FACULTY OF ENGINEERING

DEPARTMENT OF AGRCULTURAL MECHANIZATION AND IRRIGATION ENGINEERING

FINAL YEAR PROJECT REPORT

DESIGN AND CONSTRUCTION OF A SOLAR POWERED CHEMICAL SPRAYER FOR SMALL SCALE FARMERS

CASE STUDY: TORORO DISTRICT

BY

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This project report is presented to the department of agricultural mechanization and irrigation engineering as a partial fulfillment for the award of a Bachelor's degree in Agricultural mechanization and irrigation engineering at Busitema University

ABSTRACT

A sprayer is a mechanical device used to spray the liquid chemicals like herbicides, pesticides, fungicides and fertilizers to the crops in order to control pests and diseases on crops to maximize production. Sprayers are of many different kinds which include knapsack sprayers, motorized sprayers, tractor drawn sprayers etc. the most commonly used type by the Ugandan farmers are the knapsack sprayers because they are cheap in terms of capital cost. The main drawback with these sprayers is that they cannot be used for long working hours due to human drudgery and they also have low pressure. Motorized sprayers have high pressure but with high investment cost and maintenance cost. Due to the above shortcomings of the commonly used sprayers, the need for another means which provide output in between the knapsack sprayers and the motorized sprayers calls for the invention of solar powered sprayers. These can have between low to high pressure depending on the capacity of the pump. These sprayers also cost moderately and have low maintenance costs.

For this project, the emphasis was put on the design, construction and testing for the performance of a solar powered sprayer using low power pump and solar panel. During the design process, the required solar panel, pump, battery and angle of solar panel inclination were obtained based on the required output of $1m^3$/min of the chemical. The system was tested under varying conditions of insolation strengths an angle of inclination of the solar panel. It was observed that the rate of discharge is affected by the strength of solar insolation and angle with the appropriate angle being 45degrees. The cost analysis was also carried out using the method of net present value over four year period with interest rate of 10% and the NPV value got was Ugx.**7,807,622** which is positive hence making the project feasible. Implementation of this project will help in saving costs spent on fuel purchase and reduce the spraying time due to moderate pressure and improve on the yield in ground nut.

DECLARATION

I, **OTHIENO FRANCIS**, declare that the information in this report is my own work and was compiled from September 2017 to May 2018

Name: OTHIENO FRANCIS

Signature: …. …………………

Date: ……………………….

DEDICATION

I dedicate this project report to my parents Mr. **CHARLES MENYA** and **Mrs. SALUME AURO** and my siblings for the selfless care and support you have always provided to me. I thank you for the spirit of hard work, courage and determination you have instilled in me throughout my school days till today. May the almighty God bless you abundantly

ACKKNOWLEDGEMENT

First of all, I take this opportunity to thank the almighty God for guiding me during my information gathering, project system design, fabrication of the prototype, testing of the system and report writing. Special thanks also go to my precious family for their constant support both financially and spiritually.

Special thanks go to my supervisors Mr. Kilama George and Mr. Igga Huzzairu for the constant support they have given me during the process of working on this project for their useful advice and comments given to me during the prototype production and report writing.

Finally, special appreciation goes to my fellow colleagues with whom I study with for their inspiring words of counsel and wisdom for all the years we have spent together. May the Good Lord bless and reward you all with success.

APPROVAL

This is to certify that **OTHIENO FRANCIS** has written this report after collecting the needful information needed for the full operation of the project under the supervision of:

MAIN SUPERVISOR

Name: Mr. KILAMA GEORGE

Signature………………………………………

Date: …………………………………

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Name: Mr. IGGA HUZAIRU

Signature: …………………………

Date: ………………………………

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CHAPTER ONE: INTRODUCTION

1.0 Introduction.

This chapter contains the background of the study, problem statement, objectives, purpose, justification and the scope including the limitation to the study.

1.1. Background of the study

A sprayer is a mechanical device used to spray liquid chemicals like herbicides, pesticides, fungicides and fertilizers to the crops in order to protect them from pest and disease attack. Sprayer provides optimum utilization of pesticides or any liquid with minimum efforts.

Dusters and sprayers are generally used for applying chemicals. Dusting is the simpler method of applying chemicals and dusters are best suited for portable machineries and this usually requires simple equipment. But these devices are less efficient than sprayers, because of the low retention of the dust ***(Johanningsmeier, 2000)***.

The invention of a sprayer brought revolution in the agriculture sector. This enables farmers to obtain the maximum agricultural output since the pests and diseases that reduce the yield are controlled easily. They are used for agriculture spraying, garden spraying, weed and pest control, liquid fertilizing and plant leaf polishing. There are many advantages of using sprayers such as easy to operate, maintain and handle, it facilitates uniform spread of the chemicals, capable of throwing chemicals at the desired level, precision made nozzle tip for adjustable stream and capable of throwing foggy spray, light or heavy spray, depending on requirement ***(Rajesh et al., 2007).***

Sprayers are available in different varieties ***(Sciences, 2008)***. In Uganda farmers generally use two types of spray pumps for spraying; hand operated spray pump (knapsack sprayers) and fuel operated spray pump. The hand operated spray pumps are most popular. This is because most farmers are small scale agriculturalists who find hand operated sprayers cheap to purchase, easy to operate and maintain. The main drawback of hand operated spray pump is that it cannot be used for long working hours. Fuel motorized sprayers on the other hand give high pressure output which reduces the spraying time required. These motorized sprayers have high initial, maintenance and running cost which makes it hard for small scale farmers to purchase and maintain them. Due to the above drawbacks by the commonly available sprayers, there is need to get a means which is cost friendly and time saving. This gives rise to conventional means of sprayer operation. This involves the use of conventional energy like solar energy, wind energy, hydro-power, biogas energy etc. to power sprayers when applying chemicals to crops. For this project, the emphasis is put on solar energy

For this type of sprayer, the pumping energy is provided by solar energy which is harnessed using solar panel and stored in a battery which later runs the pump. The energy is readily available and hence can be trapped during the day. The stored power in the battery can also be used for lighting at home during the night and hence saving on the costs of fuel for the farmer.

Solar energy is the light and radiant heat from the Sun that influences Earth's climate and weather and sustains life. Since ancient times, solar energy has been harnessed for human use through a range of technologies. Solar energy technologies provide electrical energy generation by heat engine or photovoltaic means, space heating and cooling in active and passive solar buildings; potable water via distillation and disinfection, day lighting, hot water, thermal energy for cooking, and high temperature process heat for industrial purposes. Sunlight can be converted into electricity using photovoltaic cells (PV), concentrating solar power (CSP), and various experimental technologies. PV is the mainly used means of trapping and converting solar energy to electrical energy used to power small and medium-sized appliances, from the calculator powered by a single solar cell to off-grid homes powered by a photovoltaic array. A solar cell, or photovoltaic cell (PV), is a device that converts light into direct current using the photoelectric effect ***(Hersch & Zweibel, 1982)*****.**

The solar insolation intensity for Tororo district from January 9 to March 22 has with an average daily incident shortwave energy per square meter above 6.7 kWh. The brightest day of the year is March 2, with an average of 7.2 kWh.

The darker period of the year lasts for 4.0 months, from April 23 to August 24, with an average daily incident shortwave energy per square meter below 5.5 kWh. The darkest day of the year is June 22, with an average of 5.1 kWh. This proves that the solar energy has enough strength and hence can be harnessed and utilized ***("Average Weather in Thiruvananthapuram, India, Year Round - Weather Spark," 2016)***.

The average sunshine hours for Tororo are also at 7hours a day. This gives enough time for the energy to be harnessed ***("Correlation Between Sunshine Hours and Climatic Parameters At Four Locations in Uganda," 2004)***.

1.2. Problem statement

For maximum agricultural production, there is need for appropriate application pressures for uniformity to be achieved and time saving during the praying of pesticide and herbicides in order to eradicate the pests, weeds and diseases affecting crops. The knapsack sprayers have low pressure hence time consuming whereas the motorized sprayers with moderate to high operating pressure have high purchase and running cost and also require expertize to operate it.

The burnt gases during the combustion of petrol fuel in a motorized sprayer is also a hazard to the community as it causes air pollution and can lead to global warming. There is also noise pollution from petrol engine which lead to noise pollution.

