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Semi-Automatic Fertilizer Sprayer V2023

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Abstract: Liquid fertilizers are very important in maintaining nutrients for plants. These fertilizers are commonly applied by using a knapsack sprayer. The usage of knapsack sprayer is low in safety, which can lead to muscular fatigue and pain on the neck, leg and the upper arm left. To address this problem, Semi-Automatic Fertilizer Sprayer is developed by remove load of fertilizer in the knapsack and introduce new design based on wheelbarrow concept. Hence, in this project, various concepts of semi-automatic fertilizer sprayer are compared in many aspects and parameters. Concept and parametric design are developed and analyzed according to the performance, structure construction and development costing. These tools aim to be able to spray the fertilizer without manually pumping it, reduce time consumption and minimize required energy while using this sprayer.

Keywords: Fertilizer Sprayer, Liquid Fertilizer, Muscular Fatigue

1. Introduction

There are several forms of fertilizers, such as chemical fertilizer, organic-chemical fertilizer, and fully organic fertilizer [1]. One of the methods to spread this fertilizer is by using liquid application [2]. This is because liquid fertilizers are mobile in the soil water solution [3].

One of the conventional spraying methods is by using knapsack sprayer as **Figure 1** below. This method is very suitable in applying liquid fertilizer due to its low cost, easy maintenance, and portable factor [4]. However, this method has one problem, which is the weight of the knapsack sprayer during filled with liquid fertilizer is quite high, which leads to tendency for the operator to suffer muscular fatigue for a long-time usage.

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Figure 1: Knapsack spraying process

According to Nordic Body Map questionnaires and analysis, it was found that the operator suffered muscular fatigue and pain in the neck, upper arm, and their leg. Also, the dangerous zones are the flexion of hip, neck and shoulder based on Range of Motion criteria. The analysis also recommends resting time for knapsack sprayer operators is 125 minutes for 4 hours of working time [5].

Rapid Entire Body Assessment (REBA) was conducted for the knapsack sprayer to evaluate work posture in detail. The three main movements of knapsack sprayer as shown by **Figure 2** below are lifting movement of the piston pump, which is the picked-up pump up to the maximum range, the movement of pressing piston pump handle and movement of the piston presses with maximum traction. The hand on the pumping work element had a high REBA score of 10 because shoulder flexion position was 118º. Rating scores are influenced by shoulder muscles' work force against gravity and mass grip the pump. Thus, the operators would suffer a faster rate of fatigue because of the greater angle of upper arm movements done repeatedly [5].

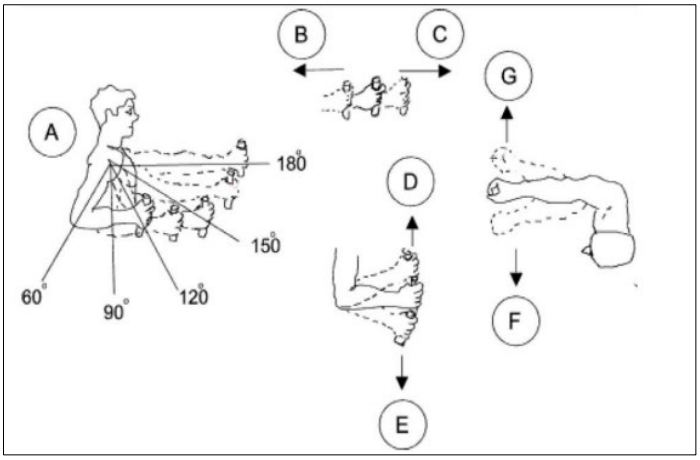

Figure 2: Stress position for upper arm

Many parties have tried to overcome this problem by providing various alternatives, either semi or fully automatic design concept. However, there are gaps in this solution, which is the price of the available product in the market is quite high. This can be a problem for small-income farmers to get this machine. Other than that, the maintenance cost is high as well.

