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FABRICATION OF ULTRA LOW VOLUME (ULV) PESTICIDE SPRAYER TEST BENCH

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A comprehensive study was carried out to find the effect of power (Batteries), swath width, discharge rate and wind speed on droplet size and density of locally available ULV sprayer with the objective to minimize the application rate, drift and wastage of pesticides while increasing insects mortality. Conventional tractor mounted boom sprayers apply spray on the upper side of the leaves. Most of the sucking insect (whitefly, aphid, jassid, thrips, etc.) have there kitchen houses on the lower side of leaves of the upper half portion of cotton plant which not only get protection from sprays but also enjoy the shadow of leaves as of umbrella coverage. Therefore, the spray chemicals by conventional sprayer do not hit the actual target and cause wastage of the spray material to the ground and air. Different pests and insects required different number of droplets per cm^2. The test bench consists of a rectangular frame, 2 rollers, variable speed motor, ULV stand, and canvas belt with some accessories. Test bench facilitates the mounting of ULV sprayer at different heights. It has a variable speed motor to rotate the canvas belt is actually to simulate the swath width of spray while speed of belt simulates the traveling speed of a man, effect of voltage supplies, discharge rate and wind speed on droplet size and density. Droplet distribution was obtained on water sensitive papers fixed on rotating belt. A variable speed gear motor was used for power supply to the rotating belt. A bracket fan was used to create required wind speed.
Keywords*:* ULV sprayer, swath width, discharge rate, wind speed, droplet size and droplets density

INTRODUCTION

Pesticides has accused in Pakistan. But untargeted application of pesticides by conventional knapsack and boom sprayers has accused agriculture profession. Research studies indicate that very small amount of the spray is deposited on the targeted areas when sprayed with knapsack sprayers. According to Central Cotton Research Institute and AMRI, Multan about half of the pesticides sprayed is wasted during applications which not only adds to the cost of production but also pollute the surrounding soil, water and air environment (Rehman, 1994). A major reason for such a big loss of pesticides is inefficient spraying machines which are unable to maintain specified nozzle pressure, uniform droplet size and even distribution with the result that dribbling or drift occurs during spray operation. Dribbling can cause soil/water pollution while drift may cause air pollution in addition to wastage of costly pesticides. Mathew (1988) indicated two major reasons for pesticides loss: (i) unawareness of farmers and (ii) use of inefficient machines. The control of boll weevil on cotton was poor when the droplet size was 300 μm. Ghaffar (1988) studied the efficacy of different spraying techniques such as knapsack sprayer, ULV and electrodyne against insect pest of cotton crop with a view to find the most efficient and economical spraying technique. He found that a ULV sprayer had a cost-benefit ratio of 1:9 as compared to 1:8 for knapsack sprayer. The control of insect pest with all the three spraying techniques was comparable but many other advantages like narrow spectrum of droplet size, light weight, less manual fatigue, good coverage, low energy consumption and less maintenance cost outweighs the conventional sprayer.

Conventional spray techniques are mostly inefficient because of a much broad spectrum of droplet which do not fall on the target surface and go waste. However, the use of ULV sprayers has radically changed spray technology as they produce small droplets. It was recognized that droplet size is the most important controllable parameter. It influences the distribution of spray downwind (small droplets are carried farther and can therefore produce a wider swath). The size of droplet influences work rate and biological efficacy of the pesticide. It can also influence the environmental impact of the spraying operations. For example there may be negative impact if spray consisting of large droplet fall on the soil in the target area or small droplet drifting on to neighboring crops or animal/human habitat.

Pesticide collected on the upper side of the target with conventional sprayers may be washed off by rain or in some cases by overhead irrigation. Some studies have suggested that upto 80% of total pesticide applied to the plant may eventually reach the soil. In this manner, pesticide contamination of the soil has caused major changes in the population of non targets organism (Courshee, 1960).