1.3.Purpose of the study

- To utilize the renewable energy source (solar energy) for the purpose of running a herbicide/ pesticide sprayer
- The study is also to help reduce the burden the farmers face during the use of manually hand operated and fuel powered sprayers when working for longer hours
- This will be achieved by fabricating a solar sprayer that purely utilizes solar energy to run the system.

1.4.Objectives of the study

1.4.1. Main objective

- To design, fabricate, assemble and test for performance of a portable solar operated chemical sprayer

1.4.2. Specific objective

- To design component parts of the system that uses solar energy to run a pesticide sprayer
- To fabricate and assemble the system parts
- To test the assembled prototype
- To carry out economic analysis of the system

1.5. Scope of the study

The study is limited to design of a solar powered sprayer, fabrication of the parts of the system, assembling of the parts and testing of a solar powered pesticide/ herbicide sprayer. This involves getting a means of trapping solar energy which will be done with the help of solar panel to generate the energy needed to operate the system. The crop to be sprayed will be ground nuts in Tororo district.

1.6. Justification

Since most of the spraying of crops and plants is done during the day and in Uganda there is an average of seven sun shine hours per day, enough solar energy can be cheaply obtained to power and run the sprayer. This helps to save the money that would be spent on fuel and long working hours can also be achieved. The use of this type of sprayer also helps in conserving the environment since both noise and gas pollution is eliminated.

The system has a battery that stores power that can be used to work even during the time when the solar energy is not available or not enough and the stored energy can also be used for other purposes like lighting at home at night. This also helps the rural farmer save on the cost for buying lighting materials

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter provides the review on pesticides, sprayers used to apply the pesticides, and solar energy availability and means of harnessing it. It includes the types of pesticides and the forms in which they are available in the market, types of sprayers available for use and the proposed one for the project including their advantages and constraints and the origin of solar energy harnessing principles and the methods used and the different methods of carrying out the cost analysis for the project

2.1 Pesticides and herbicides

Pesticides are defined according to Food and Agriculture Organization (FAO) as: Any substance or mixture of substances used for preventing, destroying, any pest, including vectors of human or animal disease, unwanted species of animals, causing harm or interfering with the production, processing, storage, transport, or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs, or substances that may be administered to animals for the control of insects, arachnids, or other pests in or on their bodies ***(Algae et al., 2013)***.

The term pesticide includes all of the following: herbicides, insecticides, insect growth regulators, animal repellant, etc. The most common of these are herbicides which account for approximately 80% of all pesticide use. Most pesticides are intended to serve as plant protection products (also known as crop protection products), which in general, protect plants from weeds, fungi, or insects.

On the other hand, herbicides may be defined as any substance or combination of substances uniformly mixed and is used to control or destroy weeds that interfere or harm the crops in the garden hence reducing their yield. Herbicides can either be applied when the crops have grown or to garden without crops in order to kill the weeds before the crops are planted.

2.1.1 Types and forms of pesticides

Pesticide can be broadly classified by the form in which they are supplied which include;

Solid pesticides

These are pesticides which are always packed in solid state and they are mostly fertilizer. Solid pesticides are either in granular form or in powder form

Granular pesticides are those that are in crystalline form. These can either be applied in solid state or dissolved with a solvent commonly water before being applied to the crops. They can be applied either to the crops or to the seedbed before the crops are plants

Powder pesticides are those that are packed in powder (fine grains). These like granular pesticides can be applied in solid state or dissolved in a solvent. Most powder pesticides are insoluble in water so they are applied in their solid state. They can also be applied to the already growing crops or to the seedbed before planting of the crops.

Liquid pesticides

These are pesticides that are mostly packed and supplied in liquid form. The liquid pesticides are dissolved in water or other solvent in order to reduce on its concentration such that they don't affect the crops adversely. The pesticide can either be applied to seedbed before growing the crops most especially herbicides to kill the weeds before the crops are put in the seed bed or applied to already growing crops to either kill weeds, pests or enhance growth of the plants.

The liquid pesticides are applied to the crops using sprayers and so this project will majorly concentrate on application of liquid chemicals.

2.2 Sprayers

Sprayers are the equipment used to apply liquid chemicals to crops in order to protect the crops from pest, weeds or to add nutrients to the soil

Types of sprayers

There are many types of sprayers and some of them are listed below ***(Rao & Mathapati, 2013)***.

a) Knapsack sprayers

These are sprayers that are mounted on the back of the operator during the spraying operations. The tanks of these sprayers may either r be plastic or metallic. They are the most common type of sprayers used by farmers in Uganda due to their ready availability and cheap cost and include the following:

- Hydraulic knapsack sprayers

These ones are of small size with a tank ranging from 12litres to 20litres. The agitation of the chemical in the tank is done either manually or hydraulically with the help of a hand lever in order to maintain constant pressure.

These sprayers have some drawbacks which include being tiresome to work with since they are mounted on the back of man. This reduces the working time and the area covered.

- Manual pneumatic sprayers

These ones are almost similar to the hydraulic type only that they do not require pumping during the spraying process. This is because the tank is pressurized after filling it to about $2/3^{rd}$ and it has a built-in hand pump.

These sprayers have the disadvantages that the spray pressure lowers after some time of spraying and this brings about uneven spray. The use of these sprayers is limited to paddy.

b) Motorized sprayer

There is low volume contained in the tank due to the tank size. A blast of air flows through spraying jet of delivery hose and nozzle tube and ejects spray liquid in this blast. This air blast atomizes spray liquid to fine droplets. The carrier for the liquid is air. The faster the air is pressurized the more the atomization of the liquid chemical. The sprayer is suitable for concentrated liquid due to the high pressure that is generated by the pump.

The main advantages of these sprayers are; they are portable during the operation and the spray speed is high which leads to large coverage of land within a short time

These sprayers also have the following drawback which include; low volume carried leads to loss of time during subsequent refilling, spraying uniformity may be hard to achieve if the pressure is high, the cost of buying the fuel to run the sprayer is high and operation of the sprayer requires skilled personnel.

Below is a diagram showing a knapsack sprayer

Figure2-1: showing a knapsack sprayer

c) **Foot Sprayers / Pedal Pump Sprayers**

These are sprayers which are foot operated or pedaled. They have provisions for 1-2long delivery horses fitted with either lance or nozzle booms.

The diagram of a foot operated sprayer is shown in figure2 below

Figure2- 2: showing a peddle sprayer under use

d) **Tractor mounted sprayers:**

These are high pressure sprayers with spray pressure of between 1.4 to 2.8 kg/cm^2 and fitted with multi nozzle boom. They are very useful in herbicide application for large holding of farmers. Tractor mounted sprayer fitted with booms are used to spray road side vegetation. Tractor run sprayers have the following advantages; high uniformity of sprayers, high working efficiency, full utilization of tractor during idle time.

These sprayers also have some drawbacks which include; they are expensive to purchase and maintain by small scale farmers, they are not suitable for fragmented land

A tractor mounted/drawn sprayer is shown in figure3 below

Figure2- 3: showing a tractor drawn sprayer under operation

e) **Aerial sprayers:**

This is where the herbicides or pesticides are applied with the help of a low flying craft fitted with a boom sprayer. This mode of sprayer is limited to treating aquatic weeds like water hyacinths, paddy fields, large sugar cane plantations.

The advantages of this sprayer are; that it can cover large acreage in a short period of time, they can be used even in water logged places or through thick plantations

The main drawbacks with this sprayer are; they are expensive for rural farmers to purchase, there is high chemical drift which may lead to bad effect on the neighboring gardens or animal and human health

Herbicide application from air is limited to treat aquatic weeds like water hyacinth, paddy fields, and big sugarcane plantations. Presence of obstacles like trees and diversified farming in India are bottle necks in its use.

f) Solar sprayers

These are types of sprayers that are run with the help of solar energy from the sun which is trapped with a photovoltaic cell and converted to electrical energy which is stored in the battery or used direct to run the sprayer. The type of these sprayers that are now available are mounted on the back like knapsack sprayer but with a solar panel which generates energy for pumping the chemicals ***(Lad, Patil, Patil, Pati, & Patil, 2015).***

Solar powered sprayers have the following advantages over other types of sprayers; the cost of running is low since solar energy is freely available, the sprayers are also easy to operate and have moderate spray pressure which greatly reduces on the chemical drift and large acreage can also be covered within a short working period. Solar powered sprayers also reduce on noise pollution of the environment since they are silent during operations. Gaseous pollutants which are associated with motorized sprayers or tractor drawn sprayers, or aircraft sprayers are eliminated with the use of solar sprayers since there is no burning involved during the spraying operations.

