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A Future for Ultra-Low Volume Application of Biological and Selected Chemical Pesticides

Matthews Graham A

Imperial College, United Kingdom

ABSTRACT

A project to improve the yields of cotton in Rhodesia and Nyasaland involved a study on a key pest, the Red Bollworm (*Diparopsis castanea*), which included laboratory studies to determine the impact of certain insecticides, a change in spray equipment to minimise exposure of the operator to the spray and timing of sprays to control the first instar larvae. Later it was noted that the spray deposits of insecticide formulations that were mixed with water, were removed by rain. This ultimately resulted in insecticide pollution in rivers. Small scale farmers also had difficulty obtaining sufficient water to spray with a knapsack sprayer, so trials using an ultra-low volume using an oil-based formulation showed similar yields. Hand carried sprayers with a rotary atomiser powered by batteries to apply sprays with specific size range of droplets were used effectively on cotton. ULV sprays had already been recommended to control locusts and further research showed that an electrostatic sprayer could also apply ULV sprays very effectively. By avoiding using a water-based formulation, the insecticide was more effectively applied.

***Corresponding author**
Matthews Graham A, Imperial College, United Kingdom.

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Introduction

Growing cotton in Southern Rhodesia and Nyasaland [now Zimbabwe and Malawi] began in the 1920's, but yields of Cotton remained low due to different insect pests. A project was established by the UK and in 1958 I was recruited to show farmers how to use DDT to control the insect pests. Some trials had been started using a knapsack sprayer fitted with a lance with two nozzles spraying Endrin laterally as the operator walked between the rows of cotton plants (Figure 1).

I began by setting up a system to establish a culture of the bollworms, specifically the Red Bollworm (*Diparopsis castanea*) so that it was possible to do tests in the laboratory to assess which insecticide was effective to control it. The tests involved spraying potted plants and placing an egg on a leaf surface and timing when the first instar larva started to walk across the sprayed surface seeking a bud or boll to enter (Figure 2). Whereas on unsprayed leaves, the larva could be walking for 166.7 + 81.8 minutes, The time the larva survived on the plant was only 27.6 +7.8 minutes, when the spray contained 1% carbaryl. Walking continued longer with less insecticide. In contrast a fully-grown larva would have required a significantly larger amount of pesticide, so the key to controlling the red bollworm was to control the first instar larvae before they were protected inside a bud or boll.

It was decided that in field trials, the use of lance on the knapsack sprayer would expose the operator to the spray, so a vertical rod was attached on the back of the sprayer tank and up to 8 nozzles fitted so that when the plants were small, only two nozzles angled to project spray between branches and deposit some spray on the under surface of leaves. As the plants increased in height, spray was applied with additional cone nozzles (Figure 3).

Figure 1: Sprayer Used with Lance

Figure 2a: Red Bollworm Egg

Figure 2b: First Instar Larva on a Bud

Figure 3: Knapsack Sprayer with Tailboom

Later in Malawi, farmers pointed out that in villages with limited access to water, it was impossible to take sufficient water to use a knapsack sprayer. This resulted in trials examining a completely different type of sprayer which used a rotary atomiser and not hydraulic nozzles. This was possible as Micron Sprayers in UK had developed this equipment (Figure: 4)

Figure 4: ULVA Sprayer

Results

Table 1: Yields from Trials in 1966 and 1967

	Yield*			% damage	
Location	Sprayed	Unsprayed	Increase	Sprayed	Unsprayed
Malawi Shire 16 sites	1285 1046	742 431	543 615	10.2 11.5	20.9 36.3
Central region 13 sites	1264 1407	448 648	816 759	4.4 4.0	17.1 20.3
S. Rhodesia Middle veld 5 sites	1939 1941	724 517	1215 1424	5.9 0.9	45.6 11.6

- Mean yield in Pounds seed cotton per acre obtained in trials in 1960 and 1961 Data from and Matthews & Tunstall [1].

In a separate trial, the yields of seed cotton obtained when different swath width were used (Table 2) were similar to the yields with a knapsack sprayer, if the operator walked along each row, but using a swath of 5 rows resulted in a lower yield, although the yield was higher than on unsprayed plots [2].

Table 2: Comparison between using a ULV Spray and Knapsack

	Yield seed cotton kg/ha	Percent damage
Unsprayed	457	13.8
Knapsack	2259	6.7
ULV 1 Row Swath	2255	12.1
ULV 5 Row Swath	1595	10.4

In Japan, farmers did not like walking through rice fields with a heavy sprayer on their backs, so a company designed a small helicopter with a single rotor, but without a pilot that could spray their rice fields. This unit was operated by a person on the ground using Global positioning data to control the aircraft's movement across the rice fields (Figure 5.). In the USA, the same "Drone" was used to spray vineyards on sloping ground, but using hydraulic nozzles applying large volumes of spray per hectare (94l/ha), so the drone had to be land frequently to refill the tank [3].

