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Design and Construction of a Chemical Spraying Machine

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ABSTRACT: In the medium to low-income countries where farming is usually subsidence and most farmers cannot afford industrial spraying machine but have to resort to the use of small backpack spraying can for the application of pesticides and herbicides to control pest and weed from their farm. Backpack spraying can expose their skin to chemicals and is also laborious. This study aims to design and fabricate a motorized spraying machine to take care of the shortcoming of the backpack spraying can. Standard components such as chain, sprocket, nozzle, spraying can, and mild steel sheets were sourced from local shops. The trolley and frame of the machine were made from mild steel sheets and pipes. Various parts were then assembled and joined by bolting and electric arc welding before painting to improve the aesthetic. The machine was tested after painting and was found to reduce the spraying time by 50% and is also inexpensive as the cost of production is thirty thousand six hundred and twenty naira ($74). The machine is very effective in controlling the weed.

KEYWORDS: Herbicide, sprayer, backpack, insecticide, pest control, weed.

I. INTRODUCTION

A chemical sprayer is a device for spraying liquid such as water, weed killer, liquid chemical, fertilizers, pesticides, and disinfectants. Sprayers are used by chemical industries, gardeners, and farming industries to spray ingredients, pesticides, and herbicides; or to water plants on farms and gardens.

An agricultural spraying machine is designed for spraying pesticides, herbicides, and water in vegetable gardens. Usually, the gardener will do the water spraying process every day while the pesticide and herbicide spraying process at least once a week. Gardeners also need to spray their gardens with pesticides and herbicides to control weeds and prevent the gardens from bugs, caterpillars, and other pests. Normally, gardeners will use the 1.6 liters manual knapsack sprayers for spraying their gardens. The time spent is usually long because of the use of a single nozzle and the capacity of the tank

In modern agriculture, the usage of pesticides by spraying in droplet form is still a practice. The argument for using existing conventional equipment is that farmers will face economic difficulties in the case of motorized or electrical-powered pumps. Farmers will also face health issues in the case of hand-operated pumps.

One way to overcome this problem is to use the equipment developed for the application of pesticides through the use of mechanical power. However, in selecting a pump for spraying insecticides, herbicides, and pesticides we must ensure it was designed for the job. The unit should have sufficient capacity to supply the needed amount of water and spray material in the allowable time.

The farmers who use conventional backpack sprayers face many problems like fatigue, tiredness, pain in the spinal cord, and muscles among others.This research aim is to design and fabricate an agricultural spraying machine. The machine will be motorized without the use of fossil fuel or external sources of energy.

The purpose of developing such a machine is primarily to prevent the three major drawbacks of the most commonly used agro-sprayer (backpack sprayers). Firstly, the farmer has to carry the entire weight of the spraying tank (approx. 20+kg) pump on his back. Secondly, he has to continuously use one of his hands to pump the liquid using the handle. Thirdly, it uses one nozzle, this will affect the time needed to spray or apply a chemical to a portion of land or thing. The aforementioned constraints and factors such as cost-effectiveness and machine weight were considered in this research. The available commonly used sprayer with the farmers will be modified and adapted for use

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with the designed and fabricated chain drive mechanism.

II. LITERATURE REVIEW

The spraying machine plays an important role in applying herbicides and pesticides in agriculture and pest control in the environment. Spraying chemicals through the sprayers is a means of applying a small quantity of liquid in fine droplets through the nozzles of various dimensions. Currently, farmers used all forms of manually operated knapsack sprayers that can cover 0.4 ha/hr, and motorize sprayers that can cover 1.2 – 1.5 ha/hr for spraying pesticides on crops such as cotton and red gram [1].

There are various manually operated and motorized sprayers in the market. The ease of operation, cost of equipment, spraying time, and efficiency of the spraying system differentiate one sprayer from another.

One type of sprayer is a backpack sprayer [2] which allows an operator to carry the tank on his back and use one hand to pump the liquid with the aid of a level while the second hand holds the spraying nozzle. Hydraulic type of sprayers convert pesticides, herbicides, and any chemical formulation that is mixed with water into droplets before being applied to crops or an area of interest [3]. In this type of spraying the user will have to carry the tank with the content which often leads to fatigue and is also limited by the human capacity to carry the load.