Types of solar sprayers

Just like other sprayers solar sprayers also have varying sizes and mode of construction leading to variation in output pressure. There are two common types of solar sprayers that is; the backpack solar sprayers and trolley driven solar sprayers

Backpack solar sprayers

These are almost like the knapsacks the only difference being that they don't have the diaphragm pump embedded in the chemical tank. The chemical is pumped by an external pump which is powered by the solar energy trapped by the solar panel and stored in the battery. The pump, battery and solar panel are all constructed on the chemical tank and carried on the back when spraying. An illustration of a backpack solar sprayer is shown below

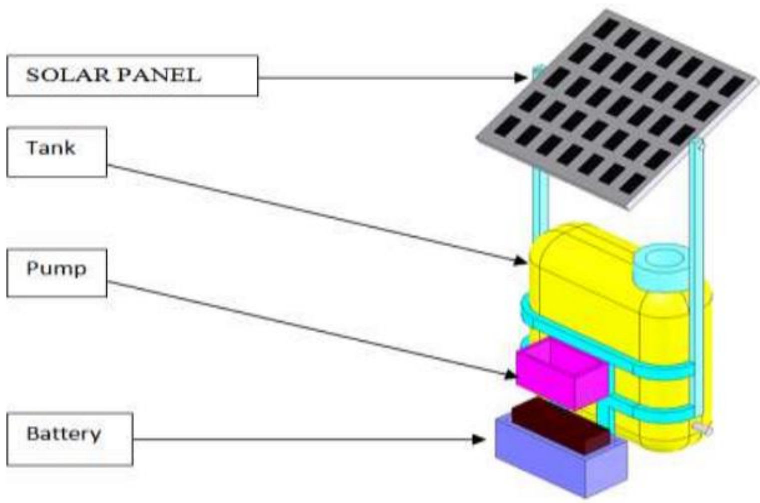


Figure2- 4: showing a backpack solar sprayer

Just like knapsack sprayers, these sprayers have low operating pressure and the tank size is restricted to a size that can be carried during operation with an average weight of about 30kg when the tank is full (***Lad et al., 2015)***

- Trolley driven solar sprayers

These are solar sprayers which have the tank, battery, solar panel, external pump assembled on a frame which is rolled to the field when spraying is to be done. These have tanks of varying sizes from 30litres up to a maximum of about 100litres. The pumps also vary in size depending on the required operating pressure required for the system. They the sprayers have moderate pressure which shortens the operation time. While in the field the whole system can be move while spraying or its made with a long horse pipe which is the only component moved during spraying while the rest of the components are stationed somewhere in the field. Below is an illustration showing a trolley mounted solar sprayer.

For this project, this is the type of sprayer of main interest but specifically trolley drawn. This is so to eliminate the problems associated with both knapsack sprayer, fuel powered sprayers and solar sprayers mounted on the back. This solar sprayer is intended for small scale farmers who may not be in position to purchase and maintain the other types of sprayers mentioned above

Ground nut growth in Uganda

Groundnut (Arachis hypogaea L.) also known as peanut, is cultivated in the semi-arid tropical and subtropical regions of nearly 100 countries in six continents between 40˚ N and S of the equator. It is an important legume grown and consumed globally and in particular in sub-Saharan African countries. For people in many developing countries, groundnuts are the principal source of digestible protein (25 - 34%), cooking oil (44 - 56%), and vitamins. These qualities make groundnut an important nutritional supplement to mainly cereal diets of maize, millet and sorghum of many Ugandans.

In Uganda ground nuts are commonly grown in Eastern and Northern parts of the country. The crop can either be broadcasted or planted in rows. When planted in rows the spacing depends on the growth habit of the variety, botanical type, and the seed mass germination rate of the seed-lot. The recommended space between rows is 45 cm while the recommended spacing between plants within a row is:

- Semi-erect types: 10 - 15 cm (e.g. Igola 1, Serenut 1 and Serenut 2)
- Bunch types: 7.5 - 10 cm (e.g. RedBeauty, Serenut 4T, Serenut 6T)

Groundnut is not suited to growing in very dry areas or at altitudes higher than 1500 metres above sea level (around 5000 ft). Generally higher altitudes with cooler climates are not suitable for groundnut production. Optimum temperatures are 27 - 30 °C for vegetative growth and 24 -

27 °C for reproductive growth. Between 450 mm and 1250 mm of evenly distributed rainfall is required annually for good growth and yield. Early maturing small seeded varieties require 300 - 500 mm while medium to late maturing large seeded varieties need 1000 - 1200 mm rainfall. All soils, other than very heavy ones are suitable for growing groundnut, but the best are deep, well drained sandy, sandy loam or loamy sand soils. The latter facilitate the forcing of the developing fruit into the soil (pegging). Groundnut will not grow well or fix nitrogen in acidic or infertile soils. Groundnuts grow best on soils limed to a pH of 5.8 to 6.2, provided other essential elements are in balance and available to the plant Fertilizer requirements: Groundnuts respond better to residual fertility than to direct fertilization. If a well-fertilized crop precedes groundnuts, direct fertilization may not increase the yield or quality of the groundnuts. If fertilizer is needed, broadcast and incorporate it with the soil during the land preparation. A soil test is the best way to determine whether fertilizer or lime is required in groundnut growing. Liming is necessary only when the soil pH is below 5.8. However if soil test results are not available, the general fertilizer recommendation is: NPK kg /ha: 25 kg of N - 50 kg of P2 O5 - 100 kg of K2 O. Do not apply potassium fertilizers after the groundnuts have emerged. Foliar sprays of nutrients are generally ineffective or not economically feasible, except to prevent or correct some micronutrient deficiencies ***(Kefa, n.d.)***.

Figure2- 5: showing a raw planted ground nuts

Major pests and diseases of ground nuts

Major diseases of ground nuts

- Ground nut rosette

Groundnut rosette disease is a very serious viral disease of groundnuts widespread in sub-Saharan Africa and its off-shore island. It is the major disease of groundnut in Uganda. It is transmitted by aphids feeding on the crop. There are two types of symptom seen in the crops: green and yellow or (chlorotic). The plants affected by this disease look stunted and presents a bushy appearance. Rosette can be controlled by spraying whole plant with insecticides, such as dimethoate 14 days after emergence (usually 5mls per 2 litres of water, but read the label for instructions) and then at 10-day intervals for a total of four sprays.

Figure2- 6: shows aground nuts affected by ground nut rosette

- Early and late leaf spots

Early leaf spot (Cercospora. arachidicola) and late leaf spot (Phaeoisariopsis personatum) are the most damaging diseases of groundnuts worldwide. Besides adversely affecting the yield and quality of pod, they also affect the yield and quality of haulm. Although just one leaf spot pathogen usually predominates in a production region, both leaf spot species are generally found in a single field. Shifts in leaf spot species also have been observed over a period of years. Multiple applications of a fungicide such as benomyl, captafol, chlorothalonil, copper hydroxide, mancozeb or sulphur fungicides may control early and late leaf spot. However, carbendazim (0.05%) controls both leaf spots very effectively. Three sprays of 0.2% chlorothalonil at intervals of 10 - 15 days starting 40 days after germination up to 90 days provides effective control to early and late leaf spots, and rust.