Hashmi (1994) reported different types of sprayers used in Pakistan. Conventional tractor mounted boom sprayers apply spray on the upper side of the leaves. Most of the sucking insect (whitefly, aphid, jassid, thrips, etc.) have there kitchen houses on the lower side of leaves of the upper half portion of cotton plant which not only get protection from sprays but also enjoy the shadow of leaves as of umbrella coverage. Therefore, the spray chemicals by conventional sprayer do not hit the actual target and cause wastage of the spray material to the ground and air.

Conventional hydraulic sprayer's nozzles are not suitable for ULV spraying as these are incapable of producing droplet spectra and emit a very wide range of droplet sizes (Cooper *et al*., 1998).

To overcome these problems Ultra Low Volume (ULV) sprayers, a controlled droplet application method may be used. ULV sprayers are much more superior to conventional knapsack and tractor mounted sprayers in many respects. As there is no storage tank and pressure pump involved in ULV sprayer, so they are light in weight and 10 to15 times less costly than conventional sprayers. The field capacity of ULV sprayer is 5 times higher than that of conventional sprayers as this does not need mixing/dilution of pesticide with water. They can maintain more uniformity in droplet size and number of drops per unit area by employing centrifugal-energy. Hence their crop coverage is more effective than conventional sprayers. A simple construction of ULV sprayers incurs minimum maintenance and operational costs. In spite of all these advantages ULV sprayers have not been adopted at large scale mainly, due to unawareness of farmers about its advantages and air pollution problems due to drift which can be overcome by simple modifications in the design. Air pollution caused by drift of concentrated formulations is thought to be sometimes fatal to humans. ULV sprayers are mostly imported from abroad as a handheld device equipped with single nozzle. Until and unless, the air pollution problem is not properly addressed during fabrication of ULV, the technology may not get popularity among farmers. Moreover, boom type ULVs need to be fabricated locally to minimize initial costs and spray large tracts of cotton, rice and other crops while promoting ULV technology among farmers and agro-industries

MATERIALS AND METHODS

The main objective of this study was to establish a test bench for ULV sprayers. An indigenous test bench was developed in the workshop of Farm Machinery and Power Department with the assistance of local machine shops and expertise. Following major components and material were purchased from local market.

Development of ULV test bench: The test bench consists of a rectangular frame, 2 rollers, variable speed motor, ULV stand, and canvas belt with some accessories.

Test bench facilitates the mounting of ULV sprayer at different heights. It has a variable speed motor to rotate the canvas belt is actually to simulate the swath width of spray while speed of belt simulates the traveling speed of a man.

Testing Material and Equipments

- D.C Supply – to supply constant voltage (e.g., 6, 9 and 12 V)
- Anemometer – to measure wind velocity
- Digital Tachometer – to measure speed of spinner
- Multi-meter – to measure voltage and current
- Camera Coupled Microscope – to capture and analyze droplet image
- Water sensitive strips – to capture droplets
- Bracket fan – to simulate wind speed
- Miscellaneous (tape, surgical gloves, stop watch, 1000 mL cylinder etc.)

Nozzle Flow Rate: The nominal flow rates as specified by the manufacturers of ULV sprayers are 30, 50, 70 and 125 mL/min for yellow, orange, red and black nozzles respectively. To verify these flow rates of four different nozzles, all the three sprayers were checked one by one. The bottles supplied with the ULV sprayers were removed from the spinner assembly and filled with water. Filled bottle was fitted back onto the spinner assembly with a nozzle to be tested for flow rate. Time taken by the bottle to empty into a 1000 mL cylinder was noted with the help of a stop watch. The volume collected in one minute was noted and compared with the nominal flow rate (discharge) of nozzle. This process was repeated for all the nozzles.

Voltage Drop: ULV sprayers are conventionally operated with 9 volts dry battery cells. The spinner speed which controls the droplet diameter of a ULV sprayer is dependent upon voltage available from the cells. The voltage of dry battery cells drop with time. To understand voltage drops with time, tests with dry battery cells were conducted by spraying water with different nozzles. After every minute, the potential (voltage) of dry battery cells was measured with the help of a multimeter.

