Development of Push Type Manually Operated Multi Nozzle Sprayer

THESIS

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MASTER OF TECHNOLOGY

In

AGRICULTURAL ENGINEERING

(Farm Machinery and Power Engineering)

By

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CERTIFICATE – I

This is to certify that the thesis entitled "**Development of Push Type Manually Operated Multi Nozzle Sprayer**" submitted in partial fulfillment of the requirement for the degree of **MASTER OF TECHNOLOGY** in **AGRICULTURAL ENGINEERING (Farm Machinery and Power Engineering)** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Mr**. **Vikas Lilhore** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.

All the assistance and help received during the course of the investigation have been duly acknowledged by him.

Place: Jabalpur **(Prof. R.K Dubey)**

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The matter embodied in the thesis has not been submitted for the award of any other degree/diploma. Due credit has been made to all the assistance and help.

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Place: Jabalpur

Date: **(Vikas Lilhore)**

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LIST OF ABBREVIATION

Symbol/Abbreviation	Stand for
%	Per cent
=	Equals to
©	Copy right
0^0	Degree
a.i.	Active Ingredient
Avg.	Average
CAE	College of Agricultural Engineering
CV	Coefficient of variation
et al.	And other
Fig.	Figure
h	Hour
ha	Hectare
ICAR	Indian Council of Agricultural Research
JNKVV	Jawaharlal Nehru Krishi Vishwa Vidyalaya
kg	Kilogram
km/h	Kilometer per hour
l	Litre
m	Meter
m^2	Square meter
min.	Minute
mm	Millimeter
MP	Madhya Pradesh
Sec.	Seconds
gpa	

CHAPTER – 1

INTRODUCTION

INTRODUCTION

Agriculture, with its allied sectors, is the largest source of livelihoods in India. 70 per cent of its rural households still depend primarily on agriculture for their livelihood, with 82 per cent of farmers being small and marginal (India at a glance, www.fao.org). Hence, it is said that India is an agricultural-based country. But till now our farmers are doing farming in the same traditional ways. They are doing seed sowing, fertilizers, and pesticides spraying, cultivating by conventional methods. In general, there is a need for development in this sector and particularly, in the application of the pesticide spraying technique, because it requires more effort and time to spray traditionally. Most Asian nations are at the developing stage and they are facing the problem of high population and as compared to that agricultural productivity is much lower as compared to developed nations. India is one of the nations that is facing the same problem. This is caused due to low-level farms, insufficient power availability to farms, and poor level of farm mechanization. In the Agricultural sector use of economical and beneficial equipment for effective spraying to increase productivity is the demand of today. Generally, mechanization of small farms is very difficult and non-affordable because of the costly farm machinery. With the introduction of modern time-saving machines, we have increased the level of mechanization along with the increase in production also.

The agriculture sector is facing problems with capacity issues, shrinking revenues, and labour shortages, and increasing consumer demands. The prevalence of traditional agriculture equipment intensifies these issues. Besides, most formers are desperately seeking different ways to improve the equipment quality while reducing the direct overhead costs (labour) and capital.

Thus, a significant opportunity rests with understanding the impact of a sprayer in an agriculture field.

Insects are largely responsible for crop damage. Insecticides or pesticides, whether man-made or natural preparation is being used to kill insects or otherwise control their reproduction. These herbicides, pesticides, and fertilizers are applied to crops with the help of a special device known as a "Sprayer," sprayer provides optimum performance with minimum efforts. The invention of a sprayer for spraying pesticides and fertilizers brought a revolution in the agriculture or horticulture sector in past decades and enabled farmers to obtain maximum agricultural production. They are used for garden spraying, weed, and pest control, liquid fertilizing, and plant leaf polishing. There are many advantages of using sprayers such as their easy operation and maintenance. Also, it facilitates the uniform spread of the chemicals, capable of throwing chemicals at the desired level, precision-made nozzle tip for the adjustable stream, and capable of throwing foggy spray, light, or heavy spray, depending on the requirement.

The majority Indian farmers are using conventional methods for spraying, these methods include the knapsack sprayer which has to be mounted on the back and requires the lever to be operated manually to spray. Continuous weight on the back of the farmer leads to back pain and manual pumping leads to drudgery on farmers. There is a need to make this operation less drudgery and to speed up the spraying application in the field. The study of different spraying practices and sprayers being used in Indian farming is important for the effective design of a new kind of sprayer. Present sprayers, which are being operated on fossil fuels, also increase the cost of operation.

In markets tractor operated, battery operated and fuel operated sprayers are available. But fuel operated sprayer is to need to purchase the fuel or external source of energy which increases the working cost of production. These all types of sprayers are not having a uniform distribution of chemicals in the field and also not beneficial for small farmers and all types of crops.

Now day’s farmers are used different types of insecticide, fungicides, and other agents that control or eliminate unwanted insects, pests, and weeds in farms to get enhanced crop production. To overcome these problems, I have suggested a wheel driven multi-nozzle sprayer, in this push type sprayer rotary motion of the wheel is converted into reciprocating motion of piston which is fitted in the knapsack sprayer and nozzles or boom which are connected at the front end of the spraying equipment. The goal of the project is to reduce human efforts, save fuel, time, reduce the application rate of the chemicals (like insecticide, fungicides, and pesticides) and the cost of operation during the spraying in the field. It is a movable device and does not require any fuel for its operation, easy to move, and sprays all types of liquid chemicals by moving the wheel.

Keeping all these views we have selected the topic under the title design and development of a push type wheel operated multi-nozzle sprayer with the following objectives.

1. To design and develop a push type wheel operated multi-nozzle sprayer.
2. To evaluate the performance of developed push type multi-nozzle sprayer.

CHAPTER – 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

This chapter briefly reviews the results carried out by various researchers in the field of design and development of manually operated push type multi nozzle sprayer. The reviewed literature reveals various problems faced during spraying operation and also highlights recent developments of wheel operated sprayer. A number of researchers have worked on spraying and plant protection. The literature under this section has been divided into four sections as mentioned below.

2.1 Yield Losses due to Pests and Diseases

Plants are the source of the air we breathe and most of the food we eat, yet we often don't think about keeping them healthy. This can have devastating results. FAO estimates that up to 40% of food crops are lost due to plant pests and diseases annually. This leaves millions of people without enough food to eat and seriously damages agriculture - the primary source of income for rural poor communities.

The term 'pest' refers to all biotic agents that cause diseases of crops and other valued plants, insects, plant-parasitic nematodes, mites and vertebrates that feed upon them, and weeds that compete with them. Insecticides, fungicides and herbicides are all crop protection products. Insecticides are used to control insect pests such as aphids or greenfly. Fungicides deal with the fungi or moulds that can affect seed germination, crop growth and the quality of the harvested produce. Weed-killers control plant pests such as chickweed, cleavers and black grass that rob the crop plant of light, water and food. Prevention is critical to avoiding the devastating impact of pests and diseases on agriculture, livelihoods and food security and many of us have a role to play.