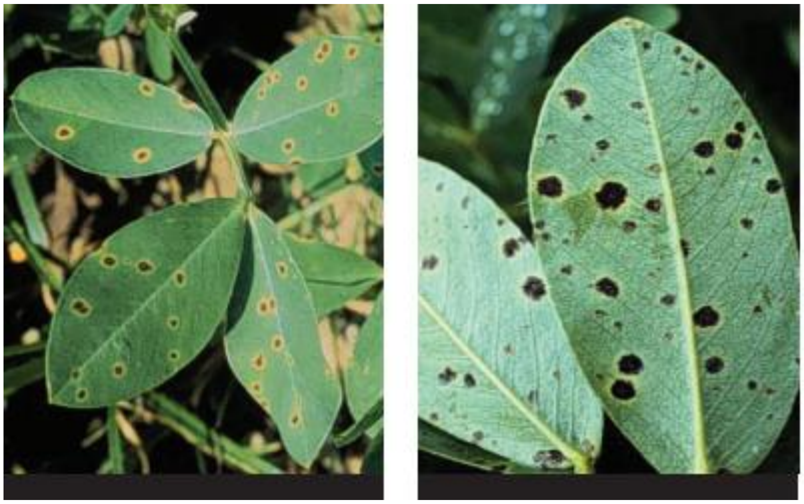


Figure2- 7: shows ground nut leaves affected by early an late blight from left to right respectively

- Ground nut rust

Rust (Puccinia arachidis Speg.) is one of the important foliar diseases that causes substantial losses to groundnut (Arachis hypogaea L.) production worldwide and reduces seed quality. Rust and late leaf spot can together cause over 50% loss to groundnut production and affect seed quality. Spray chlorothaalonil 0.2%; or mancozeb 0.25% or Hexaconazole/propaconazole to reduce disease incidence.

Figure2- 8: shows ground nut leaf affected by ground nut rust

Major ground nut pests

- Aphids:

These are brownish-gray polyphagous insects. They are vectors of groundnut rosette disease, peanut mottle virus and peanut stripe virus in Asia and Africa. Aphids can cause yield losses upto 40%. They can cause serious damage in drought situations when the crop is still young. Aphids are sporadic pests and attack crops at all stages. Both adults and nymphs feed mostly on growing tips and young foliage by sucking sap. Spray dimethoate 30EC at 650ml/ha or monochrotophos 36WSC at 600ml/ha in 600 liter water

Figure2- 9: shows aphids on ground nut stem

- Leaf miner

Groundnut leaf miner (Aproarema modicella Deventer), a defoliator from the order Lepidoptera, is a very serious pests of groundnuts attacking in both the rainy and post rainy season crops and is regarded as the most important pest threatening groundnut production whenever outbreaks occur. It is much more damaging during the short rainy cycle when long drought precedes rains. In Uganda, total crop losses have been reported by some farmers. No resistant variety is yet available in Uganda though tolerant variety Serenut 10R was released in 2011. Spraying with Monochrotophos 36SL 600ml/ha or Dimethate 30 EC at 650ml/ha in 600 liter water

Figure2- 10: shows ground nut leaf eaten by leaf minors

Solar energy

Solar energy is the form of energy that is basically from the sun and comprises of light and radiant heat. This energy influences earth's climate and weather and sustains life. Solar power is sometimes used as a synonym for solar energy or more specifically to refer to electricity generated from solar radiation. Since ancient times, solar energy has been harnessed for human use through a range of technologies which include; solar heating, solar thermal energy, molten salt power plants, artificial photosynthesis, etc. Solar energy along with other secondary energy sources such as wind and wave power, hydroelectricity and biomass account for most of the available flow of renewable energy on Earth. Solar energy technologies can provide electrical generation by heat engine or photovoltaic means, space heating and cooling in active and passive solar buildings, potable water via distillation and disinfection, day lighting, hot water, thermal energy for cooking, and high temperature process heat for industrial purposes. Solar energy can either be used directly or by converting it into electrical energy. The energy from the sun in form of radiations and heat is trapped by a device that is used to convert the radiation into electrical energy. The converted energy can either be stored in a device like a battery for later use or it can be used directly to perform different activities like drying grains, running machines, cooking, pumping water and many others.

Solar energy and its technology is broadly characterized as either active or passive depending on how they capture and distribute solar energy or how they convert it into solar power.

Active solar technology includes; use of photovoltaic system, concentrated solar power, and solar water heating to harness the solar energy. Here the solar energy is trapped by a device which absorbs the energy and converts it to another form of energy

Passive solar technology includes; orienting a building to the sun, use of materials with good thermal mass or light dispersing properties and designing spaces that naturally circulate the air.

Most of the solar energy radiated reaches the earth's surface. This provides abundant solar energy which is managed properly can give high source of electricity.

Sunlight can be converted into electricity using photovoltaic (PV), concentrating solar power (CSP), and various experimental technologies ***(Is & Energy, n.d.)***

The solar energy can be trapped by any of the following;

- Photovoltaic cell (Solar cell)

A solar cell or photovoltaic cell is a device that converts solar energy into electricity by the photovoltaic effect. A photovoltaic cell is an assembly of cells. The cells absorb solar radiations and heat and convert them into electrical energy. Photovoltaic cells generate direct current. The electric energy generated is then transferred through a direct current cable to either an appliance or to a battery for storage. The first solar cell was constructed by Charles Fritts in 1880s using copper oxide. Later in 1931 a German engineer, Dr. Bruno Lange developed a photo cell using silver selenide in the place of copper oxide

- Concentrated solar power (CSP)

This system uses lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. The concentrated heat is then used as heat source for a conventional power plant. A wide range of concentrating light energy exist, the most common and developed are the parabolic trough, the concentrating linear Fresnel reflector, the Stirling dish and the solar power tower. In all the above systems of solar concentration, a working fluid is heated by the concentrated sunlight and then used to power generation or energy storage

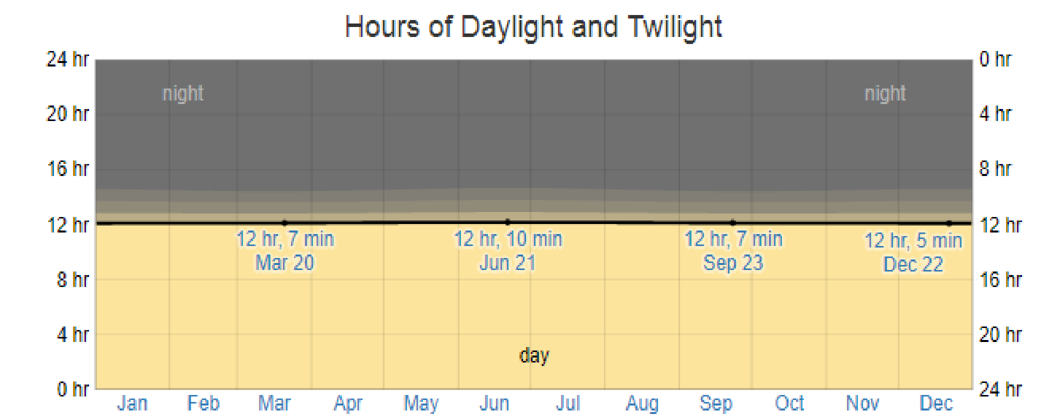
For the aim of this project, a photovoltaic cell will be used as a means of trapping the solar heat and converting it into electrical energy which will be used to run the system

A solar panel that is used for trapping solar energy is illustrated in the figure5 below

Figure2- 11: shows a solar panel fixed on a roof

Sunshine hours for Tororo district

The length of the day in Tororo does not vary substantially over the course of the year, staying within 9 minutes *of* 12 hours throughout. In 2018, the shortest day is December 22, with 12 hours, 5 minutes of daylight; the longest day is June 21, with 12 hours, 10 minutes of daylight***(“Correlation Between Sunshine Hours and Climatic Parameters At Four Locations in Uganda,” 2004)***.

