PERFORMANCE EVALUATION AND MODIFICATION OF KNAPSACK SPRAYER

BY

ABDULLAHI, ABUBAKAR
(MATRIC NO. 96/5037EA)

DEPARTMENT OF AGRICULTURAL ENGINEERING
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BEING A FINAL YEAR PROJECT IN PARTIAL FULFILMENT FOR THE AWARD OF BARCHELOR OF ENGINEERING (B.ENG.) AGRICULTURAL ENGINEERING

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DEDICATION

This write-up is dedicated to my parents, Alhaji Abdullahi Usman and Hajiya Aisha Abdullahi for their support and highly above all, their upbringing in a culture accepted as norm by most, which helped immensely in my struggle to the present status and shall be of more future; Alhaji halilu Shaba, Alhaji Abdul-Rahman Gara, Alhaji Muhammad Bello and Alhaji Magaji (Kawu Gado) for they all are, the family I have.

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ABSTRACT

The performance evaluation and modification of knapsack sprayer is aimed at looking into the existing knapsack sprayer improving its system, working condition and maintenance practices. This work employ the use of diaphragm connected to the pressure chamber to ensure high pressure at the trigger head for spraying. The sprayer was constructed, tested and found to be effective (i.e. efficiency of about 60% compared to that of the existing sprayer about 50%).

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CHAPTER ONE

1.0 INTRODUCTION

1.1.1 Background:

Insecticide means 'insect killer'. Although the name seems to suggest that only insects are killed, in reality this is not so. Insecticides are chemicals that affect the biological process of many living species. It is this property of insecticides that is utilized in killing insects and other pests. Broadly, insecticides are chemicals used to combat pests. Many of the problems encountered during crop protection are now known and control measures are available at different stages of their growth and during storage. There are various equipment available for applying chemicals during these control measures.

The chemicals are formulated as solutions, emulsions, wettable powders, granular materials and as dusts. It may be applied broadcast, in narrow bands, as individual spot treatment or directed to a particular part of the plant. The quantity of the chemical may be varied from a few drops to several thousand pounds per acre. Obviously, to provide uniform coverage, special equipment is needed. Emulsions, solutions and wettable powders are usually applied as sprays. Water or oil is the usual diluents or carrier. Granular materials are spread by hand, or by special mechanical spreaders like those used in broadcasting seed or fertilizer. Dusts are applied dry, by hand, dust guns, or by powered equipment.

1.1.2 Characterisatics of crop protection equipments:

Crop protection equipment has to be able to cope with a wide variety of conditions, each requiring different control measures. For instance, control equipment designed to deal with pests may be required to deal with any of one or a combination of the following;

1- Insects, which may be flying around the crop or hidden in them (within the leaves or flowers or in the root zones).
2- Fungi;
3- Bacteria and viruses;
4- Mammals such as monkeys, bats e.t.c.
5- Birds (practically all types).

Also, the plant requiring protection may be of many forms. For instance;

1- Low-growing crops like groundnut and cowpeas.
2- Tall-growing crops like sorghum, millet and sugar cane.
3- Tree crops grown in orchids like citrus and palm.
4- Mixed crops with low-growing and tall growing plants together, like groundnut intercropped with sorghum.

The targets for the protective measure (insect or unwanted plants) also respond differently to treatment. For example, chemicals that need to be ingested (stomach poison) by relative immobile insects should be applied so that they completely cover the plant. For insects that move actively, like caterpillars, the requirement for complete coverage is not so great as these insects that move, come in contact with the chemical.

Systematic pesticides are chemicals that can be applied to any part of a plant, are absorbed and translocated to most parts of the plant.

1.1.3 Equipments of chemical control.

The following are the equipment used for chemical control;

1. Duster: - for dry powder carried by air.
2. Mist blower: - for both air and liquid carried.
3. Sprayer: - for liquid carried chemical.

1.1.4 Sprayers

Sprayers rely on liquid as carrier (water and oil). Generally, the chemical when mixed can form one of the following;

a- Solution: - In which chemical (whether originally powder or fluid) is completely dissolved when mixed.

b- Suspension: - In which the chemical remains floating and needs agitation.

c- An emulsion: - In which the chemical disperses in the water but does not actually dissolve.