Shetty et al. (2008) found that lepidopteron, coleopteran and dipterans insect pests cause severe yield losses in many of the commercial crops grown all across India. For instance, Helicoverpa armigera infests a variety of crops like cotton, tomato, brinjal, cabbage, cauliflower, bhendi, red gram, etc. The tropical climate is more conducive for the development of insect pests, than the disease-causing pathogens. However, fungal diseases in many crops of commercial importance are a problem in India during the rainy season. The genus Phytophthora is the most severe across many crops, including potato, cardamom, banana, etc. Powdery mildew affects a wide range of crops (cucurbits and grapes), including major cereals like wheat, sorghum and millet. Fungal anthracnose affects crops such as black pepper, beans, cassava and sorghum. Bacterial diseases cause huge crop losses, particularly diseases caused by the genus Xanthomonas, which include blights in banana, rice and cotton in India.

Abdul et al. (2016) found that the Warmer temperatures, changes in precipitation, increased drought frequency and higher CO2 concentrations due of climate change will have a devastating effect on abundance of insect pests, which might lead to the emergence of new pests. It is likely that if measures and global collaborative efforts are not undertaken, most pests will have a cosmopolitan range wherever the climate is favourable and the hosts are available. Further, pest control strategies such as host plant resistance, biological control, synthetic insecticides, etc., may be rendered less effective. Understanding insect-plant interactions, efficacy of natural enemies, host plant resistance, bio pesticides and synthetic insecticides under climate change need to be studied carefully to devise appropriate methods for pest management.

2.2 Classification of Spraying Equipment

Selection of appropriate spraying equipment is very important as it is to be used successfully and economically. The size of the appliance should be such as to cover the field in a short time that is often critical. Different types of application equipment are used to apply pesticides formulated in liquid, dust and granule forms. An equipment applying pesticide in liquid form is called a sprayer. This application equipment may be manual or power operated. Farmers use manually operated knapsack sprayers, motorized knapsack sprayer and power operated hydraulic sprayers for spraying the vegetable crops.

Bindra and Singh (1977) studied on various types of nozzles, which are adopted for the atomization of the pesticides. The nozzles are classified according to the form of energy used for atomization of spray liquid as Hydraulic energy nozzles, Gaseous energy nozzles, centrifugal energy nozzles, kinetic energy nozzles and thermal energy nozzles.

Pal and Gupta (1996) classified the commonly used spraying equipment as hand operated hydraulic sprayers (knapsack sprayers), power-operated hydraulic sprayers (tractor-mounted sprayers), air carrier sprayers (mist blowers), electrodyne sprayers (electrostatic sprayers), birky sprayers (birky knapsack sprayers), controlled-droplet application sprayers, and dusters.

Jain and Philip (2009) classified the sprayer according to the type of energy used for droplet formulation and according to the power used for application as hydraulic energy sprayer which includes foot sprayer, hand compression pump, manually operated knapsack sprayer, power sprayer etc. gaseous energy sprayer which includes air atomiser, air flow sprayer, spray blower, mist blower, motor operated knapsack sprayer and air blower, centrifugal energy sprayer and kinetic energy sprayer. He also classified sprayers as manually operated and power operated according to the power used for application.

Gurjar et al. (2015) reported about working of a solar powered sprayer. Solar powered sprayer is a technology suitable application in the farming community of India. Solar powered sprayer can be used as a fuel alternating device. It works on the principle of solar photovoltaic (PV), with certain modifications on the existing power sprayer in the market. The annual maintenance charge of the sprayer was found to be around Rs.500 with the initial investment of Rs.5000 towards the cost of the sprayer.

Bhagat (2017) designed and developed a technology for spraying and seed sowing. This technology could be run on mechanical power and required less time for spraying and seed sowing than those which were hand operated. He came –up with a mechanically operated multipurpose spray pump and seed sowing machine. They also claimed huge advantages of this technology in agriculture. The developed sprayer 2 number of nozzles which will cover maximum area in minimum time and having maximum discharge rate 0.001 mm^3 /sec at 36 rpm.

2.3 Problem during the operation of Knapsack Spray

Phadke et al. (1992) evaluated the ergonomic conditions of a knapsack sprayer operator during spraying operation. They conducted tests on four models of knapsack sprayers for their study. The results obtained were: average effort to lower the pumping lever of 71.40 N and to raise, an average effort of 18.70 N, not distinguishing the right arm from the left; number of strokes required to create 300 kPa pressure was 10.15 and the number of strokes required to maintain the 300 kPa pressure was 11.05, mean values.

Souza and Santana (2011) reported the effects of using heavy equipment by the workers. These workers were subjected to fatigue and development of musculoskeletal problems. The authors recommended the adoption of posture training, workout gymnastics and the adoption of scheduled breaks to mitigate the risks involved due to the sprayer weight.

Sasaki et al. (2014) conducted research work on indirectly measurement of the physical effort while using knapsack hand sprayers (cardiac frequency and O_2 consumption). They also classified the use of hand operated sprayers as moderately heavy activity.

Franca et al. (2015) reported that during the development of hand operated knapsack sprayers, the effect of repetitive effort on muscular fatigue were not considered. The knowledge of this characteristic had also led to the development of alternative equipment based on the knapsack hand sprayer using the tractor as a power source.

Lambrecht et al. (2018) found that the employed methodology was adequate to measure the operator's upward and downward effort required for the operation of knapsack hand sprayers. Considering the Brazilian laws, CLT - Law no. 6,514, all sprayers obtained satisfactory results, i.e. with effort values below the expected limit. However, only “A” and “E” sprayers obtained satisfactory results for the international indications (NASA-STD-3000B) for manual activation lever. The results demonstrated that the maximum (downward) effort required by the sprayer pumping lever was 69.3 N (Sprayer D). Considering the CLT - Law no. 6,514, the activation effort required to achieve the 300 kPa pressures was below the proposed limits. However, compared to that recommended by NASA-STD-3000B, the effort is above the limit of 60.8 N for the left arm, but within the limit for the right arm of 71.2 N in descending movement which is the predominant arm of the operators.

2.4 Factors Responsible for Effective Spraying

The various factors responsible for uniform spray distribution of chemical across the field are nozzle pressure, height, spray angle, speed of travel; spacing between the nozzles, droplet size etc. and this section includes works done by researchers on various factors that affect spraying.

Azimi et al. (1985) found that increased nozzle height improved spray distribution and allowed nozzle distribution at reduced pressure and/or increased spacing. The distribution improved as pressure increased within the range of pressures used for fan nozzles. Higher pressures created wider spray angles that created less variation in the spray distribution across the swath. The smaller capacity nozzles were more vulnerable to poor distribution due to fluctuations in height and pressure when they were operated at 510 mm or larger spacing.

Matthews (2004) discussed the main factors that need to be considered in describing an application of a pesticide in field studies. The factors included nozzle type, spray volume, spray concentration, operating pressure, spray quality, spray angle, Position of nozzle or nozzles relative to a crop canopy etc. which should be considered while spraying chemicals.