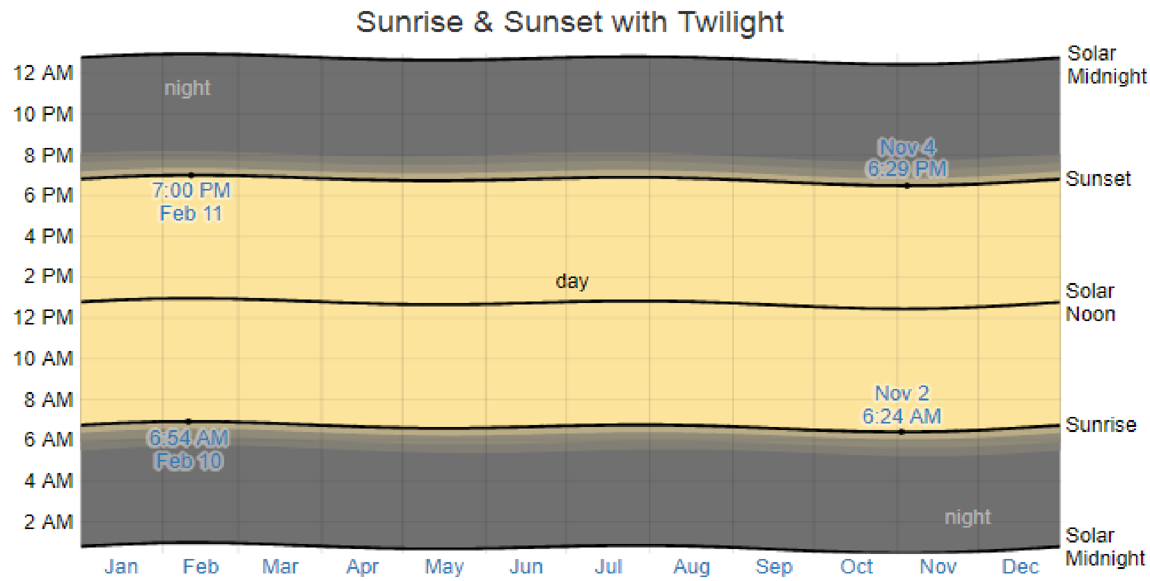


The number of hours during which the Sun is visible (black line). From bottom (most yellow) to top (most gray), the color bands indicate: full daylight, twilight (civil, nautical, and astronomical), and full night.

Figure2- 12: shows the hours of daylight and twilight for tororo district

The earliest sunrise *is at* 6:24 AM on November 2, and the latest sunrise *is* 31 minutes later *at* 6:54 AM on February 10. *The* earliest sunset *is at* 6:29 PM *on* November 4, and the latest sunset is 31 minutes later at 7:00 PM on February 11.

Daylight saving time (DST) is not observed in Tororo during 2018.



The solar day over the course of the year 2018. From bottom to top, the black lines are the previous solar midnight, sunrise, solar noon, sunset, and the next solar midnight. The day, twilights (civil, nautical, and astronomical), and night are indicated by the color bands from yellow to gray.

Figure2- 13: shows the sunrise and sunset with twilight for tororo district

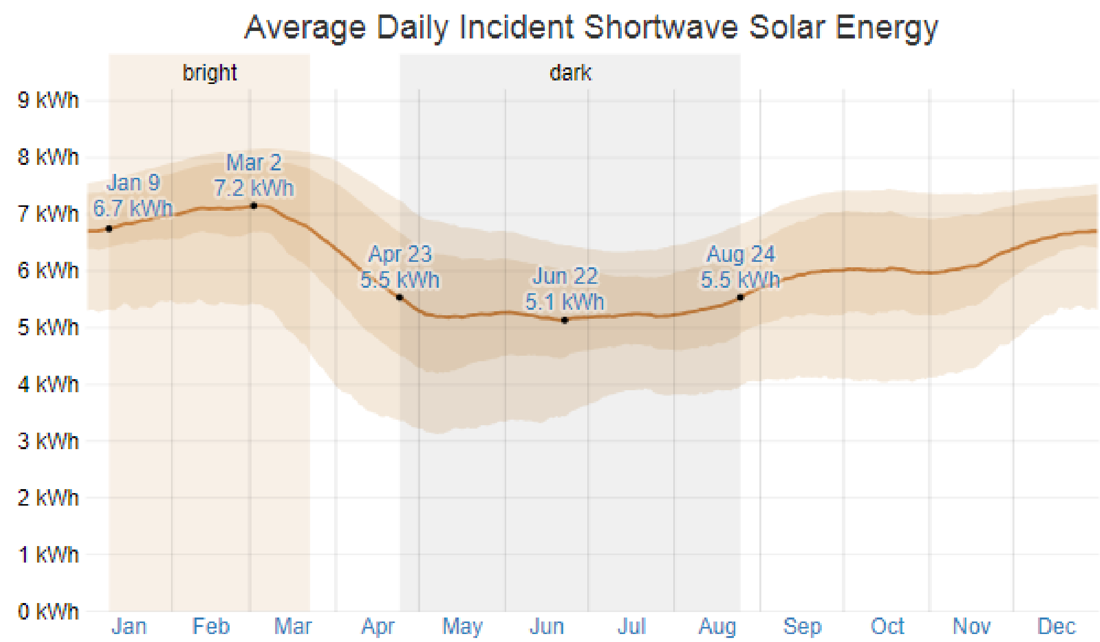
Solar insolation for Tororo district

The total daily incident shortwave solar energy reaching the surface of the ground over a wide area, taking full account of seasonal variations in the length of the day, the elevation of the Sun above the horizon, and absorption by clouds and other atmospheric constituents is detailed below. Shortwave radiation includes visible light and ultraviolet radiation.

The average daily incident shortwave solar energy experiences some seasonal variation over the course of the year.

The brighter period of the year lasts for 2.4 months, from January 9 to March 22, with an average daily incident shortwave energy per square meter above 6.7 kWh. The brightest day of the year is March 2, with an average of 7.2 kWh.

The darker period of the year lasts for 4.0 months, from April 23 to August 24, with an average daily incident shortwave energy per square meter below 5.5 kWh. The darkest day of the year is June 22, with an average of 5.1 kWh ***(“Average Weather in Thiruvananthapuram, India, Year Round - Weather Spark,” 2016)***



The average daily shortwave solar energy reaching the ground per square meter (orange line), with 25th to 75th and 10th to 90th percentile bands.

Figure2- 14: shows the average daily incident of shortwave solar energy for tororo district

Project economic evaluation

Determining the value of a project is challenging because there are different ways to measure the value of future cash flows. Because of the time value of money, money in the present is worth more than the same amount in the future. This is both because of earnings that could potentially be made using the money during the intervening time and because of inflation.

The different methods of economic evaluation include; Net Present Value, Payback Method, Internal Rate of Return and Profitability Index as defined below:

Payback Method (time of capital return)

This method seeks to find out when the initial capital invested would be recoupled or when it will be got back. Pay back method fails to account for the time value of money and when calculated for longer investments, have greater potential for inaccuracy as they encompass more time during which inflation may occur and skew projected earnings and, thus the real payback period as well. It is illustrated in the equation;

$$C_0 = \sum_{i=0}^{n} cf.$$

Where: cf is the cash flow, C_0 is the capital employed, n is the number of periods ……2-1

Net Present Value (NPV)

Net present value is the sum of the present values of incoming and outgoing cash flows over a period of time. Incoming and outgoing cash flows can also be described as benefit and cost cash flows respectively, discounted at the project's cost of capital and deducting the initial outlay. Decision criteria are to accept a project with a positive net present value. Advantages of this method are that it reflects the time value of money and maximizes shareholder's wealth. Its weakness is that its rankings depend on the cost of capital; present value will decline as the discount rate increases. This is illustrated in the equation below;

$$NPV = \left(\sum_{i}^{n} \frac{cf_i}{(1+r)^i} \right) - i_0$$

Where: $\frac{1}{(1+r)}$ is the discounting rate, cf_i is the cash flow (future), n is the number of periods, r is the interest rate, i_0 is the initial capital investment

……2-2

Internal Rate of Return (IRR)

This method equates the net present value of the project to zero. The project is evaluated by comparing the calculated internal rate of return to the predetermined required rate of return. Projects with Internal rate of return that exceed the predetermined rate are accepted. The major weakness is that when evaluating mutually exclusive projects, use of internal rate of return may lead to selecting a project that does not maximize the shareholders' wealth. The equation showing the calculation of IRR is given below;

$$IRR = Hr + NPV_{Hr} \frac{(Lr - Hr)}{(NPV_{Hr} - NPV_{Lr})}$$

Where: Hr is the higher rate, NPV_{Hr} is the higher net present value, NPV_{Lr} is the lower net present value, Lr is the lower rate

.…….2-3

Profitability Index (PI)

This is the ratio of the present value of project cash inflow to the present value of initial cost. Projects with a Profitability Index of greater than 1.0 are acceptable. The major disadvantage in this method is that it requires cost of capital to calculate and it cannot be used when there are unequal cash flows. The advantage of this method is that it considers all cash flows of the project. This is shown in equation below;

$$PI = \sum_{i=1}^{n} \frac{\frac{cf_i}{(1+r)^i}}{i_0}$$

Where: $\frac{1}{(1+r)}$ is the discounting rate, cf_i is the cash flow (future) n is the number of periods, r is the interest rate and i_0 is the initial capital investment …..2-4

CHAPTER THREE: METHODOLOGY

This chapter basically consists of description of the steps taken to achieve the purpose of the project. This ranges from identifying methods of data collection, the materials used for the different components of the prototype, how each specific objective is achieved and the work plan and budget put to achieve the objective of the study.