Hence, the purpose of this project is to design and develop a Semi-Automatic Fertilizer Sprayer prototype through low-cost design and development. This prototype is based on wheelbarrow concept and combines with sprayer system generated from rotational motion from wheels, gears, and chains combination. However, the constraint of this prototype requires flat ground during spraying process. It is due to the difficulty to control when moving through uneven crop areas or flabby soil areas.

2. Literature Review

There are a lot of efforts to create a quick and effective way of spraying fertilizer. Among products sold in the market are towing-behind sprayer, tractor sprayer, and fertilizer drone. Towing-behind sprayer is one of the products available in the market. This product is suitable for residential and commercial use. This automatic versatile large broadcast and spot sprayer configured to tow behind a standard ATV, UTV or lawn tractor. **Figure 3** below show this product come with 15-ft reinforced hose and 7-ft coverage spray boom [6].

Figure 3: Tow Dripless Fertilizer

In addition, there are patent for a portable agricultural sprayer using compressed air as **Figure 4** below. It consists of a narrow elongated wheeled frame, with the wheels closely spaced for operation between rows of plant. The handle is attached to the frame for hand-moving. The compressed air use the electrical operated compressor as a source and power provided from electric storage batteries. The storage tank is attached on the frame, containing a solution of fertilizer, and connected at the end to the output side of the compressor to be provided with compressed air for pumping the liquid. The other end of the storage tank is connected to valve connections to the outlet end of a pair of swivelled booms which carry adjustable nozzles for spraying fertilizer solutions. The booms are provided with a suitable locking device to support in any position. The support for the swivelled booms is adjustably supported on the wheeled frame for vertical movement [7].

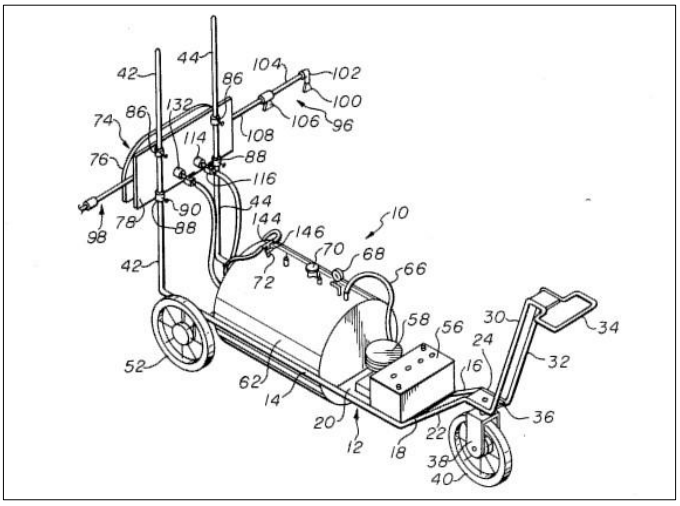

Figure 4: Portable Agricultural Sprayer

Figure 5 below shows the sprayer based on wheel driven concept targeted for the small-income farmers. This sprayer is based on the transmission of power with the help of motion transmission. The arrangement of chain and sprocket makes the plunger cylinder spray the liquid to the desirable place. The sprocket converts the rotary motion of the sprocket into the reciprocating motion. The cam mechanism, which moves up and down, makes reciprocating motion of the piston of a single acting reciprocating pump mounted in front of the tank.

During the upward motion of the connecting rod the liquid is drawn into the pump and during the downward motion of connecting rod the liquid is forced to the delivery valve, the delivery is connected to the pipe carrying the number of nozzles [8]. The limitation of the design is only can be used in flat area due to the shape.

Figure 5: Wheel Driven Pull Type Agriculture Sprayer

3. Methodology

3.1 Methods

The Semi-Automatic Fertilizer Sprayer has gone through design and development progress. The main methods do a literature review of the available product and registered patent either in the online (website) or offline (observation). Each product is evaluated and compared according to the material, weakness, strength, mechanism and price.

Besides that, this Semi-Automatic Fertilizer Sprayer is already assessed at a stage of Design Formulation, Concept Design, Embodiment Design and Parametric Design. This product parametric Design has been developed using *Solid Work 2019*.

