THE HISTORY OF MALATHION ULV USE FOR BOLL WEEVIL CONTROL

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ABSTRACT

A history is presented of the use of ultra low volume (ULV) applications of malathion for the control of insects in general. The use of the ULV technique, defined as the application of volumes of 0.5 gallons per acre or less, is discussed. The use of malathion against the boll weevil was begun in 1964, following the successful use of this compound in controlling grasshoppers and the cereal leaf beetle. A review of the research on the effect of droplet size and dosage of malathion ULV applications is presented, This insecticide's role in current boll weevil eradication programs is discussed.

The Ultra Low Volume (ULV) insecticide application technique originated in the control of the desert locust in East Africa. ULV is defined as volumes of 0.5 gallon or less per acre. Experiments were carried out shortly after World War II with solutions of DNOC (4,6-Dinitro-o-cresol) and dieldrin in diesel fuel (Maas, 1971). The limited availability of water and its high evaporation rate as spray droplets in hot, arid climates were important factors in this development. Maas (1971) reported that ULV was first used in crop spraying with the application of DDT and oils. Further use of ULV applications was supported by the successful use of technical grade or undiluted malathion concentrate by American Cyanamid. The development of the technical requirements for applying insecticide concentrates by aircraft was completed in 1963 by the United States Department of Agriculture (USDA) Agriculture Research Service, Plant Protection Division [now Plant Protection and Quarantine (PPQ) Animal and Plant Health Inspection Service (APHIS), USDA] (American Cyanamid, 1970). This ULV application technology resulted in considerable cost savings over the standard high volume spray applications (American Cyanamid, 1970).

Work began with trials for grasshopper control reported on by Messenger (1963) and Skoog et al. (1965). At that time USDA was actively involved in grasshopper survey and control programs on millions of acres of western rangeland. Federal, state and private landowner cooperative control programs were conducted with field operations run by what is now USDA APHIS, PPQ. Programs were authorized by the Incipient and Emergency Control of Pests Act (1937), the Organic Act of the Department of Agriculture (1944), the Cooperation with State Agencies in the Administration and Enforcement of Certain Federal Laws Act (1962) and the Food Security Act of 1985.

Malathion as an insecticide concentrate was first tested against the boll weevil in 1964 by Burgess (1965). This was based on its control success in 1963 tests with grasshoppers and in 1964 with the cereal leaf beetle. The combined research on malathion ULV, application technology, and the control of boll weevils preparing for diapause by Brazzel (1959) and Brazzel et al. (1961) became the basis for the 1964 federal, state and private cooperative boll weevil suppression program on the eastern margin of the Texas High Plains (Adkisson et al. 1965). This program was designed to prevent the boll weevil from infesting the millions of acres of High Plains cotton in Texas and New Mexico. A ten-year history of this successful Program is well documented by Rummel et al. (1975) and the research activities by Adkisson et al. (1965, 1966). The 1964 control program started on September 16 with 7 malathion ULV applications made at 10 to 14 day intervals. The1965 control program was modified to utilize a 2 phase approach of three applications in early and mid-September at a 5 day interval followed by 4 applications at 10 to 14 day intervals (Adkisson et al. 1966). This large area diapause control program developed the initial control strategy for boll weevil eradication.

The terminology for this malathion formulation is inconsistent in the literature. It has been more recently referred to as ULV malathion (Mulrooney et al, 1997) and malathion ULV (Jones and Wolfenbarger, 1999). ULV first was used as an adjective of spraying and application (Skoog et al, 1965; Maas, 1971). Other authors (Cleveland et al, 1966) either left application out as being understood or made ULV an adjective of malathion. Jones and Wolfenbarger (1999) have used malathion ULV based on being the common name of the trademark name on the registered label. The American Cyanamid (1977, 1987) labels lists the product as both Cythion®, the premium grade malathion (EPA Reg. No. 241-208-AA), and Malathion ULV® Concentrate Insecticide (EPA Reg. No. 241-110-AA). Both have the same active ingredient (AI) of malathion at 91 %. However in 1970, American Cyanamid listed the product as having an AI of 95%. The Boll Weevil Programs in the United States have used the registered malathion products of three manufacturers. These were Cythion® with production stopped in the early 1990's by American Cyanamid (New Jersey) and replaced by Fyfanon® ULV by Cheminova® Agro A/S (Denmark). In 1999 Atrapa® ULV manufactured by Griffin L. L. C. (USA) became the other malathion ULV product used by the Boll Weevil Programs. Products of both Cheminova (1992; 1995) and Griffin (1999) have labels which are nearly identical to the American Cyanamid labels (1977; 1987) and with the malathion AI varying formerly from 95 % to as high as 96.8 %.