The design and fabrication of a portable solar sprayer involves the following steps

3.1. Method for data collection

The data and information needed to accomplish the objectives of the study is obtained as listed below;

- ✓ Library research

This involved the use of lecture notes, and different books containing the information about the different types of sprayers, method of trapping solar energy, and plant protection mechanisms. These provide the basic information needed to achieve the purpose of the study

3.2. Specific objective one: To design a system that uses solar energy to run a pesticide sprayer

This, as the first an main objective of the project is be achieved through the following steps

3.2.1. Material selection for the different components of the sprayer

Below is a table showing the specifications for the different components of the sprayer.

This gives the summary of the major specifications for the different components for the system and the reason(s) for which they are selected

Table3- 1: showing the specifications for different component parts of the solar system

S/NO	Part	Specifications/ materials (required)	Reason
1	Tank for the chemicals	30ltr, iron steel	High corrosion resistance Easy availability in the market
2	Solar panel	Capacity: 30W, size: 500x300x20mm, weight: 1.4kg, max voltage: 17.5V, max current: 1.71A	Appropriate solar energy absorption and conversion rate to provide the required power.

3	Pump	discharge: 1l/min, max voltage: 12V	To give the medium discharge rate required for the system
4	Battery	Sealed lead acid battery, capacity: 12V, 9Ah,	Constant charge with regulations Easy availability in the market
5	Controller	12V, 5A pulse with modulation (PWM) technique	
6	Pipes for connection	1/2inch diameter pipes, plastic	High resistance to corrosion
7	Nozzle type	Full cone	Wide coverage, uniform spray
8	Trolley assembly	Steel	Ease to perform the welding operation on the machine, its availability in the market

3.2.2. Considerations for material selection for different component parts

The materials to be used for making of different components will be examined for their behaviors under the different working conditions to make sure that they suit the purpose for which they are used well without failing ***(Law, 1921)***.

The materials used will be selected basing on the following properties:

a. **Strength**: The material used should be strong enough to withstand the forces applied to it without failing by either buckling, bending etc.
b. **Durability**: The material should be durable enough such that it can be used for a good period of time before replacement is done.
c. **Weight**: The materials used should not be very heavy as this will increase on the weight of the whole system and hence become a burden to the operator'
d. **Resistance to corrosion**: The materials should have high corrosive resistance since they are going to be used on chemicals which contain varying degrees of corroding elements
e. **Machinability**: The materials should also have high weld ability and machinability in case they are to be welded or machined no damage should be done to them.

f. **Availability**: The materials to be used should also be readily available in the local market such that in case of any break down they can be easily obtained.

3.2.3. Prototype drawing and process diagrams

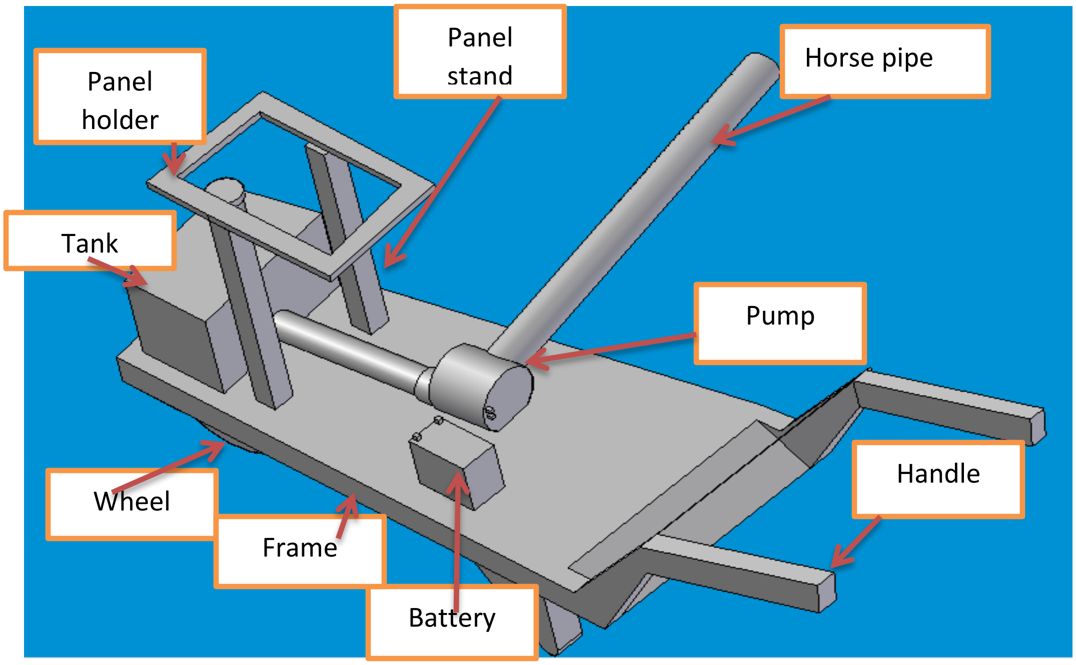


Figure3- 1: shows the system drawing for the prototype

3.2.4. Process diagram

The process diagram below shows the sequential steps for power transfer until the chemicals are pumped out

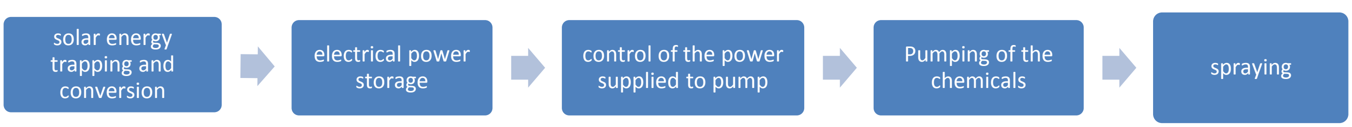


Figure3- 2: Shows the process diagram for the prototype operation

Design considerations for the different parts of the system

- *Design considerations for the component parts of sprayer.*

i. **The trolley/ the frame**

The main force acting on the frame is the weight of the components loaded on the frame and the weight of the fluid in the tank. The force is determined by the amount of load on the frame. These induce stress on the components of the frame.

The stress for which the frame is subjected to is given by the equation below

$\sigma = \frac{\text{W}}{\text{A}}$.....................1

$where$;

$W\ is\ the\ weight\ of\ the\ components\ in\ N,$

$A\ is\ the\ area\ of\ the\ frame\ in\ m^2,$

$\sigma\ is\ the\ stress\ in\ N/m\hat{}2$

The area is determined from the equation below

$A = L1 * B$.......................2

L1=1000mm =1m

B=500mm =0.5m

$$A = 1 * 0.5$$

$$\boldsymbol{A = 0.5m\hat{}2}$$

Where, L1 is the length covered by the implement, and B is the maximum width. All in meters (m)

$W = M * g$...............3

M is the mass of the frame and all the components assembled on it (kg), the mass includes the tank containing the chemicals, the solar panel, the battery, controller and the pump

g is the acceleration due to gravity (ms^{-2})

M=50kg

g=9.81ms^{-2}

$$W = 50X9.81$$

$$\boldsymbol{W = 490.5N}$$

Stress on the frame is given as

$\sigma = \frac{\text{W}}{\text{A}}$, as from in equation 1

$$\sigma = \frac{490.5}{0.5}$$

$$\boldsymbol{\sigma = 981.0N/m2}$$

Where; σ is the stress in the frame (N/m^2)

W is the total weight of the equipment carried on the frame (N)

A is the area covered by the equipment (m^2)

For the wheel, considering the maximum height of ground nuts 0.3m, wheel of diameter 30cm is selected with gripping width of 20mm

ii. The tank

A tank of 32litres is made from steel with the dimensions got by the equation

$V = b * w * h$……………….4

$$V = 0.39 * 0.355 * 0.23$$

$\boldsymbol{V = 0.0318m3}$ **=31.8litres**

Where: **V** is the volume of the tank (m^3); **b** is the length of the tank (m); **w** is its width (m) and **h** is the height of the tank (m).

