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Evaluation of a Developed Electrically Operated Knapsack Sprayer

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ABSTRACT

An electrically operated knapsack sprayer of ten (10) liters capacity was developed using locally available materials and its performance evaluated. This device is developed to reduce the constant application of energy to throttle to regulate air pressure a problem in conventional knapsack sprayers. The major components include; tank, 12 volts electric water pump, 12 volts accumulator battery, strap (belt), delivery pipe and a sprayer handle together with lance and nozzle. Electric water pump that bended with the designed parameter was Mercedes Benz wind screen washer pump, powered by 12 volts, 2.5 amperes battery (motorcycle type). Laboratory and field tests were conducted to determine flow rate, application rate and distribution rate. Basic hydraulic principles were considered for determining flow rate, while application rate was determined by effective use of walking speed on field. The results showed that the sprayer has a flow rate of 531ml, application rate of 250 l/ha and a spray distribution area of 0.000675 m^2.The result from the laboratory test indicated that decrease in liquid head leads to decrease in flow rate and vice versa. Efficiency of spray decreased with decrease in voltage of battery and application rate is influenced by walking speed. The sprayer is capable of spraying 250 l/ha in 4.17 hrs at a walking speed of 0.7 m/s. This device cannot be operated continuously for more than 2 hrs due to decrease in voltage. It is advisable for extra batteries to be carried along to the farm for large hectare spraying.

Keywords: *Evaluation, Developed, Electrically & Knapsack Sprayer*

I. INTRODUCTION

The growing concern to control plant diseases, insects and weeds for qualitative yield of agricultural products is increasing speedily in developing countries especially Nigeria [2] and [3]. Crop spraying is employed for various varieties of purposes in traditional farming system. Traditionally, sprays were done by dipping broom, brushes or leaves into diluted (water added to chemicals) in a basin or any open container and sprinkling on the target area [4] and [1].

The traditional method is time consuming and less effective, and the conventional knapsack sprayers entail the use of hand to throttle or pump to generate pressure at intervals of spray. Therefore it becomes very necessary to develop sprayers that will overcome these deficiencies [5]. Many researchers and developers of spraying machine reported that, frequent changing of parts, training of local or rural farmers and the cost of some sprayers has defeated their earlier efforts [11].

[9] Produced a line of pressure sprayers from 5 to 20 liters and motorized units in 15 to 20 liters range. Each sprayer is designed for comfort, convenience and ease of use. The most prevalent type of knapsack 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. This easily causes fatigue on the operators back, shoulder and the muscles of the hand. Most home owners, gardeners and landscapers rely on one, two to four-gallons knapsack sprayers for everyday application.

Portability and convenience of use are two features previously lacking in spraying equipment. Earlier efforts at developing sprayers were made by many researchers such as [9], [11], [6], and [1]. These sprayers had varying performances. Some perform very excellently while others have limitations. This design is an improvement over the hand-held ULV sprayer designed by [11] and the Ultra-Low Volume (ULV) Sprayer developed by [1], as both operate by gravity which makes them ineffective in upward spraying. The objectives of this study are: To develop an electrically operated knapsack sprayer which will eliminate constant agitation and pumping to regulate air pressure in conventional knapsack and evaluate the performance of the developed sprayer.

II. MATERIALS AND METHODS

The main functional parts of the machine include, the backpack, 10 liters tank, 12volts battery, 12volts electrically operated water pump (Mercedes Benz wind screen washer pump), Extension, battery case, filter and sprayer handle with lance and nozzle. Backpack tank is a reservoir of spray mix with maximum capacity of 10 liters. The top opening with a cover is for filling and refilling of liquid. An outlet orifice constructed at the extreme bottom of the tank for discharge of liquid as shown in Fig. 1.

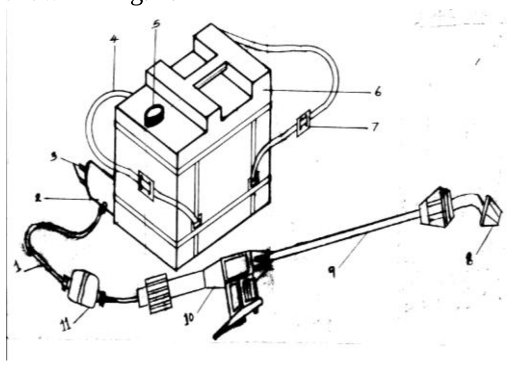

Figure 1: Assembly of Electrically operated knapsack sprayer

Note. 1 delivery tube, 2 Electrical pump, 3 Pump terminals, 4 Belt 5 Tank cover, 6 Tank, 7 Belt slide, 8 Nozzle, 9 Lance, 10 Handle and 11 Filter.