3.2 Materials

The material selection process has been carried out by following the aspects outlined below for guidance. The essential factor that should be considered in material selection is its strength. Metal base material used in this project. The different metals strength needs to be considered, which are tensile strength, ultimate strength, impact strength and compressive strength [9].

The material chosen for the fertilizer-tank is made from plastic type (polyethylene). The reasons for the selection are this material suitable with chemical liquid, lightweight, have impact resistance and corrosion resistance. Hence, it's suitable to store fertilizers [10]. This project will also use pneumatic tires. The material of pneumatic tire is based on synthetic rubber. Pneumatic tire is chosen because of the ability to absorb the uneven terrains that allow smoother and less bumping movement [11][12]. The selected material of the sprocket is alloy steel. This material is chosen because the alloy steel-based material sprocket is primarily lightweight. This sprocket is corrosion resistance and durable [13].

3.3 Fabrication Process

Figure 6 below presents fabrication process flow of the Semi-Automatic Fertilizer Sprayer. These activities involve measuring, cutting, machining, welding, and spraying activities.

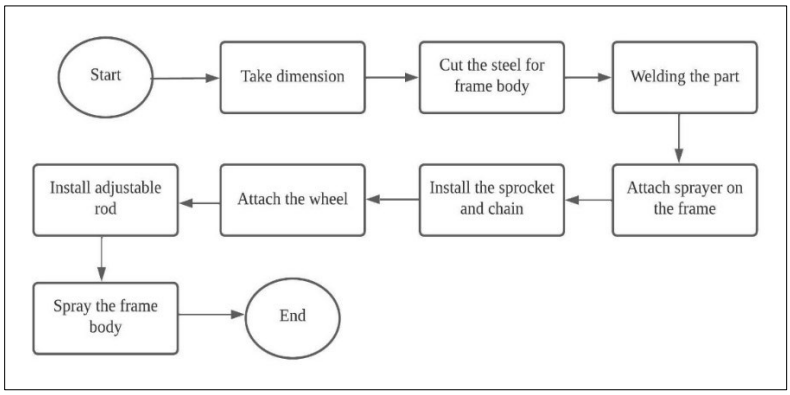

Figure 6: Fabrication Process of Semi-Automatic Fertilizer Sprayer

3.4 Equations

There are several equations involved in this study such as the equilibrium of forces and the equilibrium of moments. This equation is used to analyze the force after the free-body diagram is drawn.

$$\Sigma Fx = 0 \qquad \textbf{Eq. 1}$$

$$\Sigma Fy = 0 \qquad \textbf{Eq. 2}$$

$$\Sigma M = 0 \qquad \textbf{Eq. 3}$$

Another than that, if we know number of front and rear gear teeth, the number of turns of the rear gear can be calculated from the formula below:

$$\frac{t_{front}}{t_{rear}} = \frac{n_{front}}{n_{rear}} \qquad \textbf{Eq. 4}$$

Where;

t_{front} = number of turns of the front gear

t_{rear} = number of turns of the front gear

n_{front} = number of front gear teeth

n_{rear}= number of rear gear teeth

Next, the flow calculations on water hoses can be calculated based on the formula stated below:

$$\text{Area} = \pi r^2 \qquad \textbf{Eq. 5}$$

$$\text{Cross -sectional area} = A_{outer} - A_{inner} \qquad \textbf{Eq. 6}$$

$$\text{Velocity of water, } v = \frac{d}{T} \qquad \textbf{Eq. 7}$$

$$\text{Water flow rate, } Q = Av \qquad \textbf{Eq. 8}$$

4. Results and Discussion

Figure 7 below shows the drawing of full assembly of the Semi-Automatic Fertilizer Sprayer. The main components are tank, nozzles, hose, frame, chain, sprocket, and wheel.

