

# Design and Evaluation of an Electrically Operated Ultra–Low Volume Sprayer.

John O. Awulu, Ph.D.<sup>1\*</sup>; Jonathan A. Enokela, Ph.D.<sup>2</sup>; and Danladi D. Shatalis, B.Eng.<sup>1</sup>

<sup>1</sup>Department of Agricultural and Environmental Engineering, University of Agriculture, PMB 2373, Makurdi, Nigeria.

<sup>2</sup>Department of Electrical Engineering, University of Agriculture, PMB 2373, Makurdi, Nigeria.

E-mail: [jawulu@yahoo.com](mailto:jawulu@yahoo.com)\*

## ABSTRACT

A ten-liter ultra-low volume (ULV) sprayer was developed using locally available materials and its performance was tested. The machine was developed so as to minimize costs. The major components include the tank, spray head, battery case and extension pipe, delivery tube, and the strap (belt). The spray head is powered by 5 dry cell batteries which generate 7.5 Volts to actuate the electric motor for spinning the atomizer. Laboratory and field tests were carried out to determine flow and application rates. The laboratory test was conducted using basic hydraulic principles while the application rate was investigated by effective use of the walking speed. The results showed that the machine has average swath width of 1.5m, application rate of 30l/ha, and flow rate of 201ml/min. The results from the laboratory test indicated that flow rate increased with increasing liquid head and vice-versa. The application of this machine will uplift the agricultural mechanization status of crop husbandry practice by removing drudgery associated with the to and fro movements of arms in the use of the conventional knapsack. The convenience and ease with which the machine can be put to use will make it suitable for both rural and large scale farmers.

(Keywords: electric ultra-low volume sprayer, agricultural mechanization)

## INTRODUCTION

Agricultural plants are exposed to various degrees of danger during the stages of planting, germination, and maturing to full development for harvesting and storage. There is the danger that the plant may be lost at several stages of its growth as a result of damage from birds, weeds, diseases, and other factors. This danger

continues even when the crop has been harvested and stored. In modern agriculture there is a growing concern to control plant disease, insects, and weeds for qualitative and quantitative yield of agricultural products [2]. It has been observed that in developing countries, especially in Nigeria, there has been an increasing application of science and technology to farming [3], [11]. One area of this application is in crop spraying which has also been used in traditional farming system [7].

Traditionally sprays were done by dipping brooms or leaves into diluted (water added) chemicals in a basin or any open container and sprinkling on the target area [5]. This method is time consuming and less effective. The necessity of developing a modern sprayer that will overcome the deficiencies of the traditional system but yet culturally acceptable to farmers has been stressed [10]. Researchers and developers of spraying machines reported that frequent changing of parts, extensive training and re-training of local farmers, and costs of some sprayers, have defeated their earlier efforts [8].

A device using much smaller quantities of spray liquid called ultra low volume (ULV) sprayers, was initially developed in the 1950s for use against desert locusts and is now the most efficient method [1]. This involves applying between 10-15 liters as total spray liquid volume per hectare. It is also called motorized sprayer [6]. Solo produces a line of pressure sprayers from 5 to 20 liters and motorized units in the 15 to 20 liters ranges. Each sprayer is designed for comfort, convenience and ease of use [10].

The most prevalent type of sprayer in Nigeria is the mechanical type that requires operators to continually move their hands in order to spray the liquid contained in the heavy knapsack placed on their backs. This easily causes fatigue among the

operators. Most homeowners, gardeners, and landscapers rely on one, two, and three-gallon compression sprayers and four-gallon knapsack sprayers for everyday applications [12]. Portability and convenience of use are the two features previously lacking in spraying equipment [13]. The electrically operated sprayer being considered will remove these significant disadvantages.

## OVERVIEW OF THE MACHINE

The main functional parts of the ULV sprayer developed include the backpack tank, tank screen, battery case, extension, and the spray head.

### Backpack Tank

This is a reservoir of spray mix with maximum capacity of 10 liters. It measures 220 mm height, 240mm length and 160mm breadth. Two holes are constructed; one on top of the tank (inlet) which has a diameter of 45mm, for refilling of the liquid and the other, the outlet (orifice) used for discharging the liquid is situated at the bottom and has a diameter of 5mm.