Disc/Spinner Speed: Disc speed of ULV sprayer is an indicator of centrifugal force which helps in breaking up liquid pesticides into tiny particles. By changing speed, one can generate particles with varying diameter from 50 μm to 400 μm. The disc speed in turns depends upon the voltage supply which should not change with time. The disc speed of three ULV sprayers was checked by supplying constant voltage of 6, 9, and 12 volts with the help of a constant voltage supply. A non contact type tachometer (Model # TECPEL 1501) was used to measure the speed while spraying water with four different nozzles.

***Droplet Size, Droplet Density and Swath Radius*:** A locally developed Test Bench with 1.2 m wide moving belt as shown in figures above was used to simulate swath coverage. Water sensitive papers were affixed at the center of the belt and then at 15, 30, 45 and 60 cm from the center point. The sprayer was mounted on the top of the belt with the spinner located at the center of the belt. The speed of the belt was set to the waking speed of a man with the help of a variable speed motor. A constant DC voltage supply was used to run the sprayer at 6, 9 and 12 volts. A non-contact type Tachometer was used to measure spinner speed while sprayer was running. A pedestal fan was used to set the wind speed. An anemometer was used to measure wind velocity.

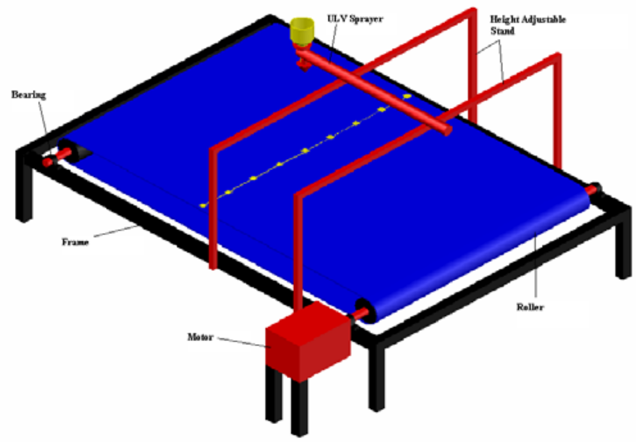

Figure 1. An Isometric view of test bench for ULV sprayer

The spray uniformity, droplet density and droplet size data was recorded onto water sensitive paper which changes its color by absorbing water drops. Figure 1 shows the set up of test bench with ULV sprayer to record different data. A camera coupled microscope was then used to take the pictures of droplets captured onto water sensitive papers. Microscope also helped to measure the diameter of the pictured droplets in microns and number of droplets per square centimeter. Droplets were grouped into different classes of diameter to calculate Volume Mean Diameter which is a weighted average of the droplets diameters. The following formula was used to do this.

$$VMD = [\Sigma Ni\ D_i^3 / \Sigma N_i]^{1/3}$$

Where, N = number of drops in each class and D = diameter of drop in µm

RESULTS AND DISCUSSION

***Evaluation of ULV Sprayers using Digital Image Analysis*:** Image analysis or machine vision is a modern way of analyzing things/objects. It is an application of electronic eye in stead of human eye to differentiate the things based on morphology (size, shape and geometry etc), color or features. A picture/image contains thousands of pixels (information) about an object and can be stored, reproduced, transported, analyzed and reanalyzed using high speed computers.

Temporal and spatial variabilities in object can be easily studied using CCD cameras and camera coupled microscope.

***Droplet Density*:** The performance of ULV sprayer is dependent upon wind velocity. Use of ULV sprayer is recommended when a wind of about 1 m/s (3.6 km/hr) is blowing. The average wind speed is 3 to 4 km/hr (0.83 to 1.11 m/sec) (Gosal, 2004). Spray under these conditions results in a more uniform droplet density within one meter swath width and less drift. This behavior of a ULV sprayer may be seen in Table 1 and Figures (2a, 2b, and 3a, 3b, 3c). These figures show number of droplets cm^{-2} under no wind and 1 m/s wind velocity over a swath radius of 60 cm using black and orange nozzles. Figure (2a, 2b, and 3a, 3b, 3c) depicts that the spray at 1 m/s wind velocity is more uniform over swath than spray under no wind. The number of droplets cm^{-2} of about $450/cm^2$ may be seen uniformly distributed over a 30 cm swath radius. Whereas, under no wind, the spray is not uniform and the droplet density varies for 430 $droplets/cm^2$ at zero radius to about 230 $drop/cm^2$ at 30 cm radius.