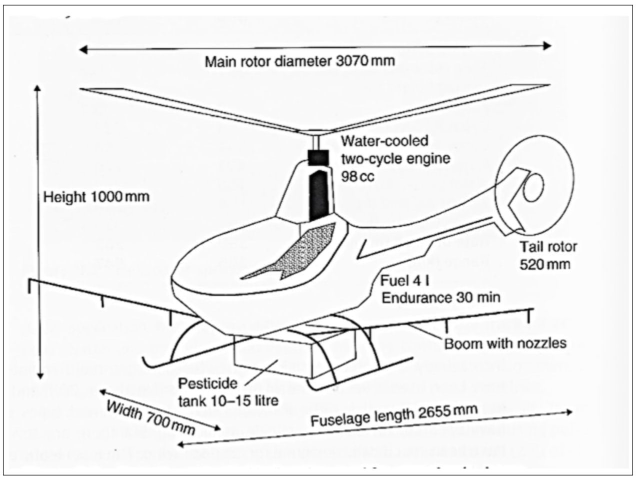

Figure 5: Unmanned Helicopter in Japan

Following Japan, other countries began adopting spray drone technology particularly China and South Korea but using multi rotor battery powered aircraft rather than gasoline powered single mast helicopter type. It was much later that other countries thought that a "Drone" could be used to spray other crops, but instead of copying a helicopter, these utilised a multirotor frame. These designs are generally battery powered, with the spray tank centrally located and with two, four, six and eight rotor designs that are now all commercially available. China was soon spraying cotton crops (Figure: 6) and subsequently other countries adopted a drone for different crops. In Malaysia a drone has been used to spray palm trees to control an insect pest on the upper part of the tree.

Figure 6: Drone Spraying Cotton in China

An Ultra- low Volume (ULV) spraying at 1 litre per hectare has been recommended for controlling desert locusts for both ground and aerial applications due to limitations in water availability in the dry arid environments that locusts occur as well as the need to treat vast areas rapidly. ULV applications utilise oil formulations to prevent evaporation of drops and improve retention and persistence of the spray on vegetation locusts move and feed on. ULV application is also routinely used in other applications against forest pests, mosquitos, tsetse flies and others. The technology is ideal for drone applications overcoming constraints with limited payload and productivity of smaller drone platforms. High volume sprays in water are more commonly used in general agriculture due to limited availability of ULV formulations for other applications, but there is more concern about the pollution of rivers with insecticides which is undoubtedly due to rain washing off the deposits of water- based formulations from crop foliage. Tests assessing the quantity of insecticide on cotton leaves, before and after rain indicated that deposits on both the upper and lower surfaces of leaves were significantly reduced by rain. (Figure: 7)

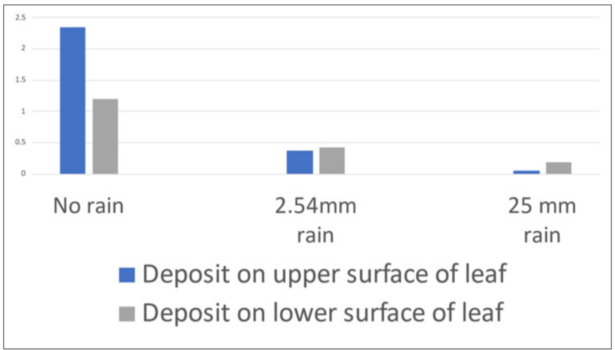

Figure 7: Impact of Rain on the Amount of Insecticide Remaining on Leaf Surfaces After Rain. Upper Surface before Rain was 2.34ug/cm2 and 1.19ug/cm2 on the Under Surface

One notable advantage of ULV formulation is that the product applied does not wash off easily with rain. ULV spraying was introduced with the ground equipment by Micron Sprayers (Bals, 1970) . The ULVA sprayer had a tube to contain torch batteries to power the small motor driven rotary atomiser (Figures 4 and 8) to create precisely controlled droplets around 60-70um in size that were dispersed with the prevailing wind over three rows of cotton. Farmers were able to treat their cotton crops in a matter of one or two hours rather than the 3 or 4 days it was taking to treat a small holding of 1-2 hectares of cotton previously using a knapsack sprayer and high water volumes. Formulations for ULV spraying were developed by Philips Duphar and then also developed by a number of other AgChem companies. As ULV formulations need to have a low evaporation rate, water- based formulations should be excluded from ULV sprays. Special solvents such as pine oil and tetraline and vegetable oils, including cotton seed oil and castor oil are suitable carriers as they have low volatility. ULV spraying was adopted in Francophone West Africa from 1975-1995, when the ULV formulation was withdrawn and subsequently sprays were using water-based formulation applying c 10l/ha with a rotary atomiser sprayer.