### Battery Case and Extension Tube

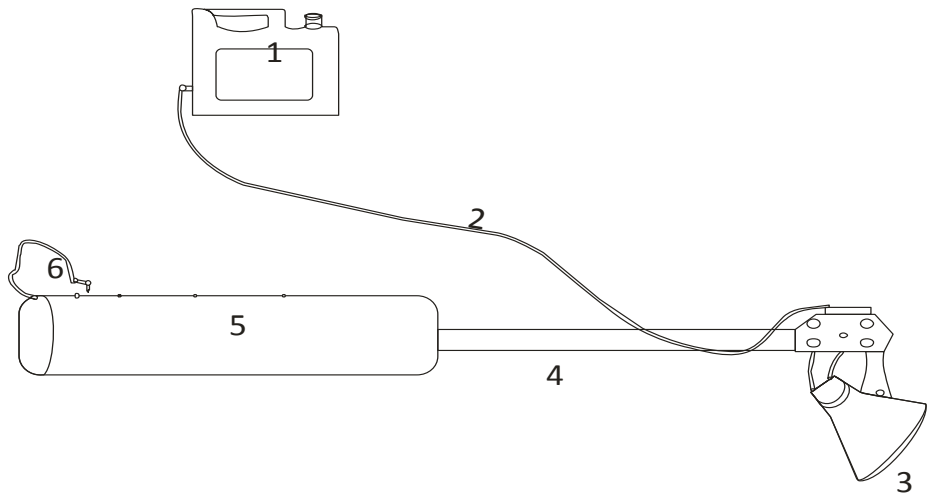
A cylindrically shaped object made of poly vinyl chloride (PVC) material for resistance to chemical attack and corrosion agents and measuring 607mm (length) by 40mm diameter is constructed to house the five dry cell batteries needed to power the motor. A 10mm x 10mm square tube with an effective length of 670mm is used to extend the reach of the machine.

### The Spray Head

This consists of an electric motor, a spinning disc (atomizer), and the nozzle. The motor used is a 7.5V DC type and when powered, actuates the spinning disc. The spinning disc (atomizer) is a plastic material of SAE with tensile strength of 46mpa. It is resistant to acid and alkali.

The assembly diagram of the machine is shown in Figure 1.

The spray liquid is fed by gravity through feed nozzle. As the liquid splashes on the disc it breaks into droplets at the serrated edges of the atomizer. The centrifugal force acting on the disc finally breaks the droplets into fine particles for disposition



1. Tank; 2. Delivery Tube; 3. Spray Head; 4. Extension Tube; 5. Battery Case; 6. Switch.

**Figure1:** Complete Assembly of the ULV Sprayer.

## DESIGN EQUATIONS

The basic hydraulic principles that influence the design of non-pressure (gravity-fed) sprayers are given by the following equations [4].

For a desired maximum discharge of spray mix,  $Q_{max}$ , in  $m^3/hr$  of a given liquid head (H) in the tank, in meters, the relationship is given as:

$$Q_{max} = a_0 c \sqrt{2gH} \quad (1)$$

In Equation (1)  $a_0$  = area of orifice ( $m^2$ ),  $c$  = overall head coefficient of discharge, and  $g$  = acceleration due to gravity ( $m^2/s$ ). Equation (1) gives the rate of flow and can also be expressed as:

$$Q_{max} = v \cdot a_0 \quad (2)$$

Where  $v$  is the velocity of the flow liquid ( $m/s$ ). The area of the orifice is expressed as:

$$a_0 = \frac{\pi d^2}{4} \quad (3)$$

Where  $d$  is the diameter of tank orifice.

For a given disc (atomizer) with radius  $r$ , its acceleration is given as:

$$a_{max} = w^2 r \quad (4)$$

$$\text{Where } w = \text{angular velocity} = \frac{2\pi N}{60} \quad (5)$$

$N$  is the speed of the motor in revolutions per minute.