A more uniform spray can be seen in Figure 3a & 3b when a black nozzle was used to spray instead of orange nozzle (Fig. 2a & 2b) under same wind conditions. The spray at 1 m/s wind velocity is more uniform over a swath radius of 45 cm wherein droplet density is around 500 $drops/cm^2$. Under

Table 1. Effect of wind velocity on droplets density for orange and black nozzles at 9 volt DC supply

Swath radius(cm)	Drops/cm^2 No wind condition		Drops/cm^2 1 m/s wind velocity	
	Orange Nozzle	Black Nozzle	Orange Nozzle	Black Nozzle
zero cm	435	562	463	526
15 cm	411	472	476	535
30 cm	232	401	447	513
45 cm	92	175	259	402
60 cm	29	20	39	43

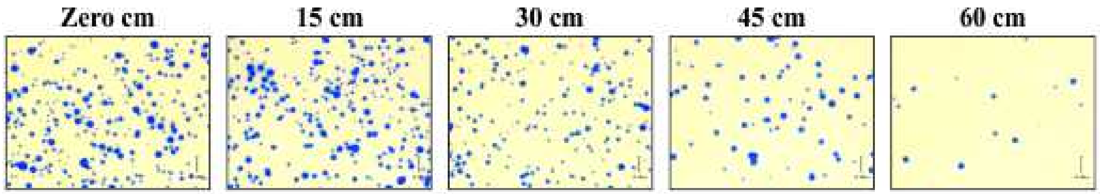

Figure 2a. Images depicting droplet density/cm^2 and spray distribution over 60 cm swath radius with orange nozzle and 1 m/s wind velocity.

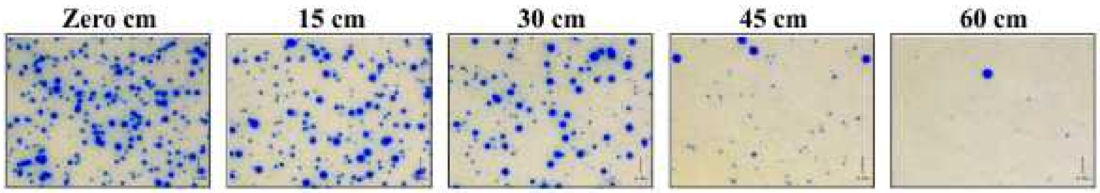

Figure 2b. Images depicting droplet density/cm^2 and spray distribution over 60 cm swath radius with orange nozzle and no wind condition.

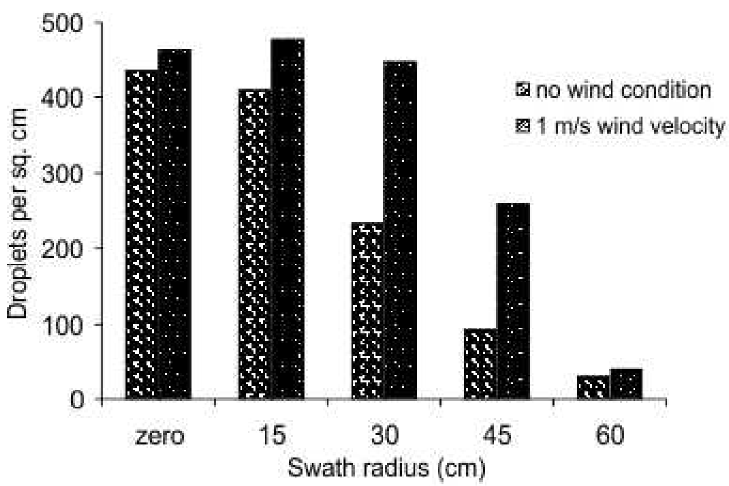

Figure 2c. Effect of wind velocity on droplets density with orange over 60 cm swath radius.

no wind condition spray is non uniform over entire swath width with droplet density varying from 560 drops/cm^2 at zero cm radiuses to 175 drops/cm^2 at 45 cm radius. From the results of Table 1, it may be concluded that spray with black nozzle under wind conditions gives more uniform spray pattern over swath radius of about 1 m than orange nozzle.