1.1.5 Sprayer component

The essential components of a knapsack sprayer include:-

Tank, nozzle, pump, pipe or hose, filter, cover, and handle.

1.2. AIMS AND OBJECTIVES.

1.2.1. Aims of the project:

This work is aimed at the evaluation of performance and modification of a knapsack sprayer.

1.2.2. Objectives of the project.

1- To eliminate the complications involved in the design, fabrication and maintenance of knapsack sprayer (i.e. by simplifying its mechanisms).

2- To remove the inefficiency that increase with usage due to wear at the moving components.

3- To make available a sprayer made of relatively light weight (mass) material.

4- To give the farmers of low income, an economically better alternative.

1.3 SCOPE AND LIMITATION.

This work shall only cover manually operated called knapsack sprayer that shall employ a diaphragm.

CHAPTER TWO.

2.0 LITERATURE REVIEW.

As long as life continues to improve always exist side by side with it, all in the effort of making life more comfortable. From inception, when no protections were offered to crops, when man just harvested and eat food without really farming to the period when man began to see it necessary to plant crops and protect it from weed attack through various primitive ways from weed pulling out, weeding through use of hand implements to the present stage of the use of sophisticated methods employed to protect the crop.

The earliest uses of Agro-chemicals in Europe, seed soaking treatments with coper sulphate and lime for bunt control on wheat, required no more than a large steeping tank for their application. Method of spraying pest control chemicals to field crops were first needed in the middle of the nineteenth century to apply sulphur dust to vineyards for powdery mildew. The earlier form of dusting machine consisted of a pair of bellows to blow clouds of sulphur dust onto the plants.

Millardest's first suggestion for applying Bordeaux mixture was to walk between the vine rows with a bucket in one hand and switch of leather in the other, flickering mixture to the right and left.

The first pressure sprayers to be used to apply Agro-chemicals were garden syringes, which drew chemical solutions from buckets. These were clearly impracticable for spraying large areas of crops. Strong insecticides to develop better techniques and equipment came from French vineyard owners who were trying to combat downy mildew. Invention was also actively encouraged by the French regional Agricultural societies who organized competition with prizes for the best and most easily used machines (Large, 1940).

One of the first field-scale sprayers invented by Armand Cazenove of La Re-ole, had a handle driven revolving brush operated through a train of gear wheels. The brush was fed with spay mixture from a portable copper tank to which it was attached. As the hand was turned a stirrer went round in the tank, the brush revolved in its trough and a scraper pressed against the bristles flicking off a fine spray.

Other implement makers, village blacksmiths and brass workers, invented other types of sprayers most of which were essentially prototype of the modern knapsack and hydraulic pressure sprayers. They consisted of a brass or copper tank, a hand operated pump, a length of rubber tube running from the tank and a spray lance fitted with a spray nozzle. Some of the best early models came from a brass worker called 'Vermorel' of Villefranche whose products soon became known worldwide. His highly successful knapsack sprayer had the advantage of excellent nozzle design and a diaphragm pump, which meant, no moving piston parts were in contact with the Bordeaux mixture. There was very little to go wrong.. Vermorel's sprayer was developed further in the U.S.A.where, by the late 1880's; C.V. Riley had produced a sprayer called the 'Eureka', using a new cyclone jet.

As the use of Bordeaux mixture expanded from vines onto potatoes (for potato blight control) in 1880's, larger hydraulic pressure sprayers produced which could be pulled through the fields by horses. Horse-drawn sprayers were also developed in the U.S.A. for use in orchards. It is estimated that between 1887 and 1892 the number of fruit tree spraying machines in U.S.A. rose from about 50 to 50,000.

In recent years, there have been significant advances in the field of electrostatic spraying (Law, 1980; Arnold and Pye,1980; coffee,1979): these have been accompanied by a greater use of lasers and computers to measure spray droplets (Arnold, 1980; Perkin et al, 1980). More complex electronic equipment is now available to monitor and control application of pesticides (Allan,1980) and the use of controlled droplet application with tractor-mounted spinning-disc sprayers has increased.