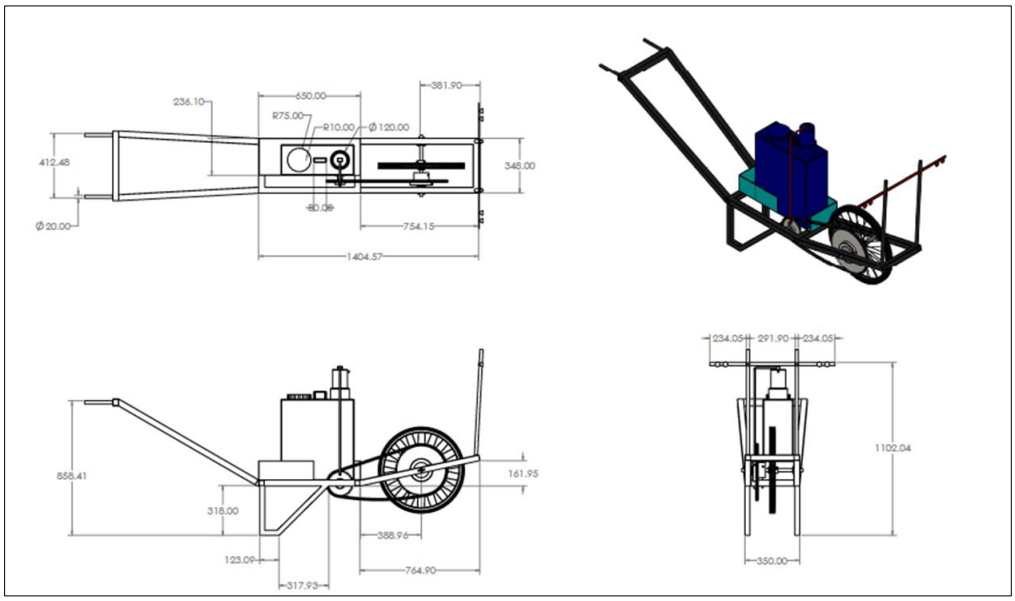

Figure 7: Full assembly drawing of Semi-Automatic Fertilizer Sprayer

The general operating procedures for Semi-Automatic Fertilizer Sprayer could be explained as below:

1. Insert the liquid fertilizer to the tank.
2. Make sure the hose is perfectly connected.
3. Push the Semi-Automatic Fertilizer Sprayer to the desired target.
4. The liquid fertilizer will be pumped, and sprayed trough the nozzles.

Table 1: Cost estimation

No.	Component	Quantity	Unit Price (RM)	Total Price (RM)
1	Frame	1	100	100
2	Tank	1	40	40
3	Nozzles	4	2	8
4	Nozzles bar	2	20	40
5	Adjustable bar	1	40	40
6	Wheel	1	25	25
7	Big Sprocket	1	30	30
8	Small Sprocket	1	15	15
9	Shaft	1	15	15
10	Chain	1	30	30
			Total	343

Table 1 above lists all the cost for every component of the prototype. The estimated cost to construct this prototype is around RM 343.00.

The testing had been conducted to the prototype of Semi-Automatic Fertilizer Sprayer as **Figure 8 (a)** below. Based on the testing, the frame can withstand the load and the width of adjustable bar is suitable for the spraying coverage. However, the movement of this prototype is not smooth as desired because the connecting rod between sprocket and the pump get in contact with the chain. The chain cannot turn as desired.