Droplet Size**:** Insecticide application efficiency can be improved only if instead of attempting to wet the whole target the optimum droplet size is selected to increase the proportion of spray which adheres to the targets. The optimum droplet size for flying insects ranges from 10-15 µm; for insects of foliage is 30-50 µm and for soil (weeds) is greater than 200 µm (Babu *et al*., 1990). A ULV sprayer is claimed to be superior over knapsack and boom sprayers due to its more uniform droplet size, droplet density and spray pattern. Studies have indicated that a droplet size of 100 to 125 µm is more effective in killing insects. The need for a droplet spectrum with 80% of the spray volume in the size ranges 50-100 µm. However, not all manufacturers provide data on this fundamental performance parameter (Bateman *et al*., 1993). Droplet spectrum of various setting of the ENS using a laser analyzer achieved a maximum of 33% of the volume of spray in the size range 50-100 µm. This compares with their suggestion that ULV sprayers should be capable (as some rotary atomizers are) of producing 80% of their

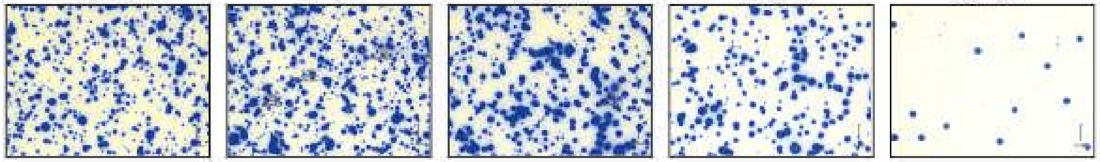

Figure 3a. Images depicting droplet density/cm^2 and spray distribution over 60 cm swath radius with black nozzle and 1 m/s wind velocity.

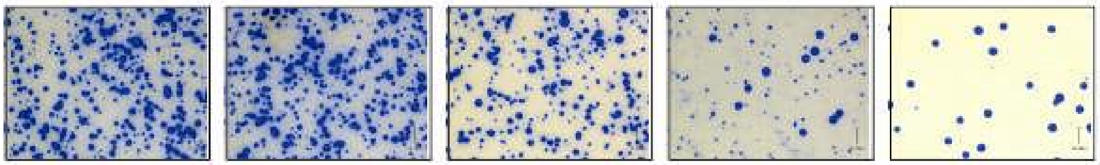

Figure 3b. Images depicting droplet density/cm^2 and spray distribution over 60 cm swath radius with black nozzle and no wind

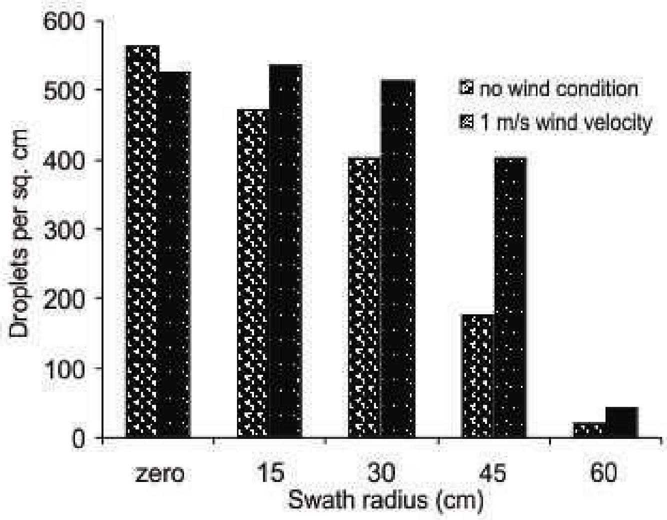

Figure 3c. Effect of wind velocity on droplets density with black nozzle over 60 cm swath radius.