Syringes: - There are various types of simple syringe type sprayers in which liquid is drawn from a reservoir into a pump cylinder by pulling out the plunger; the liquid is then forced out through a nozzle on the compression sprayer. A small syringe-type sprayer is useful for spot treatment, for example, striga can be killed in maize, using 20g/ha of ametryne solution, applying 1ml as a coarse spray to an area of 25cm diameter (Ogborn,1972).They are also used to inject systemic insecticides into holes previously bored into trees.

Stirrup pump: - Another version of the double-acting pump is the bucket or stirrup pump. Two operators are normally required. One to work the pump while the other directs the nozzle. The lower end of the pump is immersed in the spray liquid in a bucket.

The pump, which sometimes has a solid piston plunger, is steadied by a footrest or stirrup on the ground next to the bucket. Ideally, the position of the stirrup can be adjusted to allow buckets of different depths to be used. Agitation is seldom provided, but on some sprayers there is a paddle agitator in the bucket, which may cause splashing when the bucket is nearly empty. Agitation is also possible by recycling some of the liquid through a nozzle mounted at the lower part of the pump.

The outlet of the pump is near the top and is connected to a hose. Usually 6m in length, with a lance and any type of hydraulic nozzle. Longer hoses are difficult to handle. Spraying is continuous because an air chamber is incorporated in the spray line, and on some models pressures up to 10 bar can be obtained fairly easily.

Knapsack sprayers-Lever-operated: - One of the most widely used small sprayers is the lever-operated knapsack sprayer. The design of which has changed very little since they were first manufactured for the application of fungicides in vineyards in the late nineteenth century (Lodeman, 1886; Galloway, 1891).

A lever-operated sprayer consist of a tank which will stand erect on the ground and when in use, fit comfortably on the operator's back like a knapsack, a hand operated pump, a pressure chamber, and a lance with on/off tap or trigger valve and one or more nozzles.

Stretcher sprayer: - Have heavy piston pumps, which are operated by hand by a rocking motion of a long handle. Some pumps are operated by foot pedal. The pump incorporates a very strong pressure chamber and pressure up to 10bar or more can be obtained. They are designed for operation in one position with one or more hoses up to about 14m in length and lances to which various hydraulic nozzles are fitted. A separate container is needed and has to be carried separately from the pump. Two people are needed to carry the pump and operate it, while two or more others are needed to handle the lances. Stretcher sprayers are rather awkward to carry, but have been most useful for spraying large or tall trees or widely spaced bush crops. Similar sprayers are sometimes mounted on a wheelbarrow frame, together with a spray tank.

Compression sprayers: - Also refer to as pneumatic sprayers, have an air pump to pressurize the spray tank. The tank is never completely filled with liquid. A space is needed above the liquid so that air can be pumped in to create pressure to maintain the flow of liquid to the nozzle. Usually, a mark on the side of the tank indicates the maximum capacity of liquid at about two-thirds of the total capacity. These sprayers vary in size from the small hand sprayers, suitable for limited use by gardeners, to large knapsack sprayers usually of 10ltre capacity and are used for spraying a wide range of pesticides. As no agitation is provided, these sprayers need to be shaken occasionally if using wettable powder formulations to prevent the suspension settling out.

Hand sprayers: - Have small tank usually made of plastic and 0.5 – 3 liters capacity is pressurized by a plunger-type pump to a pressure of up to 1bar. Often a cone nozzle, the pattern of which can sometimes be adjusted, is fitted to a short delivery tube. The on/off valve is sometimes a trigger incorporated into the handle. They are useful for spraying very small areas, where it is inconvenient to pump continuously.

Knapsack or shoulder-slung compression sprayers: - There are two types; the ordinary and pressure-retaining types. The pressure-retaining type is used extensively on tea estates and tsetse-fly control operators in groups of five or six sprayers operated from a central point, sometimes equipped with a motorized pump unit (Davies and Blasdale, 1960).

The management of support staff and vehicles in a large-scale tsetse-fly control programme with ground equipment was described by Wooff (1964). Because of the high pressure at which these sprayers are operated, the tank had to be very soundly constructed and subjected to a hydraulic pressure test at frequent and regular intervals.