Rates of malathion ULV for boll weevil control were studied for use at different cotton plant growth stages by many researchers. These include Adkisson (1965) in Texas, Cleveland et al (1966) in Mississippi and Hopkins and Taft (1967) in South Carolina. In 1995 this author was requested by the Southeast Eradication Program in cooperation with the Texas Eradication Foundation to compare the standard 16 oz. per acre rate to a 12 oz. rate under actual Boll Weevil Eradication Program conditions. The 16 oz. rate had been used in the Eradication Programs which started in 1978 (Reference to malathion use in earlier USDA Programs is found in Boyd (1976), Boyd and Brazzel (1973) and Rummel and Frisbie (1978)). This 1995 research need was based on a new manufacturer, a malathion formulation with an increased AI (95%), higher product cost and an increase in Program acreage. Jones et al (1996) showed that 12 oz. worked as well as 16 oz. using 40 acre cotton fields as replicated plots and treated under 1995 Program conditions. As a result the Texas Boll Weevil Eradication Program changed to 12 oz. per acre in July 1995. Villavaso et al (1996) confirmed these results with small plot studies and in 1996 the Southeast Program changed to the 12 oz. rate. Economic pressures caused the Mississippi Program to reduce rates to 10 oz. per acre based on the results of 12 oz. and 8 oz. studies (Villavaso et al.1996). Villavaso et al (2001) conducted additional studies which support this decision. It should be noted that the earlier rate comparison test in Texas (Adkisson et al. 1965, Adkisson 1965) indicated that there was little difference in the effectiveness of 12 and 16 ounces of malathion ULV when applied for the control of diapausing boll weevils. Consequently by 1972, 12 ounces of malathion ULV was adopted as the standard application rate in the Texas High Plains boll weevil suppression program.

Scheduling of insecticide applications for the control of diapausing boll weevils has varied in the Southeast. Before 1997, applications started during the first 10 days of September (Wagner and Villavaso 1999). In 1997 the Mississippi Programs started applications the first week in August. The research of Brazzel and Newsom (1959) further defined by Wagner and Villavaso (1999), Knipling (1968), and Rummel and Adkisson (1971) showed that an earlier generation of diapausing boll weevils would be eliminated with an earlier stating date. This earlier spraying also helped prevent the seasonal dispersal flight of boll weevils from spreading eastward into eradicated areas.

Coverage and drift are of obvious importance in ULV rate studies, since pesticide spray that doesn't land in the target area becomes a contaminate of non-target areas. Brazzel et al. (1968) compared ULV insecticide concentrates to emulsifiable concentrates (EC) in water. More spray droplets per square inch were recovered in the EC applications than the ULV. However, more insecticide was recovered from the ULV applications than from the EC. Their conclusion was that ULV formulations applied in droplet sizes ranging from 100 to 200 microns (micrometers) in diameter drifted less than EC water diluted formulations. Using fluorometric quantitative measurements, Burt and Smith (1974) demonstrated that droplets of 140 micron diameter (ca. 0.0055 inch) or larger are necessary for reasonably good drift control. Their studies included treatments of 100, 140, 200 and 300 micron droplets. With ULV rates of 16 oz. per acre this means that there will be 347 droplets per square inch if all droplets have a 150 micron diameter. If all droplets have a 300 micron diameter there will be 5.38 per square inch (Potts, 1958). A spectrum of droplets with none less than 140 microns, while obviously not physically capable of complete plant coverage, has been used successfully in boll weevil eradication. The effectiveness of incomplete plant coverage inherent in ULV application is due to the mobility of the adult boll weevil. Boll weevils feed and oviposite in immature fruit in the plant terminal. Therefore only the upper most part of the plant requires coverage. The boll weevils' behavioral trait of moving from terminal to terminal increases the probability of contact with insecticide residue on the plant.