Bretthauer et al. (2009) studied the management of foliar soybean diseases such as Asian Soybean Rust and reported that it required good canopy penetration and thorough spray coverage. The purpose of this study was to examine how spray application rate and spray droplet size affect the efficacy of rust applications in wide-row (36 inch) soybean plantings. The VC spray quality treatment at 15 gpa had the highest coverage and deposition in both the upper and lower canopy. No significant differences in rust severity or yield were observed between the treatments. All treatments had significantly lower rust severity than an untreated control. These results demonstrated that a larger droplet spectrum application, while reducing spray drift, could also potentially provide effective control of rust in wide row soybean plantings.

2.5 Evaluation of existing sprayers

There are various types of sprayers such as self-propelled, tractor drawn, power tiller operated etc. This section includes work done by various researchers related to design and development of different sprayers.

Poratkar and Raut (2013) reported the work on development of multi nozzle pesticides sprayer pump. They suggested a model of manually operated multi nozzle pesticides sprayer pump which would perform spraying at maximum rate in minimum time. Constant flow valves could be applied at nozzle to have uniform nozzle pressure.

Kumar and Parameswaramurthy (2014) conducted research on design and development of wheel and pedal operated sprayer and reported that this wheel and pedal operated sprayer was low cost and easy to move in the fields and also improved the quality of spraying pesticides. After experimentation of this wheel driven sprayer device, it was observed that the average discharge was 1.42 l/min and application rate was 333.3 l/ha. The developed sprayer cover two parallel rows simultaneously without any additional energy being used as well as it reduced the fatigue of the operator.

Rangari et al. (2015) reported on sprayer of fertilizer and pesticides which could simply be pulled by hand or with the help of bullock. That paper suggests a model of manually operated multi nozzle pesticides sprayer. This would perform spraying at maximum rate in minimum time and optimum utilization of organic pesticides and evenly distributing it. They used a separate tank of organic fertilizer and two knob arrangement for flow of liquid fertilizer with the gravity force. Constant flow-valve was used at nozzle to have control of flow for fertilizer. The cost may be around ₹ 25000/- but it would be one time investment for the farmers for higher productivity of crops

Sanjay S. et al. (2015) worked on the design and fabrication of mechanical pest sprayer. They designed a model running without any fuel and as well as easy to operate for a user. In this model, they simply used a sprocket mounted on rear shaft which actuated piston inside cylinder in the tank. Also the assembly consisted of 4 wheels out of which 2 were mounted on front shaft and 2 were mounted as guide wheel at rear end. A sprocket was mounted on front side exactly at the end of shaft. By pushing the trolley, sprocket rotated in its direction so it actuated the piston inside the cylinder, due to this the compression took place inside the tank. So it leaded to spray Pesticides (or) water inside the tank.

Moon et al. (2015) conducted research work on the design and fabrication of paddle operated multi-point pesticide spraying machine. A low cost pedal operated sprayer was fabricated cost and easy to handle in the farms and also improved the quality of spraying pesticides. The rotary motion is converted into reciprocating with the help of piston having 150mm stroke, Ø100mm. Just on the piston the pump is placed having non-return valve which helps to create pressure in the tank nearly 13.5 psi pressure can be created in the small tank having the capacity of 3lit. Ergonomically, it was very useful to minimize the effort while spraying the pesticide also the process saved the time and improved the performance.

Malonde et al. (2016) designed and developed multipurpose pesticides spraying machine. Pesticide spraying is the necessary procedure in cultivation of the crops. The proposed idea dealt with the designing and fabricating a pesticide sprayer which would be useful and affordable to the farmers as well as would increase the productivity of crops. The authors concluded that cost of the sprayer was reduced as compared with the then existing sprayer, so it could be operated by small scale farmers. The flow rate was increased by 2.5 times as compared to the flow rate of the manually operated sprayer. Area sprayed per hour also increased by 2.6 times as that of the manually operated.

Kharche et al. (2016) carried worked on the project titled design and development of bullock cart in pesticides sprayers pump and developed a low cost chain drive sprayer which could easily be operated with good spraying qualities. The developed model eliminated the problem of returned pain, on account that there was no need to hold the tank (pesticides tank) at the lower back. As recommended version has more range of nozzles which will cowl a maximum area of spraying in minimum time. The performance of developed pesticides sprayer was found to be the total discharge 0.032 lit/sec and Application rate 415 lit/hr.

Jadhav and Sawale (2016) studied a manually operated weeder and sprayer which would be helpful for small land farmers. It consumes less time and saves money as compared with conventional spraying and weeding. It covers twice area of spraying than manually spraying and moist soil weeder efficiency increases due to proper penetrating and dig out of soil.

V. Pranavamoorthi et al. (2017) developed a mechanically operated wheel driven sprayer, portable type and did not need any fuel to operate, also easy to move and spray the pesticide by moving the wheel. This wheel operated pesticide spray equipment consumed less time and achieved uniform nozzle pressure; crank mechanism with piston pump which was driven by the wheel was also used.

Angadi and Kagale (2017) designed a cam operated agrochemical pesticide sprayer. The sprayer tank kept at rear basket of bicycle and placed for four nozzles to the pipe diameter of 10 mm. The spaying method was purely mechanical based in which rear wheel of bicycle sprocket connected with chain to cam. The kinetic energy of the moving bicycle converted into rotating energy, and then pressure pump on pressure tank creates a suction pressure to discharge the flow rate of water through nozzle. The total discharge of pesticide through nozzle 0.612 l/min and Discharge of one nozzle is 0.163 l/ min.

Sivanainthaperumal and Selvam.M (2018) studied the design and developed a working prototype of the mobile pesticide sprayer. The pesticide sprayer reduced back ache and shoulder pain and the cost of the product could be brought down if manufactured on a large scale. The product could be used to spray pesticide over multiple rows of plants in one pass there by reduced manual effort. The developed sprayer having with 25 litre tank capacity and working Pressure was 2 - 3 bars for piston pump. The pesticide sprayer was tested and following data was concluded the average nozzle Output 0.4 litre/min, Sprayer width 2 meter, walking speed 100 m/min and application rate 40 l/hr.

Yonas Mulatu (2018) designed and developed a ground wheel operated boom sprayer. The sprayer was tested both in laboratory and field for the uniformity of application, discharge rate, field capacity and field efficiency and had achieved an application rate of 281.3 l/ha with coefficient of variation (CV %) of 2.80% among the nozzles discharge rate, effective field capacity of 0.83 ha/hr., theoretical field capacity of 1.04 ha/hr. and field efficiency of 82.7%.As compared to the manually operated knapsacks sprayer of 0.4 ha/day field capacity and 56% field efficiency the prototype sprayer had improved the effective field capacity and field efficiency.

Vishal et al. (2018) suggested a model of sprayer which could eliminate the problem of back pain, since there was no need to carry the tank on the backbone and solder. More number of nozzle which covered maximum area of spray in minimum time at maximum rate. Proper adjustment facility provided in the model with respect to crop helps to avoid excessive use of pesticides which could result into less pollution. Imported hollow cone nozzle was used in the field for the better performance. Muscular problems were eliminated and there was no need to operate lever. They also found that this could easily be operated with minimum effort. The pump delivered the liquid at sufficient pressure where output of the nozzle in1min was 0.3 liter and spray width 0.4m from calculation so that it could reach all the foliage and spreads entirely over the spray surface.