Another type of sprayer is the tractor-mounted sprayer which has big tanks with a large capacity such as 8000 liters and uses multiple in-line nozzles or aluminium booms to cover a large surface area in a limited time frame [4].

There is also a motorcycle-driven sprayer that uses energy from fuel to power the motorcycle. The power from the cycle through a system of gears and chains is used to pump the dispensed droplet of pesticides and other formulations as the user rides the motorcycle [3].

Joshua et al (2010) [2] work on the solar power sprayer but the challenge for the small-scale farmer is the cost of the solar panel and battery that add to the cost of production.

Akande and Mercy [5] work on a pedal-powered grinding mill that cannot spray liquid or chemicals like the intended design. Automatic sprayers and motor sprayers are commonly used by large-scale farms to carry out spraying activities on their farms. However, they are not affordable for most subsistent farmers that constitute most farming population in the agrarian society of developing countries. A common sprayer among farmers in developing countries is the manual knapsack sprayer.

This research intends to transform a manual knapsack sprayer into a mechanical sprayer that will be more comfortable to use as the user will not need to carry the weight of the liquid chemical-filled tank. This project aims at producing a spraying machine that is more efficient than the usual single nozzle knapsack sprayer that is common among household users and farmers in developing countries. It will also be safer to use because there will not be a need for the user to carry the tank on his back, thereby avoiding the possibility of a spill of chemicals on the skin or back of the operator of the sprayer.

III. MATERIALS AND METHOD

Research Design

Sprocket Ratio/Velocity Ratio:

The sprocket ratio or gear ratio is a mathematical representation of the mechanical advantage of a gear train system (see Figure 1). It shows the change in speed between the sprocket of the pedal and the sprocket that is attached to the grinding mill.

$$\textbf{Velocity ratio} = \frac{\textbf{number of teeth on Driven Sprocket}}{\textbf{number of teeth on Driver Sprocket}} = \frac{\mathbf{N_1}}{\mathbf{N_2}} \quad \text{Eq.1}$$

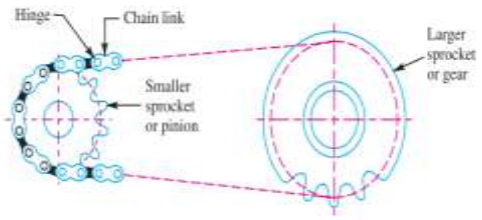

Figure 1: Sprockets and chain

$$\mathbf{V.R} = \frac{\mathbf{N_1}}{\mathbf{N_2}} = \frac{\mathbf{n_2}}{\mathbf{n_1}} \quad \text{Eq.2}$$

Where V.R – velocity ratio

N_1 = number of teeth on the driven sprocket, N_2= number of teeth on the driver sprocket, n_2= speed of driver sprocket (crank) in rpm, n_1 = speed of driven sprocket (rpm)

$$\mathbf{n_2} = \frac{\mathbf{N_1}}{\mathbf{N_2}} \times \mathbf{n_1} \quad \text{Eq.3}$$

The driving sprocket pitch angle (α) is:

$$\frac{\mathbf{360}}{\mathbf{N_2}} \quad \text{Eq. 4}$$

Thus, the chain's pitch can be calculated as follows:

$$\mathbf{P = D * Sin(180/N_2)} \quad \text{Eq.5}$$

Where: P – pitch; D – Pitch circle diameter in metres

The chain's average velocity (v)

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$=\pi DN/(60)$ Eq.6

Length of chain and center distance

To determine the length of the chain in a chain drive (see Figure 2).

Let,

$p =$ Pitch of the chain, and $x =$ Centre distance

The length of the chain (L) is equal to the product of the number of chain links (K) and the pitch of the chain (p). Mathematically,

$$L = K.p \quad \text{Eq.7}$$

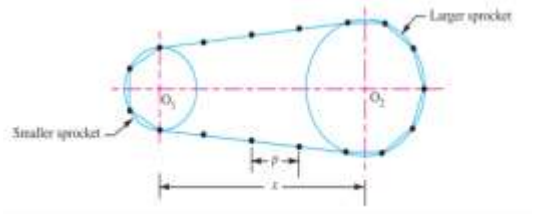

Figure 2 Length of chain

The number of chain links may be obtained from the following expression, i.e.