Design Calculations of Pump

Determination of Flow rate [7].

$$Q = AV \qquad (1)$$

From continuity consideration,

$$Q = AV = av \qquad (2)$$

Where, Q = Flow rate or discharge, A = Area of cross-section of pipe, V = Velocity of flow in pipe, a = Area of the nozzle outlet, v = Velocity of flow at the nozzle outlet, D = Diameter of pipe and d = diameter of the nozzle

Determination of static head, H_{stat} [8].

$$H_{stat} = hs + hd \qquad (3)$$

Where, H_{stat} = Static head, hs = Static suction head, and hd = Static delivery head

Determination of velocity head, Vh [7].

$$Vh = \frac{V^2 s}{2g} + \frac{V^2 d}{2g} \qquad (4)$$

Where, $\frac{V^2 s}{2g}$ = Velocity in suction head and

$\frac{V^2 d}{2g}$ = Velocity in delivery head

Determination of friction head, hf [7].

$$hf = \frac{4 fLV^2}{D \times 2g} \qquad (5)$$

Where, hf = Head lost in the pipe, f = Co-efficient of friction for the pipe, L = Length of the pipe, V = Velocity of flow in the pipe and g = Acceleration due to gravity

Total Pump head, H [7].

$$H_t = H_{stat} + H_f + \frac{V^2 d}{2g} \qquad (6)$$

Where, H_t = Total head

Pump Pressure,

$$P = \frac{F}{A} \qquad (7)$$

Where, P = Pressure, F = Force and A = Cross-sectional area of tank

$$A = \frac{\pi d^2}{4} \qquad (8)$$

But, $P = WH$ [7].

Where, W= Specific weight of liquid and H = Pump total head

Selection of Pump

The efficiency and stability of available automobile manufactured pumps were compared with the designed parameters and the Mercedes Benz windscreen washer pump was selected as the most appropriate for this design for the following reasons:

- Delivers a moderate pressure of liquid similar to standard pressure of the designed knapsack sprayers.
- Takes longer time in operation before running down the battery.
- Portability (lighter in weight)
- Easy installation and less cost.

Power Source

The performance and capacity of two available batteries (A 12volts, 2.5A Motorcycle battery and 8 dry cells batteries which is equivalent to 12volts) were compared and the motorcycle accumulator battery of 12 volts, 2.5A was selected based on durability and chargeability.
The voltage was computed using equation 8

$$V = IR \qquad (8)$$

Where, V = Voltage (v), I = Current (A) and R = Resistance (Ω).Current and resistance can be derived from equation (8)

Determination of flow rate: (laboratory test)

A conical flask was used for collecting the volume of liquid discharged into it in ml per minute. A measuring cylinder was used together with the conical flask for accurate measurement of the discharged liquid. A digital time (stop watch) was used for the timing and the result recorded. The procedure was repeated four (4) times and the varying liquid heads were noted. The mean flow rate was calculated and presented in a tabular form.

Determination of Application rate: (Field test)

A 10 liter capacity tank was filled up with a liquid and the volume marked. The tank was mounted at the back. The

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electrical system was switched "on" and the liquid was sprayed using the pressuring of the pump. The effective performance of the developed electrically operated knapsack sprayer was determined by practical trials on the field. The field test was an open field measuring 4 m by 25 m. The operator walked within a space of 0.7 m per second through the test field. The discharged volume in liters per minute was recorded. The procedure was replicated four (4) times and the mean value determined.

Determination of Spray distribution: (Area covered)

Nozzle test for spray distribution was carried out using a white card board paper. A liter of water mixed with black ink was poured into the tank. The nozzle was positioned to direct its spray on to the card board paper and sprayed upon it. The area covered with droplets of liquid on the paper was marked, measured and computed using calculation of area of circle.