More et al. (2019) developed a mechanically operated multi nozzle sprayer for which any type of energy or fuel was not required except mechanical. A low cost sprayer pump was designed and developed for poor farmers which could be operated with minimum efforts. An accurate working model was fabricated that gave similar nozzle pressure and covered maximum area. A crank mechanism along with piston pump rotated by the rotation of wheel was developed.

CHAPTER – 3

MATERIALS AND METHODS

MATERIALS AND METHODS

3. General

This chapter deals with the materials and methods adopted for the development of a push type manually operated multi nozzle sprayer. This is suitable for spraying in different crops. The various factors involved in the design were strength and durability, operational safety and easiness in fabrication. The fabrication, operation, and adjustment were made simple so that a local artesian can fabricate, repair and operate the sprayer easily.

The prototype was fabricated at the work shop of College of Agricultural Engineering J.N.K.V.V., Jabalpur (M.P.), during the year 2019–2020. The performance evaluation was conducted in laboratory of the College of Agricultural Engineering, JNKVV. The field testing of the sprayer was conducted on BSP research farm, JNKVV on the standing crop of chickpea crop (variety J 11) as per the layout of the experimental plots made for the purpose.

3.1 Development of push type manually operated multi nozzle Sprayer

The sprayer prototype is mainly consisted of mainframe, knapsack spray, traction wheel, boom, nozzles, and flexible rubber hose. The axle shaft is mounted on the mainframe which is driven by a traction wheel and carries above spray pump integration, and a boom assembly of 3.2 m length with six sprayer nozzles. The spray tank is connected to the boom with the help of distributing plastic rubber hose via the combined with a piston pump. The boom frame is attached to the front end of the mainframe. The boom frame is designed in the way that the boom height could be adjusted as per the crop height between 60 cm – 150 cm above the ground. The chemical in the spray tank is pumped to the flexible hose by the piston pump attached to the tank. The pump is driven by an offset slider-crank mechanism, which receives the power from the ground wheel. During the operation the operator simply keeps the boom in a horizontal position and operated between the rows of the crop. The handle which was designed with taking all the ergonomic consideration, fitted with sprayer for pushing the sprayer. The ground wheel rotates and transmitting the power to the attached driving sprocket which in turn drives a smaller sprocket that is attached to a shaft through the chain drive. The rotary motion of the smaller sprocket then converted into the reciprocating motion by the single lever-crank mechanism, which actuates the single-acting reciprocating piston of the pump installed in the tank, the pump is pumping the chemical to the nozzles which is mounted on boom of sprayer.

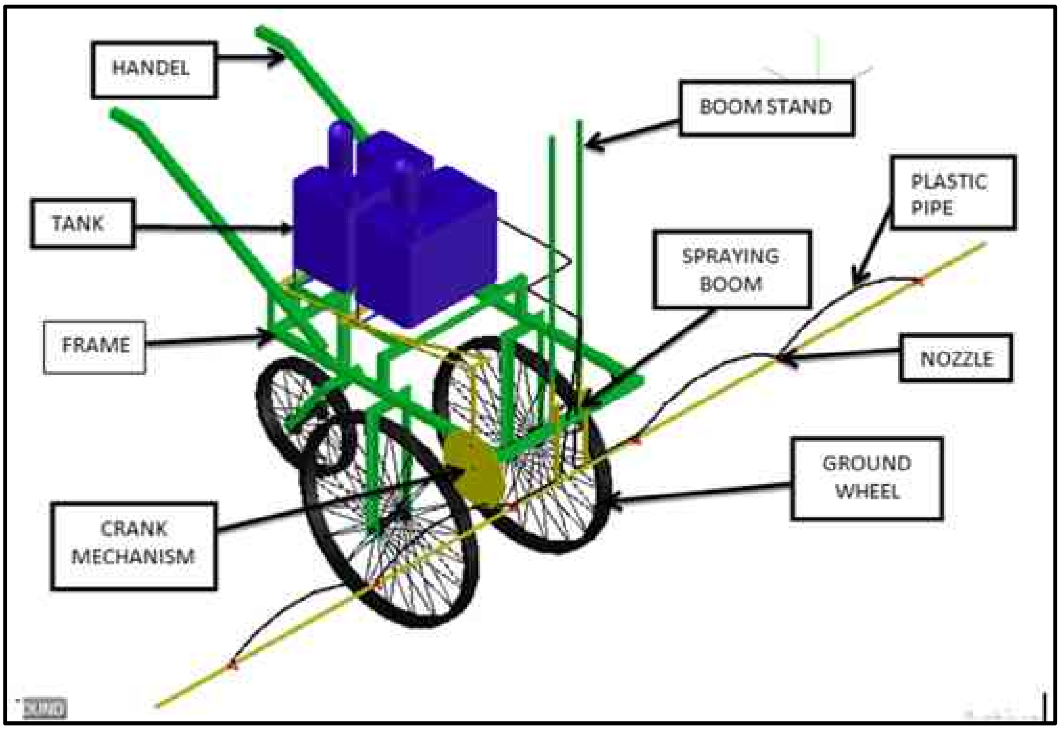


Figure 3.1 Auto Cad design of developed sprayer

3.2 Design consideration of sprayer assembly

The following points were taken into consideration for designing the manually operated sprayer

1. Selection of knapsack sprayer for development of sprayer
2. Design of main frame
3. Crop parameters
4. Selection of ground wheel for prototype
5. Selection of chain and sprocket
6. Selection of shaft
7. Selection of bearing
8. Design of slider crank mechanism
9. Selection of nozzle for sprayer
10. Design of boom setup

3.2.1 Selection of piston pump

The knapsack sprayers are used for produce enough flow, which is capable to operated six nozzles in boom. A piston type pump was used to deliver the spray liquid at the desired pressure. It is a positive displacement type of pump with discharge rate varying between 1.5 – 3.0 l/min and working pressure of 1– 3 kg/cm2. The operating speed varied from 35 to 55 rpm. Knapsack sprayer consists of a pump and an air chamber permanently installed in a 15 litres tank capacity. The handle of the pump extending over the shoulder or under the arm of operator makes it possible to pump with one hand and spray with the other. Uniform pressure can be maintained by keeping the pump in continuous operation.