$$K = \frac{N_1+N_2}{2} + \frac{2x}{p} + \left[\frac{N_2-N_1}{2\pi}\right]^2 \frac{p}{x} \quad \text{Eq.8}$$

The value of K obtained from the above expression must be approximated to the nearest even number. The center distance is given by:

$$x = \frac{p}{4}\left[K - \frac{N_1+N_2}{2} + \sqrt{K - \frac{N_1+N_2}{2} - 8\left(\frac{N_2-N_1}{2\pi}\right)^2}\right] \quad \text{Eq.9}$$

Time measurement

Time taken was measured using a stopwatch. Tests were carried out to determine the difference in spraying time between the use of a backpack (knapsack) chemical sprayer and the developed motorized sprayer machine. The time taken to complete the spraying of herbicide on a measured land area was measured when the developed machine was fitted with a single nozzle and when it was fitted with two nozzles. The procedure was repeated for the backpack sprayer with a single nozzle and when it was fitted with two nozzles.

Fabrication, assembling of components, and the principle of operation of the machine

A spraying machine is a device for spraying liquid in droplet forms onto a surface or thing. The basic components of the machine are the tank (made from mild steel) for carrying chemicals such as pesticides and fertilizer among other chemicals. The tank is made from plastic to prevent it from corrosion. Inside the tank is an inline filter to prevent nozzle clogging. The spraying machine also has two nozzles of a diameter of one millimeter which are connected through a plastic hose to the pump. The pump consists of a heavy-duty poly piston that is connected to a rod that passes through the gland at the end of the cylinder. The reciprocating motion of the piston in the cylinder causes the discharge of liquid through the nozzle.

The pump is actuated by the connecting rod or lever that connects it to the crank in the wheel. The wheel has a rolling bearing to maintain good rotational motion of the wheel. The wheel consists of rubber (tire) and a steel rim which is coupled to a trolley for carrying the tank. The pushing of the trolley to the area of interest by the operator will lead to the activation of the enabling liquid pumping mechanisms. The mainframe was fabricated by joining angle irons using welding while other parts such as chain, driven and driver sprockets were fitted to the mainframe using bolts and nuts and welding. Square tubes are used for the fabrication of the chassis (frame). All other parts such as sprocket, chain, wheel, and pump are the standard parts.

Figure 3 Electric arc welding to construct the mainframe for the machine

Figure 4 shows the assembled spraying machine.

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Figure 4 Fabricated spraying machine

IV. CONSTRUCTION COST ANALYSIS

Table 1 shows the total manufacturing cost of the chemical spraying machine

Table 1 Cost of fabrication of the spraying machine

NO	MATERIAL	PRICE PER UNIT	QUANTITY	TOTAL
1.	TYRE	₦ 3,200	1	₦3,200
2.	KNAPSACK SPRAYER	₦ 5,500	1	₦ 5,500
3.	CHAIN	₦ 1,500	1	₦ 1,500
4.	BALL-BEARING	₦ 400	2	₦ 800
5.	WHEEL SPOKE	₦ 20	36 PIECES	₦ 720
6.	MILD STEEL PIPE (IXI)	₦ 2,200	2LENGTH	₦ 4,400
7.	WHEEL (BICYCLE WHEEL)	₦ 3,500	1	₦ 3,500
8.	TIRE TUBE	₦ 1,500	1	₦ 1,500
9.	HUB	₦ 1,500	1	₦ 1,500
10.	WELDING ELECTRODES	₦2,000	1/2 PACK	₦ 1,000
11.	CUTTING DISK	₦ 1,000	1	₦ 1,000
12.	2.5MM FLAT SHEET METAL	₦18,000	1/3 SHEET	₦ 6,000
				₦ 30,620

V. RESULT AND DISCUSSION

(A) Testing and evaluation result

Tests were carried out to find out the time taken to spray herbicide over some land area using the backpack spraying machine and using the developed fabricated motorized spraying machine the results are as presented in Figure 5. The tests were carried out three times on equally measured land areas.