Calibration of Sprayer

$$\text{Area of test plot} = \text{Length x breath} \ldots \ldots \quad 10$$

$$\text{Area Rate of Sprayer} = \frac{\text{Area of Test Plot (ha)}}{\text{Time taken (hr)}} \ldots \quad .11$$

$$\text{Volume Rate} = \frac{\text{Volume collected (L)}}{\text{Time (hr)}} \ldots \ldots \ldots \ldots \quad 12$$

$$\text{Application Rate} = \frac{\text{Volume rate (L)}}{\text{Area rate (m)}} \ldots 13$$

III. RESULTS & DISCUSSIONS

Table 2 represents the flow rate to liquid head variation. These shows that when the head was at 215 mm, the corresponding discharge capacity was 546 ml and when the liquid head reduced to 170 mm, the discharged volume drop to 516 ml indicating that the rate of flow is influenced by the liquid head. This is in agreement with the findings of [11]. Similar experiment on flow rate using wider nozzle diameter was reported and the result showed that the flow rate was influenced by both the liquid head and the diameter of nozzle [1]. This was further collaborated by liquid head Vs flow rate graph Fig. 2 which indicated that flow rate increase with increase in liquid head.

Table 2: Result of Sprayer Flow Rate

Replications	Liquid head (mm)	Discharge capacity rate (ml)	Calibrated flow (ml/min)
1	215	546	546
2	200	536	536
3	185	527	527
4	170	516	516
Mean flow rate = 531ml/min			

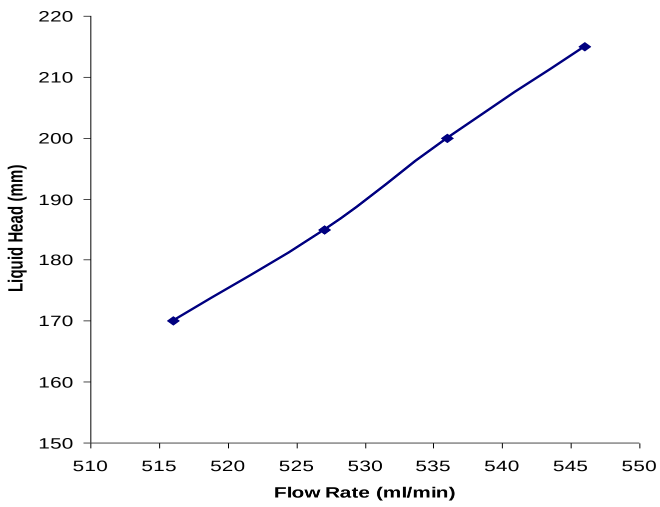

Fig. 2: Liquid Head Vs Flow Rate Graph

Table 3 indicated that the mean discharge volume is 2.5 liters; mean time taken to spray 100m^2 was 150sec. discharge rate per second was 0.0167 L/sec. The equivalent hectare coverage of this device was 250 liters per hectare. This result has higher value of liquid application over the previous ULV developed by [1]. Reason being that [1] has a fine spray pattern. There was variation in the discharge capacity recorded due to lack of constant walking speed during the field test operation. This result is in agreement with the findings of [11], [6], and [1] who reported that walking speed was responsible for altering application rate of sprayers, when constant speed was not maintained.

Table 3: Field Test (Application Rate)

Replications	Discharge Volume(l) *(a)*	Time Taken (sec) *(b)*	Discharge rate(l/sec) *(a/b)*	Area rate covered (m^2/sec)	Application Rate (l/ha)
1	2.4	144	0.0167	0.69	240
2	2.7	162	0.0167	0.62	270
3	2.4	144	0.0167	0.69	240
4	2.5	150	0.0167	0.67	250
Mean	2.5	150	0.0167	0.67	250

Table 4 is the result of spray distribution (area covered). The result showed that an average spray droplets distribution can cover an area of 0.000675m^2. Figure 3 shows the pictorial presentation of practical exercise carried out while figure 4 is a picture showing the effectiveness of application rate performance of the device on weeds control before and after application using Mulsate Glyphosate chemical to water ratio of 1:30.

Table 4: Spray Distribution (Area covered)

Repli cations	Dia. covered (mm)	Radius (mm)	Area (m^2)
1	30	15	0.000707
2	32	16	0.000804
3	28	14	0.000616
4	27	13.5	0.000573
Mean	**29**	**15**	**0.000675**

Fig.3: Field Evaluation of Sprayer to measure Application Rate

Fig.4: Effectiveness of the Sprayer after Spray

IV. CONCLUSION

This research project can be concluded that the spray efficiency decreased with decrease in voltage of the battery. The device has a flow rate of 531ml, the application rate of 250 l/ha and a spray distribution area of 0.000675 m^2. Increase in liquid head leads to increase in flow rate. Application rate is influenced by walking speed. The sprayer is capable of spraying 250 l/ha in 4.17 hours at a walking speed of 0.7 m/s. This device cannot be operated continuously for more than 2 hours. It is recommended to carry along extra batteries to the farm for large hectare spraying.

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