Table 3.1 Specification sheet of pump

S.NO	parameter	Values
1.	Discharge , l/min	2.5
2.	Volumetric efficiency, %	80
3.	Tank capacity, l	15
4.	Filling hole diameter, mm	90 circular hole
5.	Cylinder inner diameter of pump , mm	34
6.	Stroke length ,mm	65
7.	Mass, kg	4

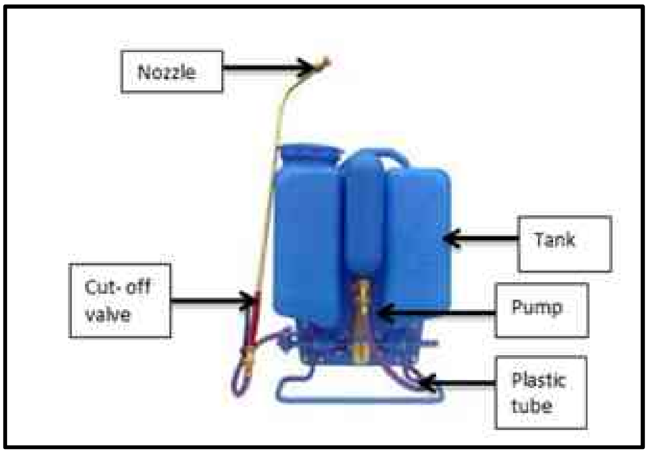


Plate 3.1 Knapsack sprayer, pump assembly outside tank

3.2.1.1 Design of sprayer components

3.2.1.1.1 Tank capacity of manually operated sprayer

The minimum capacity of manually operated sprayer tank can be estimated as under:

From the nozzle catalogue,

Assume discharge of nozzle = 0.400 l/min

Boom discharge rate (D) = no. of nozzles × discharge of nozzle

= 6× .400

= 2.4 l/min

Duration of use (t) = 15 min

Tank capacity (Q_t) = D × t ....(3.1)

= 2.4 × 15

Q_t = 36 litres

3.2.1.1.2 Design calculation for pump of manually operated sprayer

The Swept volume of pump (Vs):

From the specification sheet of pump,

Diameter of pump (D) = 3.5 cm

Length of stroke (L_S) = 6.5 cm

$$(V_s) = \frac{\pi}{4} D^2 L_S \qquad ....(3.2)$$

$$V_S = \frac{\pi}{4} \times 3.5^2 \times 6.5$$

$$V_S = 62.53 \text{ cm}^3.$$

The number of strokes required per minute to maintain the mean working pressure inside the pressure chamber can be calculated by:

Boom discharge through a nozzles (q_n) = 2400 ml/min

Swept volume of pump (Vs) = 62.53 cm^3

Volumetric efficiency of pump (η_v) = 80 %(source: IS: 3966-1995)

$$\text{Number of strokes } (n_s) = \frac{q_n}{V_S\, \eta_V} \qquad ....(3.3)$$

$$= \frac{2400}{62.53 \times .80}$$

Number of strokes (n_s) = 48 per min

Note: 48 numbers of strokes required per minute to maintain the mean working pressure inside the pressure chamber.

Theoretical discharge of nozzle (l/ min):

Diameter of pump (D) = 35 mm

Stroke length (L) = 65 mm

No. of stroke per min = 48

$$\text{Discharge (Q)} = \frac{\pi \times D^2 \times L \times n \times 10^{-6}}{4} \quad \text{.... (3.4)}$$

$$= \frac{\pi}{4} \times 35^2 \times 65 \times 48 \times 10^{-6}$$

Q = 3.0 liter/min

3.2.2 Design of main frame

The main function of frame is to carry whole assembly on it so it has to be strong enough to hold it. The frame is made of M.S. iron pipe (1×1 inch). The total length of frame was kept twice the width of tank plus 42 cm (excess length) to accommodate boom frame and rotation radius of crank. M.S. flat was used for fabrication of wheel operated sprayer.

Length of frame = 2 × width of tank (mm) + excess length (mm)

= 2 × 200 + 444

= 844 mm

Width of frame = 520 mm

Ground clearance = 780 mm

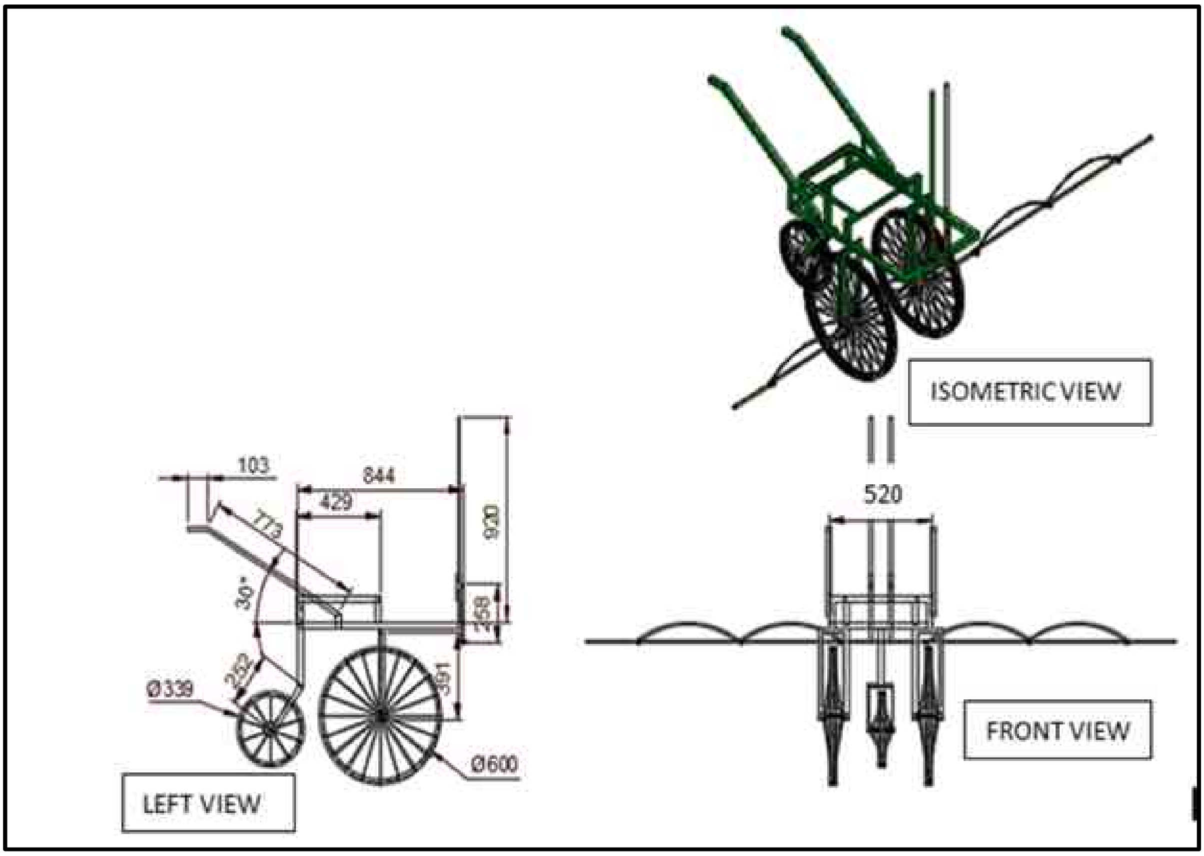


Figure 3.2 Auto Cad design of main frame of sprayer

3.2.3. Crop parameters

The design of a sprayer is based on three crop parameters plant height, row to row spacing, seed spacing. These crop parameters are important to design a track width, boom height adjustment and ground clearance of the sprayer. The average height of plant is 20 cm and row to row spacing is 30 cm.