COMPARISON BETWEEN MANUAL KNAPSACK SPRAYER AND SPRAYING MACHINE

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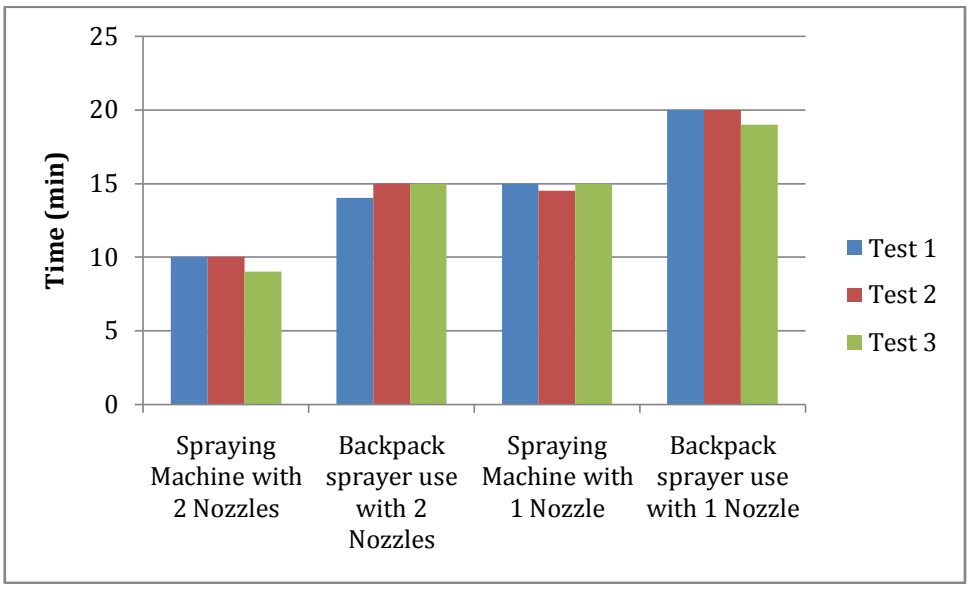

Figure 5 Time Comparison between spraying machines

Figure 6 shows the demonstration field before the fabricated machine was used to test the effectiveness of the developed machine.

Figure 6 Area in the front of the workshop before spraying with fabricated machine

Figure 7 shows the area in figure 5 after the application of herbicide using the fabricated spraying machine

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Figure 7 Area in the front of the workshop after spraying with fabricated machine

VI. DISCUSSION

From Figure 5 when a backpack sprayer with a nozzle was used to spray the herbicide over a land area it took twenty minutes to complete the spray of the herbicide as compared to fifteen minutes spent when the fabricated machine with a nozzle was used. This may be due to the ability of the operator to move faster with the trolley as compared to just walking and spraying the herbicide with the aid of a lever and spraying tank and nozzle. Similarly, when a backpack sprayer with two nozzles was used to spray herbicide over the same landed area it took fifteen minutes to complete the spraying as compared to a fabricated machine with two nozzles that took ten minutes. Therefore, the use of the fabricated machine will save quality time and reduce drudgery as compared to the manual spraying of chemicals with a backpack sprayer.

Furthermore, from Figure 6 and Figure 7 it can be observed that there is a marked difference between the landed area before the spray of herbicide and after the spray of herbicide. This shows that the fabricated machine is very effective in controlling vegetation.

The cost of assembling all the various components and fabricating the machine is thirty thousand six hundred and twenty nairas (see Table 1). This fabricated machine is affordable to most households and subsistence farmers for controlling weeds and pests.

VII. CONCLUSION

A motorized spraying machine has been developed to control pests, weeds, and fumigating the environment. Standard components such as chain, sprocket, nozzle, spraying can, and a mild steel sheet were sourced from shops. They were then assembled and joined by bolting and by electric arc welding. The pipes and sheet of metal were used to create the supporting frame and then painted to improve the aesthetic of the machine. The machine was tested after the fabrication and it was found to be very effective in controlling the weed. In addition, to being inexpensive as it cost only thirty thousand six hundred and twenty naira only, it also solved the problem of carrying a tank of chemicals on the back when using a backpack sprayer. This will help in reducing the risk of chemicals pouring on the body of the user during the spraying of the chemical. The endurance limit will also increase as the user only need to push the trolley that houses the tank instead of carrying the tank.

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