The mechanical power requirement of the atomizer, in Watts, is thus given by:

$$P = \frac{2\pi N}{60} \times T \quad (6)$$

Where  $T$  = Torque developed by the motor.

This power requirement must be met by the batteries and requires that a small motor be used for this handheld ULV.

## MACHINE CONSTRUCTION AND EVALUATION

The various parts of the machine were fabricated and assembled as shown in Figure 1. The flow rate and application rate were then evaluated.

### EVALUATION OF FLOW RATE

The height of the spray tank (having a capacity of 10 liters) was measured and marked. A liter of chemical was diluted and the tank was filled up to the height. The tank was connected to the nozzle through a discharge hose of 10mm diameter. The tank was backpacked so that the liquid flow was by gravity through the nozzle. The discharged volume was collected in the conical flask in ml per minute. The procedure was repeated five times so that the varying liquid heads were also noted. The results are given in Table 1.

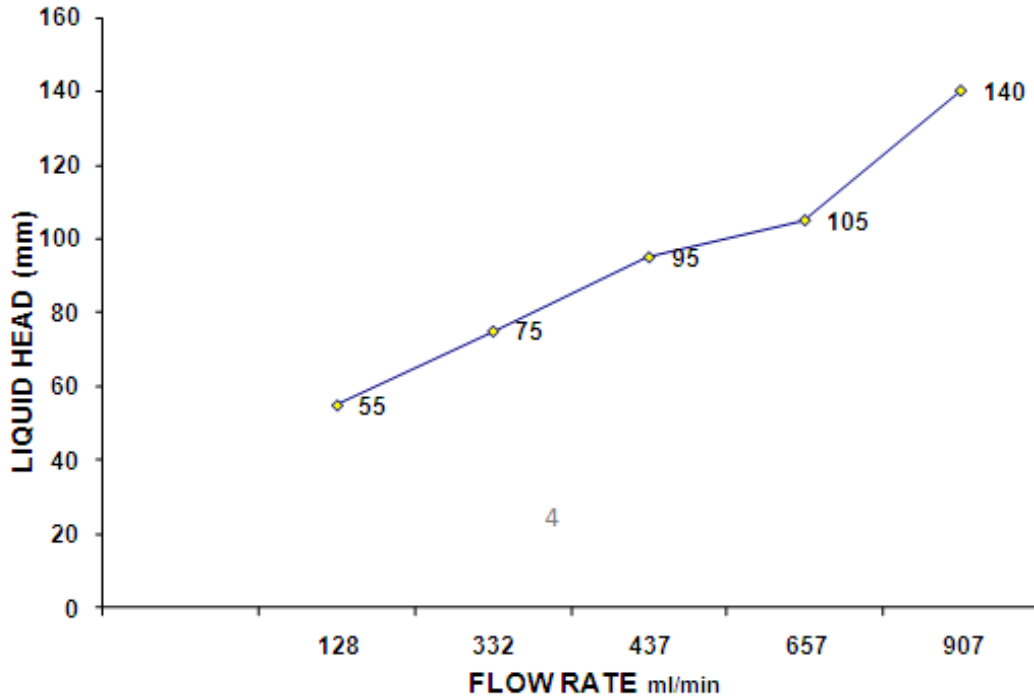
**Table 1:** Flow Rate to Liquid Head Variation.

Measurement No.	Liquid Head (mm)	Discharge Capacity (ml)	Calculated Flow Rate (ml/min)
1	140	250	250
2	115	220	220
3	95	215	215
4	75	194	194
5	55	128	128
Mean Flow Rate = 201 ml/min			

A graph showing the variation of liquid head with flow rate is given in Figure 2.

### EVALUATION OF APPLICATION RATE

The field test for application rate was carried out by measuring 10m X 10m of an open field. The tank (10-liter capacity) was filled up with liquid and the volume was marked. The tank was mounted on the back so that the liquid could flow by gravity into the spray head. The electrical power of the system was turned on and the operator walked at the pace of 1m per second through the field. The discharge volume in liters per minute was recorded. The procedure was carried out four times and the results are tabulated in Table 2.