3.2.4. Selection of ground wheel for prototype

A wheel is a circular component that can be rotated on an axial bearing. The wheel size is able to give a sufficient rotation to crank for operating the pump. One of the two wheels of sprayer is adjustable according to row to row spacing of crop. Simple bicycle wheels are used in spraying machine. The diameter theses wheels are 600 mm.

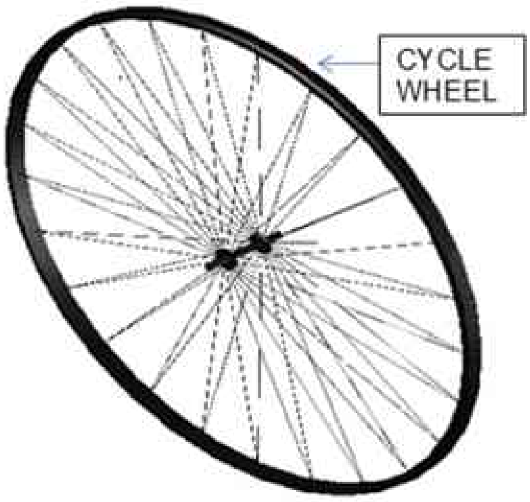


Plate 3.2 Ground wheel

3.2.5. Design and selection of chain and sprocket

Chain drive is a way of transmitting mechanical power from one place to another place. It is often used to bring power to the wheels of a vehicle. Most often, the power is dispatched by a roller chain, known as the drive chain or transmission chain passing over a sprocket gear, with the teeth of the gear meshing with the holes in the links of the chain. When gear turns, it forces the chain putting mechanical force into the system. A sprocket or sprocket-wheel is a generalized wheel with teeth, cogs or even sprockets that mesh with a chain, track or indented material. The sprocket applies generally to any wheel upon which radial projections engage a chain passing over it.

3.2.5.1 Design calculations for sprocket:

No. of teeth on Sprocket (T1) = 44

Diameter of sprocket (D1) = 70 mm

No. of teeth free wheel (T2) = 16

Diameter of free wheel (D2) = 40 mm

$$\text{Gear ratio} = \frac{\text{No. of teeth on driven gear}}{\text{No. of teeth on driver gear}} \qquad \ldots(3.5)$$

$$\text{Gear ratio} = \frac{T2}{T1} = \frac{16}{44} = 0.364$$

Sprocket (D1) is mounted on wheel therefore wheel rotation is equal to sprocket rotation.

Diameter of wheel = 60 cm, Radius (r) = 30 cm

Wheel periphery = 2× 3.14×30 = 188.4 cm = 1.884 m

Distance covered by one rotation of wheel = 1.884 m

3.2.6 Selection of shaft

A drive shaft is a component for transmitting torque and rotation, usually used to connect other components of a drive mechanism that cannot be connected directly because of distance or the need to allow for relative movement between them. The torque carriers and drive shafts are subjected to torsional and shear stresses, similar to the difference between the input torque and the load. They must be strong enough to bear these stresses, whilst avoiding large additional weight as that would, in turn, will increase their inertia.

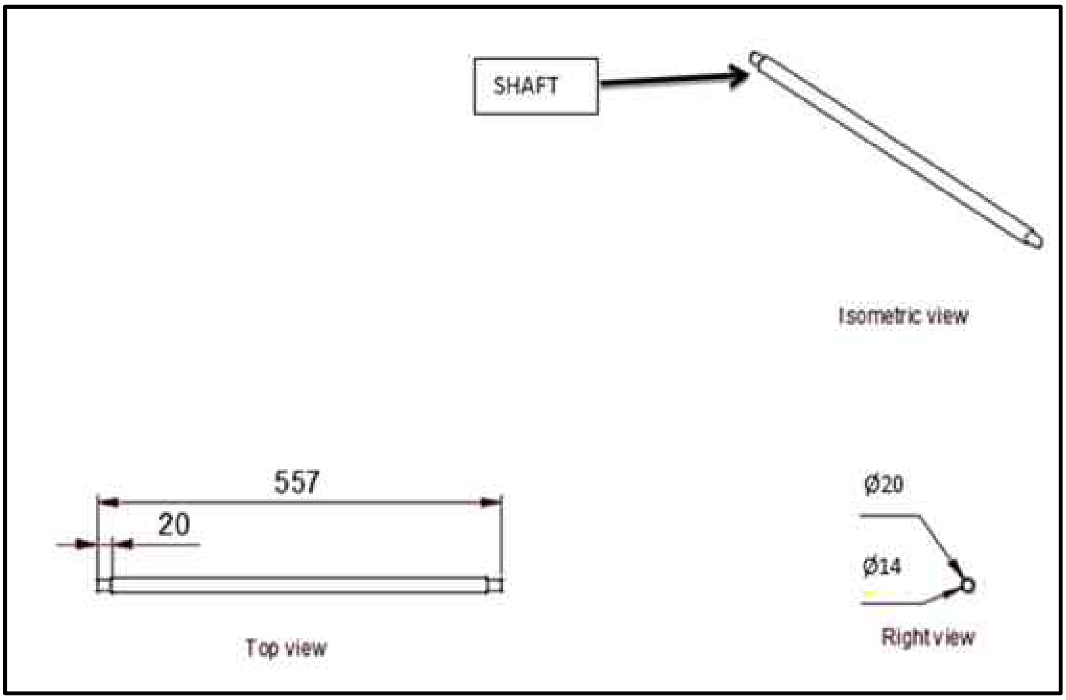


Figure 3.3 Auto Cad design of shaft

3.2.7 Selection of bearing

A bearing is a machine element that constrains relative motion and reduces friction between moving parts to only the desired motion. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis; or, it may prevent a motion by controlling the vectors of normal forces that bear on the moving parts. The specification of bearing is given as brand HCH 6201 ZZ, internal diameter, outer diameter, and width is 12 mm, 32 mm, and 10 mm respectively.

Plate 3.3 Ball bearing

3.2.8. Design of slider crank mechanism

3.2.8.1 Crank

A crank is an arm attached at to a rotating shaft by which reciprocating motion is admitted to or received from the shaft. This mechanism is used to convert circular motion into reciprocating motion. The one end of the connecting rod attached to the crank moves in a circular motion, while the other end is move to linear sliding motion.

3.2.8.2. Connecting Link

Material selected is M.S because of its having good strength, durable and cheap. Length is selected by considering stroke length and crank radius. Length is increases or decreases by reducing or increasing stroke length.