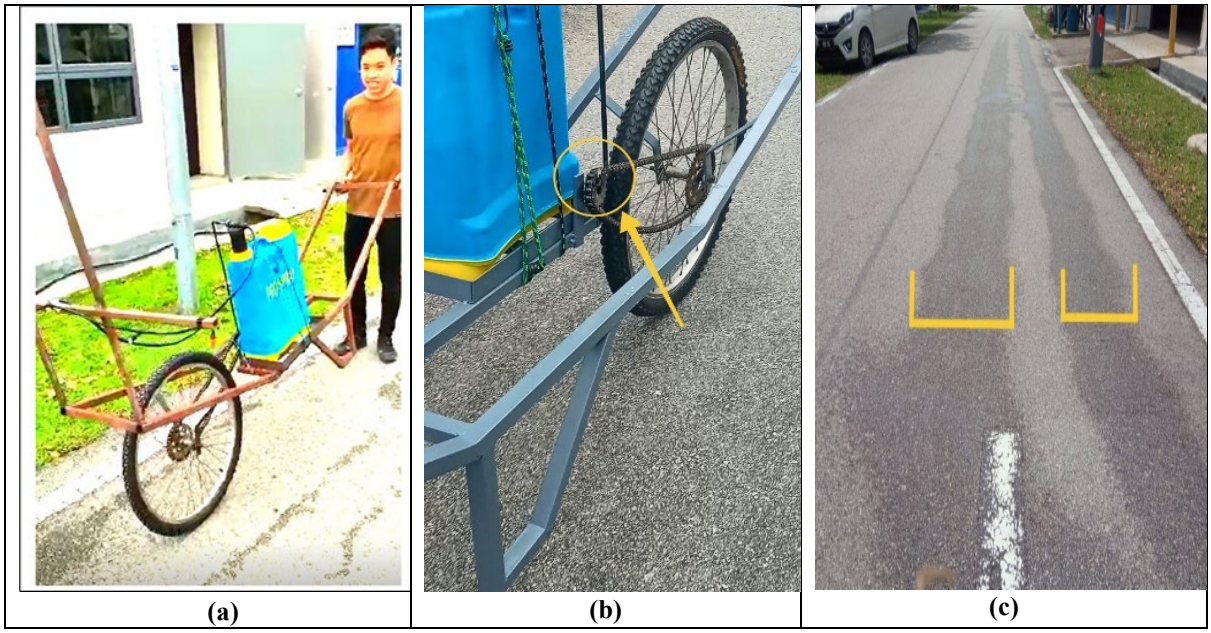

Figure 8: Initial prototype (a) Testing session, Adjusted chain and sprocket, (c) Width of spraying

During early prototype testing, found out that wrong chain length also affects the wheel movement. Hence, suitable chain length with sprocket is important and the initial prototype was modified so get the result as desired resulted in final prototype fabrication as **Figure 8 (b)** above.

During final prototype testing, the spray coverage area was also identified. The project use four nozzles at both side of the Semi-Automatic Fertilizer Sprayer. The steps of the testing procedure are firstly, select the nozzles, then measure the flow rate in L per minute by measuring sprayer output while pumping over one minute. Then, measure the walking speed in meters per minutes by measure how many meters the user walks in one minutes. After that, measure the Band Width by spraying on dry ground. The width of spray pattern produced is measured as **Figure 8 (c)**. Based on the analysis, the walking speed is about 50 meters per minutes and the width of the spray is about 30 cm. Thus, this information can be used to determine how much needed to spray the liquid fertilizer at the farm.

The testing that had been conducted shows that Semi-Automatic Fertilizer Sprayer free of carbon emission, as this prototype working without the engine. This shows that the design is very good for the environmental in term of air pollution, compared to the motor-powered fertilizer sprayer machine at the marketplace. The testing that has been done shows the liquid fertilizer can be sprayed through four nozzles through the target area by the pump, thus validate that the liquid fertilizer sprayer is successful.

5. Conclusion

In conclusion, the Semi-Automatic Fertilizer Sprayer is one of the solutions for the ergonomic problem on existing knapsack sprayer. This project is designed to small scale farmer who still use manual knapsack sprayer as the tool to spread/spray the liquid fertilizer. Although many inventions and product that have been sold out there to solve this ergonomic problem, but the cost is high for the small agriculture farmer. Compared to existing manual knapsack sprayer, this Semi-Automatic Fertilizer Sprayer working mechanism refer to wheelbarrow, which is the operator push the sprayer when working with it. This tool is very suitable at flat ground working environment. This tool also has been designed to make the work execute efficiently.

There are a few recommendations for future project. First, the Semi-Automatic Fertilizer Sprayer can be provided with brake. The brake can facilitate the operator to stop this tool. Thus, this can make

the work done efficiently. Next, this tool can be designed for foldable instead of fixed on every part. This can save space when the user wants to store this tool after use it.

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