As these sprayers are very expensive, their use has declined except in Colombia where they are used to treat coffee. On the other hand, there area large number of compression sprayers in which the air pressure is released before refilling the tank with liquid.

In China, handymist sprayer, a lever-operated sprayer with an air pump has been designed by Tu Y.Q. (1990). The sprayer is essentially a compression sprayer but in addition to pressurizing the liquid, some of the air is fed to a single twin-fluid nozzle. The manually operated sprayer provides an expensive means of applying a very low volume mist sprayer and has been used to spray insecticides on rice and cotton.

Air-assisted field crop boom sprayers: - Several attempts have been made to reduce the proportion of dównwind spray drift. The boom was covered (Edwards and Ripper,1953) or its design modified with an aerofoil so that with forward movement of the sprayer (8 – 12km/h) air was directed downwards to reduce trailing vortices behind nozzles (Jegathecswaran, 1978; Goehlich,1979; Lake et al, 1982; Rogers and Ford, 1985).

Unfortunately, at the higher forward speeds at which the aerofoil performance is improved, there are problems of controlling the spray output while accelerating and slowing down at the field edges.

More recently, a work was done on the knapsack sprayer relocating the internally placed pump externally (Ozue, 2001).

CHAPTER THREE

3.0 MATERIAL AND METHOD

3.1 DESIGN CONSIDERATION AND MATERIAL SELECTION

The aim of any engineering practice which include design, is to obtain optimum output (efficiency) while minimizing the input (resources e.g. labour). In minimizing the input, the cost of production is minimized. Other factors considered in the design of a machine include the choice of suitable material and its availability. The selection of material is dependent on the material availability, durability, workability and economic justification among others.

Aluminum is the best material but others like stainless steel, grey cast iron plastic and brass can be used. But galvanized mild steel was chosen here for its availability, durability,low mass (weight) and economic justification. This may be coated by painting through. However, for mass production, it may be economically justied to use aluminum and other materials mentioned earlier.

The basic features of knapsack sprayer from design point of view include: - Tank, Pumping device, valve, handle, hose, nozzle, strainer or filter and trigger.

The above features are discussed below:

1. Tank: - The rectangular tank made of 0.6mm thick galvanized mild steel, has two openings at the top for input of spray material and the other at the bottom for the exit of spray material.
2. Pump Chamber (system): -Made up of a diaphragm and a cylindrical reservoir. The diaphragm is installed at the bottom opening of the tank.

The diaphragm made to have openings for inlet from the tank and outlet to the reservoir, both inlet and outlet controlled by a non-return valves each. The diaphragm is connected at the base, to the sprayer handle, which pull (expand) and compress the diaphragm to achieve section from the tank and release to the reservoir respectively. The reservoir stores and build-up pressure as more spray material flow-in.

3. Valves: - The non-return valve used is one-way biased to allow movement in only one desired direction, ensure high pressure and control of fluid.

4. Handle: - Transmits energy through oscillatory motion from the power source (man) through the shaft to the pumping chamber.

5. Hose: - A rubber tube, connects the pumping unit to the lance for the delivery of spray substance.

6. Nozzles: - A device which ensures uniformity of the spray substance in droplet size.

7. Filter or strainer: - A screen of separating device placed at the outlet of the tank to protect the pump and either in the hose or fitted directly into the nozzle body. A mesh size of 50 $inch^{-1}$ (300^2/m) is typically used. A coarse or funnel strainer is also desirable to filter the spray substance as the sprayer tank is filled.

3.2 DESIGN CALCULATION

3.2.1 Volume Of The Tank (Capacity)

The volume of the tank is given by:

$V = Lbh$ ----------(1)

Where L – length of the tank.

b – breadth of the tank

h – height of the tank.