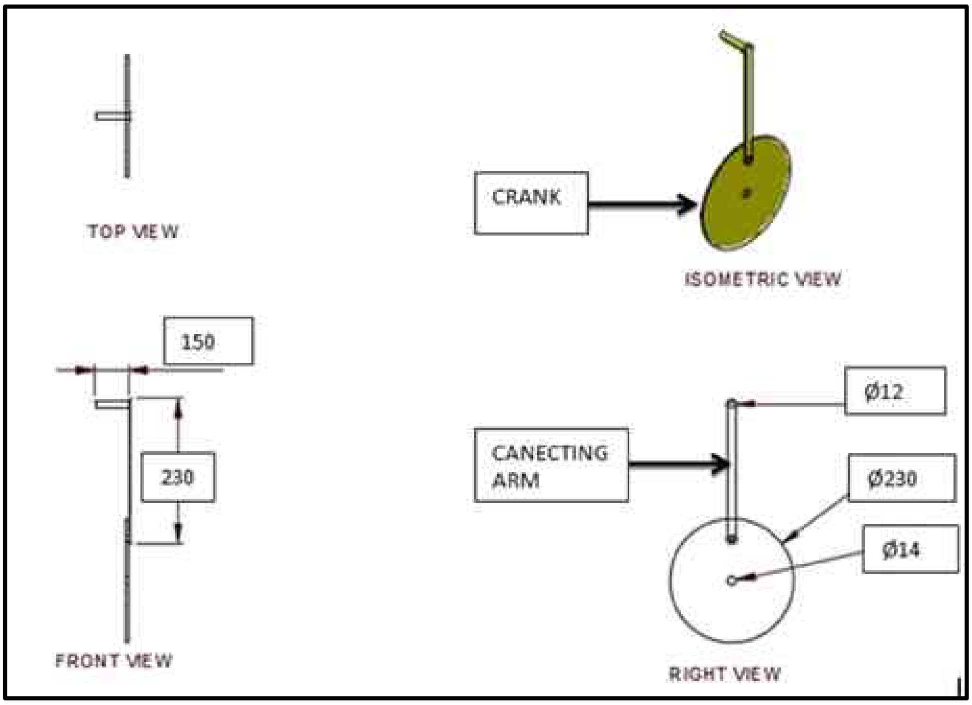


Figure 3.4 Crank and Connecting Link mechanism

3.2.9 Selection of nozzles

The proper selection of a nozzle type and size is essential for proper pesticide application. The nozzle is a primary factor in determining the amount of spray applied to an area, the uniformity of application, the coverage achieved on the target surface, and the amount of potential drift. Nozzles break the liquid into droplets, form the spray pattern, and propel the droplets in the proper direction. They determine the amount of spray volume at a given operating pressure, travel speed, and spacing. Drift can be minimized by selecting nozzles that produce the largest droplet size while providing adequate coverage at the intended application rate and pressure. Medium droplet size is suggested for foliar applied non- translocating herbicides and a coarse droplet size for foliar applied translocating herbicides. Concern for drift may cause you to consider larger droplet sizes and higher spray volumes. Generally, some common types of nozzles are used in low-pressure agricultural sprayers include: flat, flood, air induction, raindrop, hollow-cone, full-cone, and others. Special features, or subtypes such as "extended range," are available for some nozzle types. Extended range increases the recommended operating pressure range.

3.2.9.1. Type Nozzles

Nozzle types commonly used in low-pressure agricultural sprayers include: fan, hollow-cone, full-cone, and others.

3.2.9.1.1 Even Flat Fan Nozzles

Fan Nozzles is the most common type of nozzle used in agriculture. A fan nozzle is widely used for spraying pesticides, both banding (over and between rows) and broadcast applications. These nozzles produce a tapered-edge, flat-fan spray pattern (Figure 3.4). On boom sprayers for broadcast applications, nozzles are positioned so that their output overlaps.

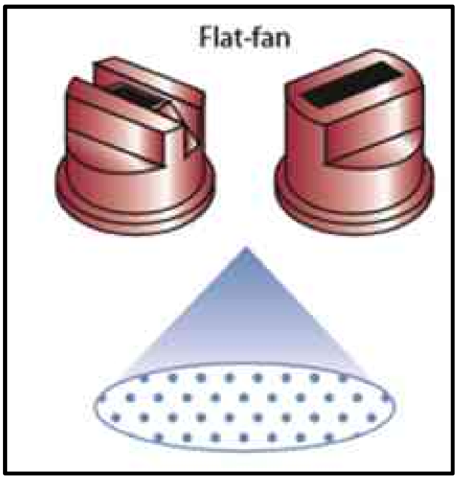


Plate 3.4 Even flat fan nozzle (XL/54P)

3.2.9.1.2 Flood Nozzles

Flood nozzles are popular for applying suspension fertilizers where clogging is a potential problem. These nozzles produce large droplets at pressures of 10 psi to 25 psi. The nozzles should be spaced closer than 60 inches apart. The nozzle spacing, orientation, and release height should be set for 100 percent overlap. Nozzle spacing of 30 inches to 40 inches produces the best spray patterns. Pressure influences the spray patterns of flood nozzles more as compared to fan nozzles. However, the spray pattern is not as uniform as with the fan nozzles and special attention to nozzle orientation and correct overlap is critical. Besides fertilizer suspensions, these nozzles are used with soil-incorporated herbicides, pre-emergence without contact herbicides, and with spray kits mounted on tillage implements.

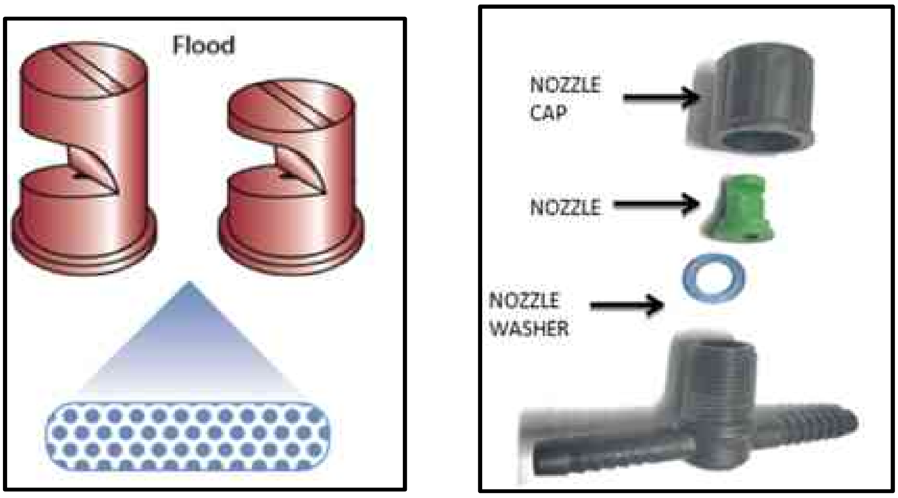


Plate 3.5 Flood jet nozzles (XLP/WP/40)

3.2.10 Design of boom setup

The boom was fabricated by galvanized pipe in three separate parts. Each part of the pipe has attached with screwed clamp for the provision of a proper folding during transportation. The six nozzles were facilitated with nozzle adapter with a screwed clamp for adjustment of nozzle spacing. The boom set is built in such a way that the boom can be adjusted at different heights and angles. Two hallow pipes of 1 meter length were attached to the boom set for providing height adjustment of the boom in a vertical direction. The nozzles must be carefully aligned to prevent interference, and at the proper height, so that adjacent patterns along the boom will provide proper overlapping for uniform coverage.

