regulators and fertilizers (Marking 1981, Wiltse and Badey 1982, Lee 1983, Reichenberger 1984, and Banos, personal communication). However, Valiulis (1968) recently reviewed the current status of CDA use in American agriculture. He reported that use of CDA technology has not yet become as widespread as had been originally predicted, and he reviewed many reasons for this situation.

The practice of ULV-oil spraying of insecticides in the cottonbelt has provided an obvious opportunity for using CDA technology. The majority of ULV-oil applications on cotton are made by aerial applicators. Most of these aerial applicators use modified hydraulic nozzles in lieu of CDA equipment (Waddle 1983, Pigg 1984, Rester 1984) despite suggestions to achieve the necessary uniformity via rotary atomizers (Mitchener 1981, Sims 1982). Nevertheless, CDA technology has been readily employed by ground operators using the ULV-oil technique (Anonymous 1983, Pigg 1984, Anonymous 1986). This is probably due to the appeal and availability of CDA equipment to the farmer for suitably converting conventional ground sprayers for ULV-oil application.

EXPERIMENTAL EVALUATION OF CDA SPRAYING SYSTEMS

Studies of CDA have been conducted in the U.S. since the introduction of this technology in American agriculture. Researchers mostly have compared CDA systems with conventional hydraulic spraying systems for deposition and/or drift of sprays, and for efficacy of chemical treatments.

In a series of controlled laboratory experiments, Bode et al. (1983) evaluated the general characteristics of a Micromax rotary atomizer. They determined that the rotary atomizer produced droplets with a much narrower size range than did a conventional hydraulic spray nozzle. Further experiments revealed that sprays of dye solution from the Micromax atomizer were more heavily deposited a few meters downwind than were sprays of the same treatment from the conventional hydraulic nozzle. However, they found no difference between the two nozzle types for downwind spray depositon at distances of 10-20 m.

Drift and deposition studies conducted under field conditions have given fair to mixed reviews of CDA atomizers using vegetable oils as carriers. McDaniel et al. (1983) used CDA atomizers to compare drift and deposition from aerially applied sprays of permethrin/ULV-oil and permethrin/conventional-emulsion. Results indicated that the oil sprays were deposited more uniformly across the spray swath than were the water sprays. No significant differences between the treatments for deposition of permethrin per plant were found. Further, no significant differences were detected in relative amounts of airborne permethrin measured downwind from the treatments.

Ware et al. (1984) conducted a similar drift and deposition study using aerially applied fenvalerate. They found that conventional emulsions deposited more fenvalerate on foliage at three different canopy levels than did CDA/ULV-oil treatments. They also found that CDA/ULV-oil at 2.3 l/ha resulted in more drift than the conventional emulsion spray; however, a CDA/ULV-oil treatment at 3.5 l/ha produced less drift than the emulsion treatment.

Robinson (1986) used fluorescent tracers to evaluate the relative distances of downwind drift from CDA/ULV-water, CDA/ULV-oil and conventional water sprays from a high-clearance ground sprayer. In one experiment, trace drift from the conventional water treatment was observed at points further downwind compared to drift from two CDA/ULV-oil sprays. However, another experiment resulted in drift from conventional water, CDA/ULV-oil and CDA/ULV-water sprays being observed at equal distances downwind.

Efficacy studies represent the bulk of the published research on CDA spraying systems in this country. For instance, a large amount of work has compared the efficacy of CDA-applied herbicides at full and/or reduced rates with the efficacy of conventionally applied herbicides (Inman 1983, Moore 1983, Pearson and Bode 1983, Gebhardt et al. 1985, Hartwig 1985). Most of these studies have revealed equivalent or better control of target weeds with CDA-applied treatments, as found by Green et al. (1982) in Texas.

A number of insecticide efficacy studies have been conducted using CDA atomizers. Many of these experiments were designed to specifically evaluate ULV-oil application, but not CDA equipment per se. Therefore care must be maintained in drawing conclusions about the merits of CDA technology alone from such studies. For example, Treacy et al. (1986) compared the residual efficacy of several insecticides. They found that two insecticides applied with ULV-oil had longer residual activity than when applied with a conventional system using water or water-oil as carriers. Their results allow for a good evaluation of the effect of the different spray treatments. However, these results do not provide a good direct comparison of CDA and conventional spraying equipment because of the multiple variables involved (i.e. spray equipment and spray formulation). A number of similarly designed experiments have been conducted by researchers and private consultants investigating ULV-oil (McCaa 1986, McKeown 1981). One can at least conclude from these studies that ULV-oil formulations can be adequately applied with CDA equipment, and that these ULV-oil formulations of insecticide (for whatever reason) are comparably effective to formulations applied conventionally.

Other efficacy studies have included treatments which more directly compared CDA equipment with conventional equipment (e.g. by applying a common formulation with both spraying systems). The results from these studies indicate that CDA-applied treatments had comparable efficacy to the same treatments applied conventionally. Moore and Hopkins (1981) obtained comparable control of bollworms with formulations of permethrin in water applied with both CDA and conventional spraying equipment. Robinson et al. (1986) also obtained equivalent control of bollworms with cypermethrin applied in water from Micromax units and from a conventional ground sprayer. Cocke and Davis (1982) compared CDA-applied and conventionally applied sprays of the same insecticide/oil-water mixture for bollworms with similar results.

CONCLUSION

Experimental results have demonstrated that the performance of CDA atomizers in agriculture is comparable to that of conventional chemical application equipment. More research is needed to confirm whether CDA technology is really as advantageous in practice as it is in theory. Specifically, more direct comparisons are needed between CDA and conventional spraying systems (with and without oil carriers) with an emphasis on evaluating efficacy of CDA-applied sprays with reduced rates of insecticide. Further, the cost efficiency of using CDA equipment over conventional application methods should be demonstrated for insecticide application, following the pattern of work recently done by Iowa State agricultural engineers (Finck 1986).

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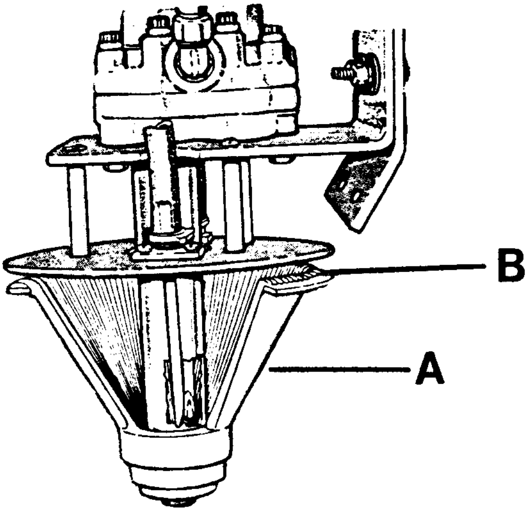

FIG. 1. Schematic of a commercial rotary atomizer; (A) spinning cone, and (B) edge of cone where droplets are released. (Reproduced by permission, courtesy of Farm Fans, Inc.).