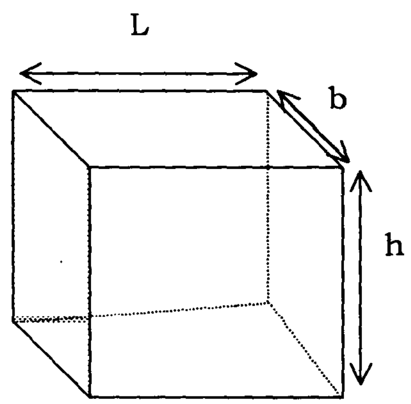

Fig. 1 Tank.

The tank is required to be 15 liters capacity. So, the total volume V = 15 liters = $0.015m^3$

from equation 1

i.e. $v = Lbh$

$V = 0.015m^3$ (standard)

$L = 0.29m$ (assumed)

$b = 0.15$ m (assumed)

$h = ?$

Substitute in equation 1

$=\quad 0.015 = 0.29 \times 0.15h$

$h = 0.3448m$

$= 0.345m$

3.2.2 Design of the Pump Cylinder

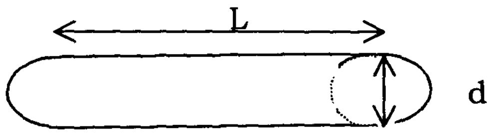

Fig. 2 pressure cylinder

The internal diameter of cylinder, $d_1 = 70mm$

The external diameter of cylinder, $d_2 = d_1 + 5mm$

The internal radius of the cylinder $r_1 = 35mm$

The external radius of the cylinder $r_2 = 37.5mm$

But Area, $A = \pi rh$

$= \pi(0.035)(0.15)$

$= 0.0165m^2$

The force produced at the pump is given by

$F = P.A.......(2)$

Where $P = 7 \times 10^5 \ N/m^2$ (Assumed)

$\therefore F = 7 \times 10^5 \times 0.0165$

$= 11545.4 \ N$

The maximum radial stress is given by

$$\sigma_r \max = \frac{r_1^2 p}{r_2^2 - r_1^2} - \frac{r_1^2 r_2^2 p}{r_2^2 - r_1^2} \times \frac{1}{r^2} \quad ....(3)$$

But $r_1 = r$

∴

$$\sigma_r \max = \frac{(0.035)^2 \times 7 \times 10^5}{(0.0375)^2 - (0.035)^2} - \frac{(0.035)^2 (0.0375)^2 (7 \times 10^5)}{(0.0375)^2 - (0.035)^2} \times \frac{1}{(0.035)^2}$$

$$= \frac{857.5}{1.8125 \times 10^{-4}} - \frac{1.723 \times 10^{-6}}{1.8125 \times 10^{-4}} \times 816.33$$

$$= 3.86 \times 10^9 \text{ N/M}^2$$

The maximum tangential stress is given by

$$\sigma_r \max = \frac{r_1^2 p}{r_2^2 - r_1^2} + \frac{r_1^2 r_2^2 p}{r_2^2 - r_1^2} \times \frac{1}{r^2} \quad ....(4)$$

But $r_1^2 = r^2$

$$= \frac{(0.035)^2 (7 \times 10^5)}{(0.0375)^2 - (0.035)^2} + \frac{(0.035)^2 (0.0375)^2}{(0.0375)^2 - (0.035)^2} \times \frac{1}{(0.035)^2}$$

$$= 3.86 \times 10^9 \text{ N/M}^2$$

The maximum axial stress is given by

$$\sigma_z \max = \frac{1}{\pi} \frac{F}{r_2^2 - r_1^2} \quad ....(5)$$

$$= \frac{1}{\pi} \times \frac{11545.4}{(0.0375)^2 - (0.035)^2}$$

$$= \frac{1}{\pi} \times \frac{11545.4}{1.41 \times 10^{-3} - 1.225 \times 10^{-3}}$$

$$= 2.03 \times 10^7 \text{ N/m}^2.$$

From Von mises theory

Failure will occur when

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2\,(\sigma_{yp})^2 \quad ......(6)$$

So failure will not occur.