Resistance to malathion ULV by boll weevil populations has never been documented in the United States. Newsom (1978) proposed this as a problem that would come with eradication programs. Bottrell et al. (1973) and Pruitt et al. (1978) showed that boll weevil resistance to malathion ULV had not occurred after years of heavy exposure in Texas. The Louisiana study by Martin et al. (1996) found no evidence of boll weevil resistance to the organophosphorus insecticides in the United States. Azinphosmethyl and methyl parathion have been the insecticides of cotton growers' choice for boll weevil control for nearly four decades with malathion used almost exclusively in the boll weevil eradication programs (Martin et al., 1996). No evidence of boll weevil resistance to malathion ULV has been experienced by the Eradication Programs. The Boll Weevil Eradication Programs affect large areas, thereby limiting heavy exposure to relatively few years, unlike the situation reported by Pruitt et al. (1978).

Harm to non-target insects is a disadvantage of area wide applications of a broad-spectrum insecticide. Beneficial insect populations will be reduced after multiple applications of malathion ULV. This was reported by Huddleston in a multi year study of the High Plains Fall program (Rummel et al., 1975). It was concluded that these treatments did not reduce predaceous insect populations for the following year. Large scale field studies were conducted throughout the North Carolina and Virginia Boll Weevil Eradication Trial Program by Dickerson et al. (1979) and Dickerson et al. (1980). Their findings showed a reduction of 50-80 % of the non-target insect populations in cotton fields during periods of insecticide applications. After applications stopped, these non-target insect populations rebounded quickly. Three early season boll weevil applications of malathion ULV caused buildups of aphid and whitefly populations but not in the diflubenzuron treated fields in Alabama in 1989 (Jones, unpublished) by eliminating predators and parasites. Layton et al. (2001) reported similar findings. Aphid population increases were documented in Texas (Reed et al., 1998) as a result of malathion ULV. These same findings are discussed extensively for the use of other broad-spectrum insecticides by Ables et al. (1983). More specific data on the effect of malathion ULV on parasitic insects has been developed by Tillman (2001). While malathion ULV can exacerbate secondary pest infestations (Layton et al., 2001) there are many other factors that can be involved including climate (Jones and Wolfenbarger, 1999). The eradication of the boll weevil gives the ultimate benefit in the reduction in insecticide use and the use of beneficial arthropods in future pest management strategies (Carlson et al., 1989: Haney et al., 1996).

An understanding of application technology is an integral part of this subject. The history of aircraft use in agriculture is reviewed by Akesson and Yates (1974) and Maas (1971) reviews the mechanics of aerial ULV application. More recently the physical problems of aerial applications and solutions were reviewed by The Spray Drift Task Force (1997). They concluded that droplet size is the most important factor affecting drift, and since drift only occurs downwind, current technology can not eliminate drift totally but can minimize it to near zero. To minimize drift they recommended applying the coarsest droplet spectrum that provides sufficient coverage and control, continuing the standard practice of swath adjustment, controlling application height, using shortest boom length that is practical and applying pesticides when wind speeds are low. These elements have been part of standard application practices of the Boll Weevil Eradication Programs since 1978. The one exception was that a shorter boom length was not required until 1983.

The high speed of agricultural aircraft makes it relatively simple to apply ultra low volumes. This is more complicated with slow moving ground sprayers. Malathion ULV was first applied by ground equipment when Taft and Hopkins (1966) mounted a mist blower on a high cycle sprayer. Burt et al. (1966) developed a boom type sprayer using a spinning disk and a metering nozzle for each row. In 1969 Taft et al. developed a boom type high cycle sprayer using air to replace the high volume of liquid required in normal boom type sprayers. While all three of these worked for malathion ULV applications, their only use was in research studies.