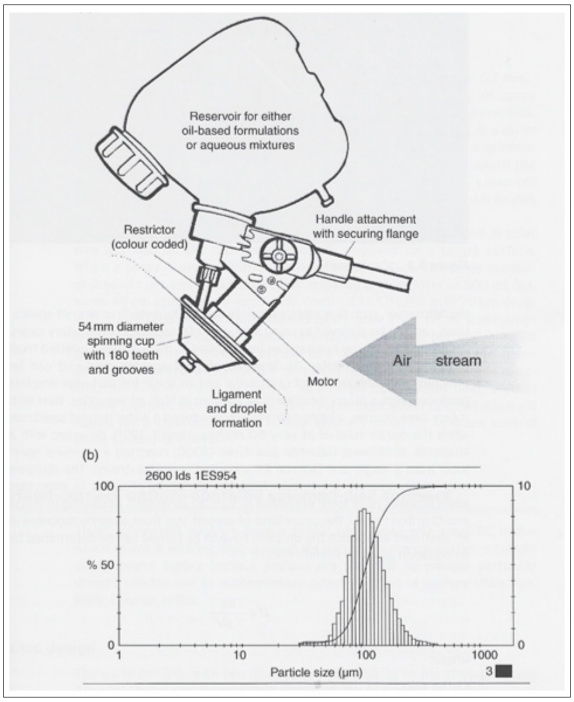

Figure 8: A hand-Carried Micron ULVA Sprayer with Rotary Atomiser

By controlling the flow rate and speed of rotation of the disc, the graph indicates that the range of droplet sizes produced is minimised compared with hydraulic nozzles. A rotary atomiser is also suitable for installation on a drone, to minimise downwind drift of small droplets as well as avoiding waste on the soil due to very large droplets.

ULV sprays have also been used with an Electrostatic sprayer (Figures. 9-10), which was developed by Coffee (1979), but these were not supported by the agrochemical industry as the quantity of pesticide required was significantly less than when a formulation designed to mix the pesticide in water was used.

Figure 9: A Hand Carried Electrostatic Sprayer being used in Brazil on Cotton

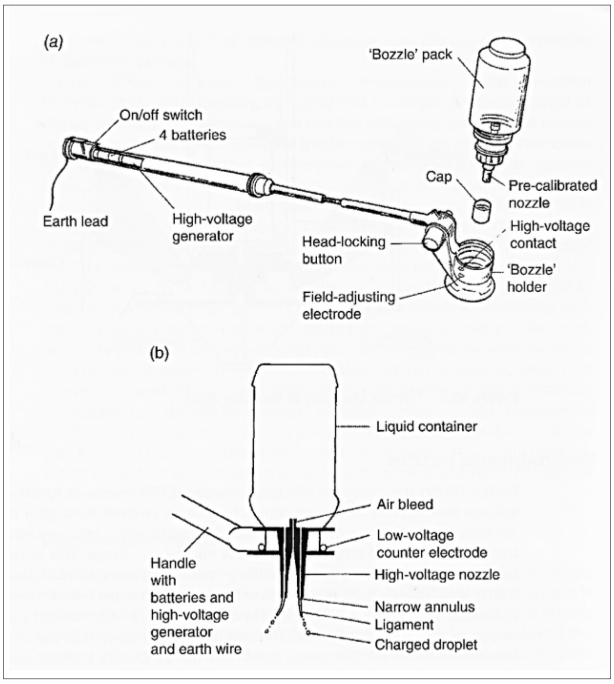

Figure 10: Diagrams Showing the Electrostatic Sprayer

Discussion

Some Further thoughts on Future Developments

1. Reducing or eliminating water saves time and energy in its collection and transport and hence a trend to lower volumes is more productive.
2. As a consequence, higher productivity improves timeliness of application and minimises pesticide use.
3. Lower spray volumes are more appropriate for automation whether by ground robotic vehicles or drones as payloads are smaller facilitating use of smaller equipment
4. High spray volumes with water and use of very large ground sprayers with wide spray booms to improve productivity simply increases soil compaction.
5. Reducing or eliminating water in sprays opens up greater possibilities for formulation and co-adjuvants such as stickers to improve retention on plant surfaces, adjuvants to reduce evaporation, spreaders to increase contact area on pant surface and assist in absorption in plant leaf, oils assist in penetration of waxy plant leaves and insect cuticles. Rain fastness can be greatly improved too and persistence on plant foliage.
6. To apply lower volumes does need improved droplet size control using rotary atomisers or other means to optimise droplet size according to the biological target.
7. Lower spray volumes need not mean increased drift if drop size and evaporation is controlled. Spray drift represents only around 9% of material escaping into waterways, the vast majority of which comes from either point source pollution by spills or washings or run off from crops onto the soil and into rivers (reference TOPPS data)
8. Increasing use of GPS and crop sensing allows for spatially selective spray application with greater precision and less waste further facilitating adoption of autonomous ground and aerial applications.
9. AgChem industry should embrace these trends and adapt formulations and labelling to allow new technologies such as drones and other low volume spray systems to be fully exploited.
10. With greater interest in applying biopesticides, during 2020-2022, in Somalia applied metharizium in an oil applied at 1 litre hectare successfully for locust control. Biopesticides can require accurate delivery to target site and fungal pathogens, so in dry environments may perform much better in oils as they do not dessicate. Desert locust control in Somalia Ower, A. & McRae, H. D (2022) [4-14].

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