Let

$\sigma_t \max = \sigma_1$

$\sigma_z \max = \sigma_2$

$\sigma_r \max = \sigma_3$

σ_{yp} = 280 Mpa = yield strength of steel (mark's standard hand book, 1987)

$= 1.47 \times 10^{19} + 1.47 \times 10^{19} + 0 = 2(280 \times 10^6) = 5.60 \times 10^6$

Since $2.94 \times 10^{19} > 5.60 \times 10^8$

$\therefore (\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 > 2\,(\sigma_{yp})^2$

So failure will not occur.

3.2.3 Determination of Velocity In The Hose

From Bernoulli's equation taking note of friction losses,

$$\frac{P}{\rho g} + \frac{U_1^2}{2g} + z_1 = \frac{P_{atm}}{\rho g} + \frac{U_2^2}{2g} + z_2 + h_{fr} \quad \ldots\ldots\ldots\ldots (7)$$

Since the pump cylinder is horizontally placed, Z_1 and Z_2 all considered to be equal to Zero.

i.e. $Z_1 = Z_2 = 0$

$$= \quad \frac{P}{\rho g} + \frac{U_1^2}{2g} = \frac{P_{atm}}{\rho g} + \frac{U_2^2}{2g} + h_{fr} \ldots\ldots\ldots (8)$$

where $h_{fr} = \frac{4F}{d} \cdot \frac{U^2}{2g}$ (Darcy) .... (9)

Substitute equation (9) in (8)

$$= \quad \frac{P}{\rho g} + \frac{U_1^2}{2g} = \frac{P_{atm}}{\rho g} + \frac{U_2^2}{2g} + \frac{4f}{d} - \frac{U^2}{2g} \ldots\ldots\ldots (10)$$

$$= \quad \frac{P}{\rho g} - \frac{P_{atm}}{\rho g} = \frac{U_2^2}{2g} - \frac{U_1^2}{2g} + \frac{4f}{d} - \frac{U^2}{2g} \ldots\ldots\ldots (11)$$

Where

$f = 0.08$ = friction factor.

$g = 9.8/m/s$. (acceleration due to gravity).

d = diameter of hose (standard).

$\rho = 1000\ kg/m^2$ (density of water).

$$U_2^2\left(\frac{1}{2x9.81} + \frac{4 \times 0.08}{0.012 \times 2 \times 9.81}\right) = \frac{7 \times 10^5}{1000 \times 9.81}$$

$$U_2^2 = \frac{71.36}{2.09}$$

$$U_2^2 = 34.14$$

$$U_2 = 5.84\ m/s.$$

3.3 Mode of Operation of the Sprayer

As illustrated in the drawing, the sprayer is normally operated through the handle which expands the diaphragm to suck from the tank via the inlet non-return valve while the outlet valve remain closed and the diaphragm contracts to pump out its content through the outlet non-return valve while the inlet remain closed. The spray material is moved from the diaphragm outlet to the pressure chamber, to the hose and finally to the trigger from where it is expelled to the target.

3.4 Routine Maintenance

1. The nozzle should be raised with clean water and never cleaned with wire or any other material.

2. When changing from one chemical to another, the tank should be drained and washed twice with clean water and detergent (about 1 kg in 45 liters of water). All filters should also be rinsed properly.

3. Concentrated chemicals should not be put into an empty tank but be preceded with water.

4. When not in use, nozzles should be removed and stored separately, after thorough rinsing. The belts should be loosened (to ease tension) and all moving parts be greased. Metallic nozzles should be stored in diesel.

5. Flush the entire sprayer with water repeatedly until the water expelled from the sprayer is clear.

3.5 COST ANALYSIS

This is the total cost enquired in the fabrication of knapsack sprayer. This cost can be divided into three parts:

1. Material cost
2. Labour cost
3. Overhear cost

3.5.1 Material cost

The total cost of materials used for the fabrication of the knapsack sprayer from the current market price (see table 1). The total cost of material is ₦1, 870.00.