spray volume in this size range (Griffiths and Bateman, 1997). Figure 4a and 4b support above mentioned statement. The Volume Mean Diameter (VMD) in microns has been plotted against swath radius for orange and black nozzles and is also given in Table 2. From Figure 4a a uniform droplet size of 88 µm may be seen for orange nozzle over an entire swath radius under zero and 1 m/s wind velocity. Figure 4b depicts the effect of black nozzle which is bigger in orifice size than the orange nozzle. A droplet size of about 97 µm is noted over the entire swath at 1 m/s wind velocity. According to Symmons (1992) the optimum droplet size for locust control is somewhere between 40 and 120 µm. The reason for this are that droplets less than 40 are more likely to fail to deposit in the target area and be carried outside it and that droplets larger than 120 µm more likely to fall onto bare soil relatively close to the sprayer. Whereas under no wind conditions, an average droplet size of 100 µm may be seen. In comparison to orange nozzle the black nozzle produced a droplet size of about 100 µm which is desired for effective control of insects. Polles and Vinson (1969) reported that higher mortality of tobacco budworm larvae with 100 µm droplet of ULV malathion than with larger, more widely spaced droplets (300-700 µm) which the larvae were able to detect and avoid them. Polles and Vinson's search strongly match with above mentioned results that the optimum droplet size is 100 µm. Droplet size is the most important parameter of ULV sprayer. An optimum droplet size (100 µm) is one, which gives most effective coverage on the target with minimum contamination of the environments. Different insects and pests require different

Table 2. Effect of wind velocity and nozzle types on droplet size at 9 volts

Swath radius(cm)	VMD (µm) No wind velocity		VMD(µm) 1 m/s wind velocity	
	Orange Nozzle	Black Nozzle	Orange Nozzle	Black Nozzle
zero cm	87	109	86	98
15 cm	90	104	83	97
30 cm	89	111	84	97
45 cm	86	101	81	97
60 cm	87	109	83	96

number of droplets per cm^2 which could be achieved only by changing voltage supply.

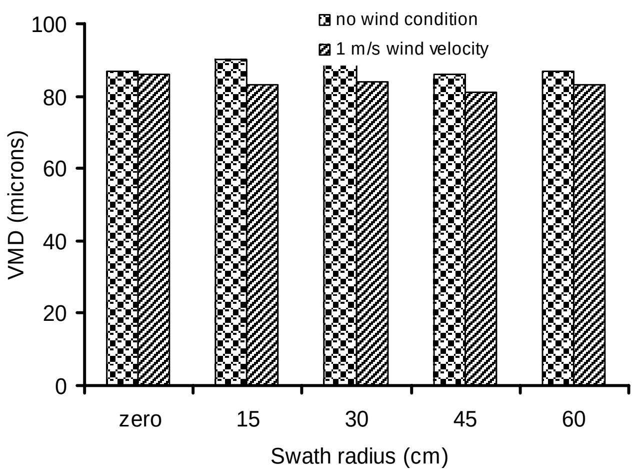

Figure 4a. Effect of wind velocity on VMD (µm) with orange nozzle at 9 volts over 60 cm swath radius.

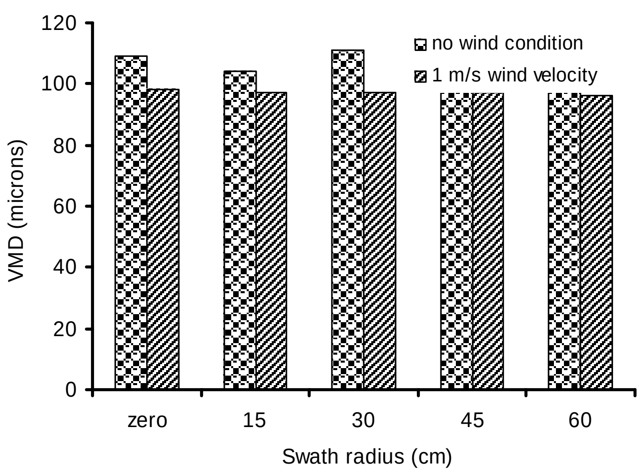

Figure 4b. Effect of wind velocity on VMD (µm) with black nozzle at 9 volts over 60 cm swath radius.

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