iii. **Discharge**,

Since the discharge is main determining factor, the require discharge is 1l/min as compared to the discharge of the ordinary knapsack sprayer of 1l/min

$$\boldsymbol{Q = 0.001m3/min}$$

The required discharge is 3ltres/min

Where; Q is the rate of chemical discharge (m^3/s), V is the volume discharged (m^3), t is the time (s)

iv. The pump selection

Considering the required discharge of 1l/min and motor of efficiency 80%, discharge length of 3m, the power required to run the pump is given as

$P1 = (\rho * h * g * Q)/\mu$……………..5

Where

ρ *is the density of the liquid*(*water*), *h is the discharge height*, *g is the acceleration due to gravity*,

Q is the discharge, μ *as the motor efficiency*, μ *efficiency of the motor*

$$P1 = (\rho * h * g * Q)/\mu$$

$$P1 = (1000x3x9.81x0.00017)/0.75$$

Q= 1l/min =0.00017m^3/s

$\boldsymbol{P1}$ **=18.4W**

v. The solar panel selection

$P0 = V0 * I0$……………….6

V0=17V

I0=1.76A

$$P0 = 17 * 1.76$$

$$\boldsymbol{P0 = 29.92W}$$

Rated power =30W

The power produced by the solar panel is given by equation below

Where; P_0 is the power generated by the solar panel (W)

I_0 is the current generated by the panel (I).

V_0 is the voltage produced by the panel after solar energy conversion

vi. The battery selection

The power stored in the battery and is given as in equation 4 below

$P2 = V2 * I2$……………..7

V2= 12V

I2= 12Ah

$$P2 = 12 * 12$$

$$\boldsymbol{P2 = 144Whr}$$

Where: P_1 is the maximum power stored in the battery

Where:

V_1 is the voltage stored in the battery (V)

I1 is the current in the battery (Ahr)

The power stored in the battery is generated by the solar panel which is the solar energy converted to electrical energy.

Time required to charge the battery, t is given by the equation below

$t = P2/P0$……………..8

$$t = 144/29.92$$

$$\boldsymbol{t = 4.8hrs}$$

Where**,** **t** is the time in hours

Time required to charge the battery to full capacity depends on the duration of solar insolation, intensity of the solar insolation and the absorption and conversion rate of the solar panel used

The operation time, T of the battery is given by the equation below

T = (Power stored in battery / Power Consumed by (pump))

$T = P2/P1$……………..8

$$T = 144/18.4$$

$$\boldsymbol{operating\ time, T = 7.8hrs}$$

Maximum pressure required to lift the chemicals is given as;

$P = \rho * h * g$…………….10

ρ=1000kg/m^3

h=3m

g=9.81m/s^2

$$P = 1000 * 3 * 9.81$$

$$\boldsymbol{P = 29430Pa}$$

Where; ρ is the density of the chemical (kg/m^3) and is a constant for a given chemical formulation. For this case, we will use the density of water which is 1000kg/m^3

h is the height of the nozzles above the ground (m)

g is the acceleration due to gravity (m/s^2)

3.3 Specific objective two: Fabricate the different parts of the system and assemble them

Different activities were carried out during the fabrication of the prototype. These activities were done in order to make the trolley with its wheel, chemical tank, the stand for the solar panel and the fan. The materials used during the fabrication of the above components were: 3mm thick sheet steel plate, angle bars, round bars, metallic pipes of internal diameter 1/2inch.

The activities carried out during the fabrication included;

- ✓ **Measurement and marking out process**

  The metal plates, angle bars, round bars, metallic pipes were measured using a tape measure to the required lengths. The measured lengths are then marked out using scriber and chalk.

- ✓ **Cutting out of the parts and welding them**

  The marked out materials were then cut out at the marked points using angle grinder

- ✓ **Assembly of the welded parts**

  The cut pieces were then joined by arc welding to form the frame, tank, stand for the solar panel, and the trolley wheel. Bolts and nuts are also used in the assembly of some components like the pump to keep in firm on the frame.

Finishing process

This included among others texturing using sand paper, and finally painting.

3.4 Specific objective three: To test the assembled system on its purpose and making of adjustments

The assembled system is then tested for performance under different conditions which include;

- The operation of the pump (rate of discharge) when connected to the solar panel direct without the battery. This is to establish the efficiency of the solar panel. This is also done when the solar panel is subjected to varying light intensities for example when the solar panel is partly covered, when the tilt angles are changed.
- The operation of the pump when connected to the charged battery. To establish the strength of the battery in running the pump and its operation time
- Testing of the charging duration of the battery

$$Efficiency = \frac{\text{(actual output)} * 100\%}{\text{desired output}}$$

3.5 Specific objective four: To carry out economic analysis of the system

The cost analysis was done based on the present value after a period of four years. The net present value (NPV) of the project after four years was got as below. It put into consideration the initials investment costs, the contribution over the four years and the total running costs over the four year period. The cost incurred and the contributions were considered under a rate of 10% per annum.

The initial investment of is the total cost incurred in the project, the contribution/revenue is got from the yield per year and the running costs include the cost of purchasing the required chemicals and maintaining the equipment

Initial cost, **I_c =1,005,000/=**

Contribution over four years, C= revenue*d.f

d.f is the discounting factor

Revenue per year: this is got by multiplying the cost of a bag of unshelled ground nuts X the number of bags harvested X number of seasons in a year

No. of seasons, 2

No. of bags per seasons, 12

Cost of a bag of ground nuts 120,000/=

R=2*12*120000

R=2, 88,000 /=

d.f (10%) over four years 3.1699

Total contribution C, 3.1699*2,880,000

C =9,129,312/=

Total running cost in a year, C_r =100,000/=

Total running cost in 4years, C_r =100000*3.61699

C_r =316990/=

$$NPV = \left(\sum_{i}^{n} \frac{cf_i}{(1+r)^i} \right) - i_0$$

From equation 2-4, the NPV is got by; this is shown in the table below with cf_i =d.f

Table3- 2: shows the net present value calculation for the project

Item	Valuation (Ugx)	d.f (10%) 4years	Present value (PV) (Ugx)
Initial investment,I_c	(100,5,000)	1	(100,5, 000)
Contribution, C	2,880,000	3.1699	9,129,312
Running cost, C_r	(100,000)	3.1699	(316,990)
			NPV **7,807,622**

CHAPTER FOUR: RESULTS AND DEUCTIONS.

Under this chapter, the results are derived based on the specific objective and the methodology and the discussions come direct from the results got.