3.5.2 Labour cost

Direct labour cost of 20% of the total material cost is assumed..

i.e. labour cost $= \frac{20}{100} \times 1870$

= ₦374.00

3.5.3 Overhead cost

This is cost other than material and labour costs (e.g. transportation). It is assumed to be 10% of the total material cost.

i.e. overhead cost $= \frac{10}{100} \times 1870$

= ₦187.00

Table 1 Materials Used and Their Cost

S/No	Material	Specification	Quantity	Unit Price (₦)	Total Price (₦)
1.	Galvanised mild steel	(300 x 120)m	½ sheet	350.00	350.00
2.	Lance, trigger, valve And nozzle	(Standard)	1	1,200.00	1,200.00
3.	Super glue	--	5	20.00	100.00
4.	Strainer (filter)		1	100.00	100.00
5.	Strap (belt)	yard	2	60.00	120.00

3.6 CALIBERATION OF KNAPSACK SPRAYER

TEST PROCEDURES:

Procedure (by Time – volume method)

- $100m^2$ area (i.e. 4m x 25m) was pegged – out.
- The sprayer tank was filled to two – third (10L) with water.
- The time taken to spray the plot and the volume of water were noted.

The spraying process was repeated for two more readings as shown in the table 2 and 3;

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 RESULTS

The result as shown below

Table 2 test result for existing knapsack sprayer

Replica	1	2	3
Time (second)	265	267	263
Volume discharged (Litre)	6.80	6.50	6.05
Litre/stroke	0.025	0.040	0.035
Piston displaced volume (Litre)	0.05	0.08	0.07
Efficiency (%)	50	50	50

(b) Area rate of sprayer

$$= \frac{0.01 \times 60 \text{ (sec)}}{\text{average Time (sec)}}$$

$$= \frac{0.01 \times 60}{265}$$

$$= 0.0023 \text{ ha/min}$$

© Volume rate

$$= \frac{\text{average volume} \times 60 \text{ (second)}}{\text{average Time}}$$

Volume rate

$$= \frac{6.45 \times 60}{265}$$

$$= 146 \text{ L/min}$$

(d) Application rate

$$= \frac{\text{Volume rate}}{\text{Area rate}}$$

$$= \frac{1.46}{0.0023} = 634.9 L/ha$$

$$\text{Efficiency} = \frac{\text{volume discharged / stroke}}{\text{volume displacement}} \times 100$$

(Shown in the table above);

The average efficiency

$$= \frac{50 + 50 + 50}{3}$$

$$= 50\%$$

For the modified knapsack sprayer;

(a) Area = 4m x 20m = $100m^2$ = 0.01 ha

Table 3 test result for the modified knapsack sprayer

Replica	1	2	3
Time (second)	263	270	260
Volume discharged (Litre)	7.02	7.10	7.08
Litre /stroke	0.03	0.04	0.04
Poison displaced volume (litres)	0.055	0.063	0.070
Efficiency (%)	54.55	63.5	57.14

(b) Area rate of sprayer

$$= \frac{0.01 \times 60 \text{ (sec)}}{\text{average Time (sec)}}$$

$$= \frac{0.01 \times 60}{264.33}$$

= 0.0023 ha/min

© Volume rate =

$$\frac{\text{average volume} \times 60 \text{ (second)}}{\text{average Time}}$$

$$= \frac{7.067 \times 60}{264.33}$$

= 1.60 L/min

(d) Application rate =

$$\frac{\text{volume rate}}{\text{area rate}}$$

$$= \frac{1.\ 60}{0.0023}$$

= 697.42 L/ha

(as shown in the table above);

The average efficiency

$$= \frac{54.55 + 63\ .5 + 57.14}{3}$$

= 58.40%

4.2 DISCUSSION OF RESULTS

The modified knapsack sprayer has a higher efficiency (i.e. 58.40%) about 60% while the existing sprayer has an efficiency (i.e. 50%). Also, in terms of cost the modified knapsack sprayer has a lower cost of ₦1,870.00 while the existing sprayer cost ₦5,000.00. This represent 62.6% reduction in cost price.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion: -

The modified knapsack sprayer is better since it has higher efficiency of spray and cost less. It is lighter and offer more distance covered while resting the handle.

5.2 Recommendation: -

While using a deflector nozzle, the trigger should be pointed upward to direct the spray on the target properly. The sprayer may be constructed using a lighter material like alluminium.

The trigger head should be properly tightened, else there will loss in pressure. Further research can be done into the application of other pumps to sprayer.

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