**Figure 2:** Variation of Flow Rate with Liquid Head.

**Table 2:** Results of Application Rate Measurements.

Measurement No.	Discharge Capacity ml	Time taken in minutes	Discharge Rate l/(10mX10m)	Calibrated Application Rate l/ha
1	350	1.4	0.00350	35
2	286	1.3	0.00286	28
3	301	1.4	0.00301	30
4	291	1.5	0.00291	29
<b>Mean Application Rate = 30 l/ha</b>				

## DISCUSSIONS

The results of the measurements of the flow rate to liquid head variation are given in Table 1. These show that when the head was at 140mm the corresponding discharge capacity was 250ml and when the liquid head reduced to 55mm, the discharged volume dropped to 128ml indicating that the rate of flow is influenced by the liquid head. A similar experiment on flow rate using a wider nozzle diameter (2mm) was reported in [6] and the result showed that the flow rate was influenced by both the liquid head and the diameter of the nozzle.

Table 2 gives the results of the field test conducted to measure the application rate of the machine. It is observed from the table that 350ml (0.35l) was discharged into an area measuring  $10m \times 10m$  which gives an application rate of  $35l/ha$ .

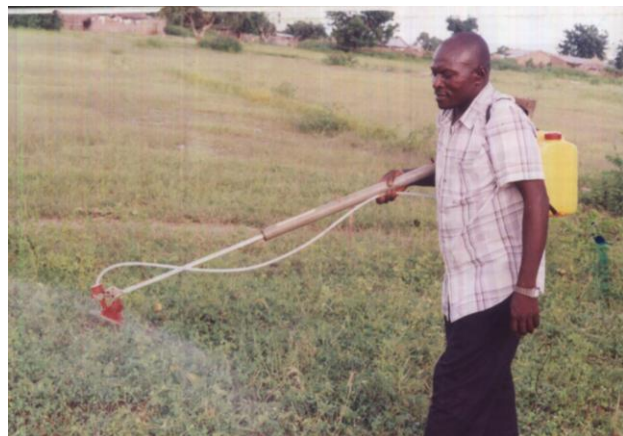
The other measurements showed variations from this value due to the fact that walking speed during the field test operation was not constant. This result is in agreement with the findings of [9] who reported that walking speed could alter the application rate of hand-held ULV sprayer if constant speed was not observed.

Figure 3 shows the machine being used in the field while Figure 4 shows the effectiveness of performance of the machine on weeds control using Glatex 500 EC herbicide chemical to water ratio of 1:30.

## CONCLUSION

A backpack ultra Low volume sprayer that is electrically operated has been developed. Laboratory and field tests show that the machine

has a flow rate of 201ml/min and an application rate of 30l/ha. The dependence of the machine on battery power for its operation makes it very portable. The battery can, however, power the machine for only 3 to 4 hours of continuous use.



**Figure 3:** ULV Being Used in the Field.



**Figure 4:** Effectiveness of the ULV Sprayer on Weed Control.

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## ABOUT THE AUTHORS

**Dr. John O. Awulu** is a Lecturer in the Department of Agricultural and Environmental Engineering at the Federal University of Agriculture, Makurdi, Nigeria. He specializes in farm power and machinery.

**Engr. Dr. Jonathan A. Enokela** lectures in the Department of Electrical/Electronic Engineering at the Federal University of Agriculture, Makurdi, Nigeria. He is a registered engineer with the Council for Regulation of Engineering in Nigeria

(COREN) and has a wide range of practical experiences. He is also a member of the IEEE.

**Mr. Danladi D. Shatalis** is an agricultural engineer employed with the government of Taraba State of Nigeria. He completed a postgraduate diploma program at the Department of Agricultural and Environmental Engineering at the Federal University of Agriculture, Makurdi, Nigeria in 2010.

#### **SUGGESTED CITATION**

Awulu, J.O, Enokela, J.A., and D.D. Shatalis. 2011. "Design and Evaluation of an Electrically Operated Ultra – Low Volume Sprayer". *Pacific Journal of Science and Technology*. 12(1):109-114.

 [Pacific Journal of Science and Technology](http://www.akamaiuniversity.us/PJST.htm)