4.1. Fabrication and test results

4.1.1. Fabrication results

Note: All dimensions are in inches

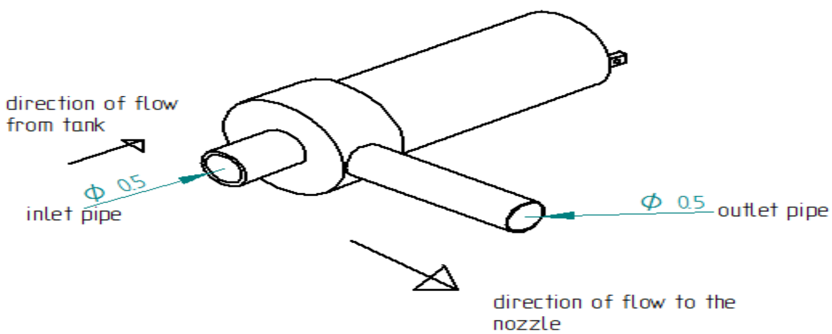


Figure4- 1: shows the system pump with the pipe diameters

Figure showing a pump with the dimensions of inlet and outlet nozzles

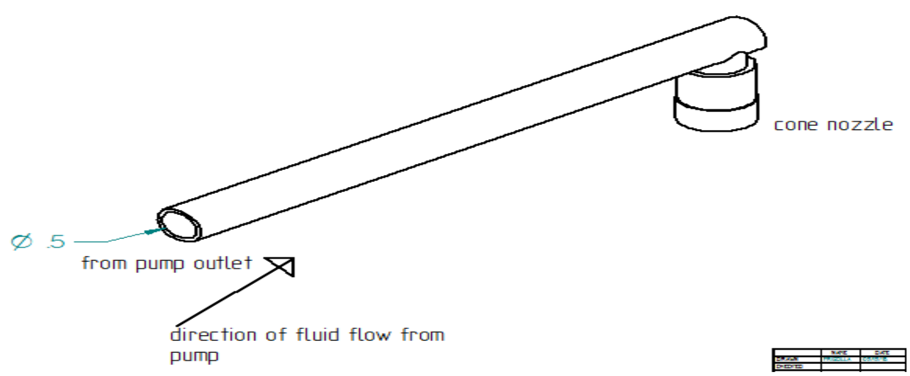


Figure4- 2: showing the horse pipe with nozzle at the tip

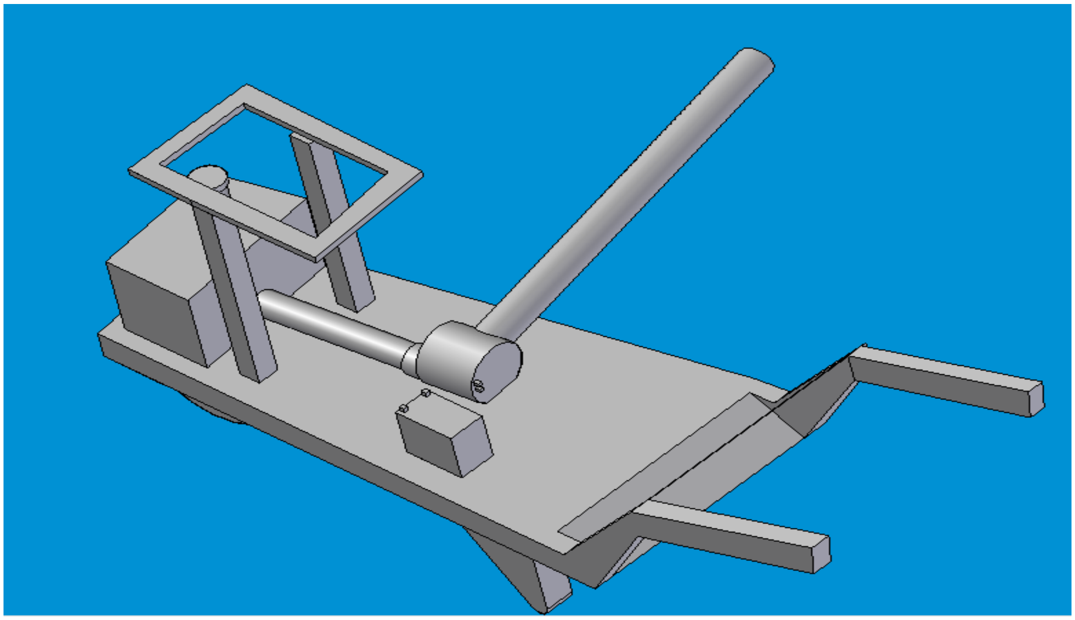


Figure4- 3: shows the fully assemble system parts without solar panel and nozzle

A table below shows all the results for the design consideration for the different components of the system

Table4- 1: showing the design results for different parts

Parameter	**Equation**	**Solution**
Stress on the frame, σ	W/A	981.0N/m^2
Volume of the tank, V	B*w*h	30litres
Required discharge, Q		1l/min
Pump required power, P	(ρ*H*g*Q)µ	18.4W
Panel specification		30W, 17.5V, 1.7A
Battery selection		12V,12Ah
Wheel selection		Ø0.3m, width 0.02m

4.1.2. Test procedure

The testing was done under different conditions but with similar procedure as below

I. The tank is filled with water and all the pipe connections are fixed
II. For direct testing of the system on solar power, the pump is connected to the solar panel terminals
III. For testing on the battery, the battery is connected to the solar panel terminal, the pump is then connected to the battery terminals via a switch
IV. In both sets of connection, the system is switched on via a switch and the pump begins to run
V. As the pump begins to run, a stop clock is started simultaneously.
VI. With a 1.5litre bottle put at put at the nozzle tip, the liquid is collected and the time it takes to fill the bottle is noted
VII. The volume collected in one minute is then got from relating the above results with the time factor.
VIII. The discharge is then calculated from Q=V/t

The process is repeated from ii for different light intensities and angle of placement of the solar panel

N.B: During operation in the field, the system is centrally positioned in the plot to be sprayed and only he long horse pipe is moved during spraying. This reduces on the system wheel damage to the crops being sprayed and the weight of the system is also not centered on the person spraying.

The results are recorded in the table below

4.1.3. System test results under different conditions

Table4- 2: shows the test results under different light conditions

Test	**Test condition**	**Results**
Pump operation under direct solar panel, rate of discharge	Normal light strength, 90degrees	0.6l/min
	Normal light strength, 45degrees	0.82l/min

	Dim light	0.2l/min
Pump operation on charged battery, rate of discharge	Fully charged battery	0.91l/min
	Half charged battery	0.83l/min
Battery charging time, time in hours	Normal light strength, 90degrees	0.90l/min
	Normal light strength, 45degrees	0.94l/min
	Dim light	0.25l/min

The table below shows the test results under different light intensities and angle of panel inclination

Table4- 3: showing summary of the test results under different conditions

Test conditions	Some of result	Average result
Normal light, 90dregrees	0.61+0.90	0.755l/min
Normal light, 45degrees	0.82+0.94	0.88l/min
Dim light	0.2+0.25	0.225l/min

4.1.4. Application/discharge efficiency of the system

System efficiency under normal light strength of the system, 90degrees, μ_{90}= (0.755/1)*100%

μ_{90}=75.5%

System efficiency under normal light strength of system, 45degrees, μ_{45}= (0.88/1)*100%

μ_{45}= 88%

System efficiency under dim light, μ_{dl}= (0.225/1)*100%

μ_{dl} =22.5%

Efficiency of the system under fully charged battery, μ_{fc}= (0.91/1)*100%

μ_{fc}= 91%

Efficiency of the system under half charged battery, μ_{hc}= (0.83/1)*100%

μ_{hc}= 83%

4.1.5. Cost analysis

The net present value of the project is shown in the table below

Table4- 4: showing the net present value for the project over four years

ITEM	VALUATION (UGx)	d.f (10%) 4years	PRESENT VALUE (PV) (UGx)	
Initial investment, I_c	(100, 5,000)	1	(100, 5,000)	
Contribution, C	2,880,000	3.1699	9,129,312	
Running cost, C_r	(100,000)	3.1699	(316,990)	
			NPV	7,807,622

4.2. Deductions

From the above observations, it is noticed that the system performance is affected by light intensity variation which affects the overall solar energy collected by the solar panel.

This in turn affects the rate of discharge for the case of direct connection from the solar panel

The angle of inclination of the panel also affects the light absorption by the solar panel.

From the cost analysis of the project over the four year period , the return can be seen based on the net present value which is **Shs.7,807,622** over four year period. Since the NPV is positive an big, it shows that the project is viable.

The work plan and cost projections for the project

The work plan

Cost analysis for the project

Table4-5: shows the project investment costs

Item	Description	Quantity	Unit cost (UGX)	Total cost (UGX)
Prototype	Frame	1	170,000	170,000
	Tank	1	30,000	30,000
	Battery	1	100,000	100,000
	Pump	1	100,000	100,000
	Solar panel	1	110,000	110,000
	Controller	1	55,000	55,000
	Horse pipe and nozzles	1 horse pipe	20,000	20,000
Labor	Man power during fabrication		200,000	200,000
Transport			150,000	150,000
Secretarial work	Printing and photocopying		50,000	50,000
Communication	Calling and data		20,000	20,000
Total				**1,005,000**

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The solar powered sprayer system was successfully designed, constructed and tested for performance

The system was tested under varying solar energy intensity, solar panel incline angles and direct use of the system on battery only when the solar panel was not connected

The system was tested using 12V motor pump and 12V, 12Ah battery

The performance is affected by solar intensity

Machine efficiency is 88%

5.2. Recommendation

The following are the recommendations for the project

For higher production, the size of the tank should be increased to cater for the large volumes required

The tank should be made of materials like plastics or aluminum with high corrosive resistance for the longer life of the tank

There is also need to increase the size of the collector panel and pump for high pressure sprays to meet the required operating pressure and given head.

From the test results also it’s recommended that the solar be inclined at 45degrees for higher discharge as greater solar energy is collected with the panel inclined at that degree.

For larger area coverage, the length of the horse pipe should also be increased such that during spraying a bigger area is covered before the system is moved to another central position.

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