The 1978 Boll Weevil Eradication Trial Program began using mist blowers mounted on pickup trucks for spraying areas such as near wires, buildings and around tree lined fields, that could not be treated with aircraft. These mist blowers applied azinphosmethyl in water at a volume 1.5 gallons per acre. Conversion to use 16 oz. per acre of malathion ULV was done by Jones and Mabry (1984) for use in the 1984 early season applications of the North and South Carolina Program. This truck mounted mist blower use continues in the Boll Weevil Eradication Programs. In 1994 the Southeast and Texas Eradication Programs converted high cycle boom type sprayers for ULV application. This conversion utilized low volume metering pumps and air blowers based on a design by McWhorter and Hanks (1992). These sprayers apply 16 oz. of malathion ULV mixed with an equal volume of cottonseed oil (once refined) per acre. Efficacy with this ULV spray mixture against the boll weevil has been reported by Mulrooney et al. (1997). The introduction of precision metering pumps for ULV application (Hanks and McWhorter, 1991) made it possible for D. D. Clayton (pers. comm.), an equipment specialist with the Southeast Eradication Program, to once again utilize a mist blower mounted on a high cycle sprayer. This mist blower has eliminated need for an expensive and fragile spray boom system for spraying in areas with trees adjoining field margins. By 1999, this high cycle mist blower sprayer system was in use throughout the active Eradication Programs. Studies of coverage and drift of this equipment applying the 16 oz. rate of malathion ULV and the boom sprayer with the 32 oz. malathion/cottonseed oil mixture showed few differences except for the difference in volume (Mulrooney , Unpublished).

Malathion ULV and vegetable oil mixtures have been studied by Harris and Jany (1986) with the introduction of a new product formulation that was 46.2% malathion ULV (technical) mixed with vegetable oils and emulsifiers. This formulation was labeled (American Cyanamid, 1986) for boll weevil control on cotton. Recommended volumes were from 18 to 36 oz. per acre. Jones et al. (1998) determined LD50's using topically applications on boll weevils. Malathion mixed with both cottonseed and paraffinic oils were compared to the malathion standard. The paraffinic oil enhanced malathion's effect on the boll weevil, but it should be noted that malathion ULV will mix alone with vegetable oils but not with paraffinic oils. In small field (1.5 acre) studies Mulrooney (2001) found that reduced rates of malathion ULV mixed in cottonseed oil were equally effective as the standard rates of malathion ULV alone. Large acreage tests by an Eradication Program are needed to determine the suitability of malathion-cottonseed oil mixtures for boll weevil control.

The aerial application of other insecticide concentrates for boll weevil control by the Eradication Programs has been limited to azinphosmethyl, used in North Carolina and Georgia. Fish kill in a few farm ponds next to cotton fields in the 1987 Georgia Program and negative media coverage caused it's manufacturer to remove it from future bid lists. Encapsulated methyl parathion was tested in South Carolina during the 1983 and 1985 Programs. USDA APHIS tests (Jones, 1983; 1986) showed poor control with the product when compared to malathion ULV in two large area tests. However, application problems with its use as a ULV material were responsible for reduced effectiveness of the methyl parathion. There is one new material on the market and one promising new formulation. Fipronil is a new chemistry that is as efficacious for boll weevil control as malathion ULV with slightly less effect at causing aphid population increases (Reed et al., 1998). The new formulation is encapsulated malathion, which has a longer residual life and thus requires fewer applications (Foster et al, 2000). Neither insecticide is labeled for use in cotton at this time.

Malathion ULV has been called the perfect insecticide for a control program of the size of current boll weevil eradication programs. It is used directly from the container with no mixing required. Its low mammalian toxicity makes it safe for workers to use. It has a high level of control efficacy for the boll weevil and a good residual life on dry cotton plants. No resistance has developed by the target insect and in consideration of previous discussions none is likely to develop under Program use. Its physical property as an oil makes it the perfect ULV aerial application insecticide. ULV aerial application costs have made the Eradication Programs affordable, especially is comparison with standard high volume treatments. The availability of malathion ULV is a large factor in the success of the Boll Weevil Eradication Programs. This success has led to a marked decrease in insecticide usage in cotton production. This in turn has made cotton production more economical and has resulted in increased cotton acreage after the eradication of the boll weevil.

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