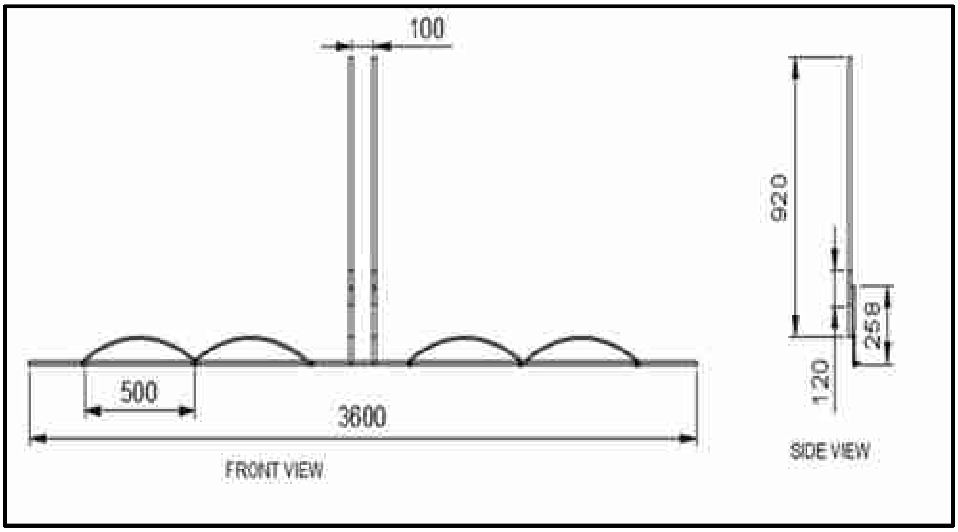


Figure 3.5 Boom setup of sprayer

Table 3.2 Specification sheet for developed sprayer

S.No	Particulars	Dimension	Material Used
1.	Name of equipment	Push type manually operated sprayer	-
2.	Type of power source	Manually operated	-
3.	Manufacturing's Address	Workshop, CAE , JNKVV	-
4.	Crop for Which suitable	Pea, mustard, wheat, safflower, chickpea	-
5.	**Overall dimension in mm** Length: Width: Height	945 1000 1394	
6.	Weight in kg.	22 kg (without water)	
7.	Shaft	Diameter – 20 mm, Length – 557 mm	Milled steel
8.	**Detail of pump** Tank capacity (l): Pump cylinder inner dia.(mm): Stroke length (mm): Number of piston in pump: Pressure chamber capacity(ml) : Displacement volume (ml) :	30 (two tank) 34 65 Two 572-660 87.24	Plastic Brass
9.	**Detail of frame** Construction: Dimension of major members:	Adjustable type 85×50	Square steel pipe (1×1 inch.)
10.	**Detail of boom set up** Construction: Length(mm):	Adjustable and folding type 3600	Galvanized steel pipe

	Adjustable height (mm):	200 – 1100	
11.	**i) Ground wheel** Diameter, cm Width, cm **ii) Detail of supporting wheel** Diameter, cm Width, cm	60 5 Stainless steel 18	Pneumatic spoke wheel
12.	**Detail of handle** Construction: Height of handle from ground level: Details of adjustment:	Adjustable type (0-20 mm to 0-40.5 mm) Adjustment through nut and bolt	Square steel pipe (1×1 inch.)
13.	Ground clearance	785 mm (ground surface to main frame)	-
14.	Details of transporting system	wheel as well as ground wheel	-
15.	Nozzle	Even flat fan nozzles and flood jet nozzles	plastic
16.	Safety aspects	No required	-

3.3 Experimental Details

3.3.1 Experimental Site

The experiment was conducted during the rabbi season of 2019-20. The experimental field plot is located in BSP unit of JNKVV, Jabalpur (M.P.),

3.3.2 Geographical condition

The project research work was carried out at the College of Agricultural Engineering, Jawaharlal Nehru Krishi Vishwa Vidyalaya, which is situated in Adhartal, Jabalpur city and located between 23º90´ North latitude and 79º58´ East longitude with an altitude of 411.78 m above mean sea level.

3.3.3 Climate condition

The general climate of the Jabalpur region is semi-humid, tropical and featured by hot dry summer and cool dry winter. It comes under the “Kymore Plateau and Satpura plateau” agro-climatic zone of Madhya Pradesh. As per the classification of the National Bureau of Soil Survey and Land Use Planning, Nagpur, this area belongs to agro-ecological region 10, named Central Highland (Malwa, Bundelkhand and Eastern Satpura) eco-region of hot, sub-humid type with the sub-humid ecosystem. To evaluate the performance of the machine and field trials were conducted in chickpea crop (variety JG11) fields and layout of the experimental plots was made to test the requirements at the dry condition.

Table 3.3 Details of Plan of Layout

S. No.	Parameters	Values
1	Field size	2500 m^2
2	Plot size	50 m ×20 m =1000 m^2
3	Row to row spacing	30 cm
4	Crop height	20

3.3.4 Crops parameters

The chickpea crop was selected for field evaluation of developed sprayer. The crop was sowing with seed drill, which having 30 cm row spacing and continuous hill dropping. Table 3.4 showing the different parameters for the selected crop.

Table 3.4 crops parameters

S. No.	Parameters	Values
1	Type of crop	Chickpea
2	Variety	GJ 11
3	Crop duration	35 days
4.	Row spacing, cm	30
5.	Average height of crop, cm	20

3.4 Performance evaluation of developed a push type manually operated multi nozzle sprayer

The performance of the sprayer was evaluated both in laboratory as well as in field condition. The relevant data was collected during evaluation.

3.4.1 Laboratory evaluation

For the laboratory studies were conducted to determine the effect of the selected parameters on the performance of the developed sprayer. The performance of the developed sprayer was evaluated for discharge rate and overlap present for two different type of even flat fan and flood jet nozzles

3.4.1.1 Nozzle discharge rate

Nozzle discharge test was done to evaluate the amount of liquid discharge from each nozzle and to check the variation between the discharge rates of each nozzle for 1 minute duration. The sprayer was operated on the test track and after each 1 minute interval the discharge data was collected and recorded for each nozzle by using a plastic bag on each nozzle. After each 1 minute of operation the sprayer were stopped, as the sprayer stops moving the pump stops pumping and each liquid was collected from the nozzle and measured using measuring cylinder. Coefficient of variation was used to analyze variation of discharge rate among the nozzles for each 1 minute operation.

Plate 3.6 Evaluation of discharge rate in laboratory

3.4.1.2 Uniformity of spray application

During spraying of insecticides, pesticides and fungicides on the crop, certain amount of overlapping in spray patterns is required for uniform application and effective control. The uniformity of spray application depends on:

1. Spray boom height
2. Nozzle spacing and
3. Degree of overlap

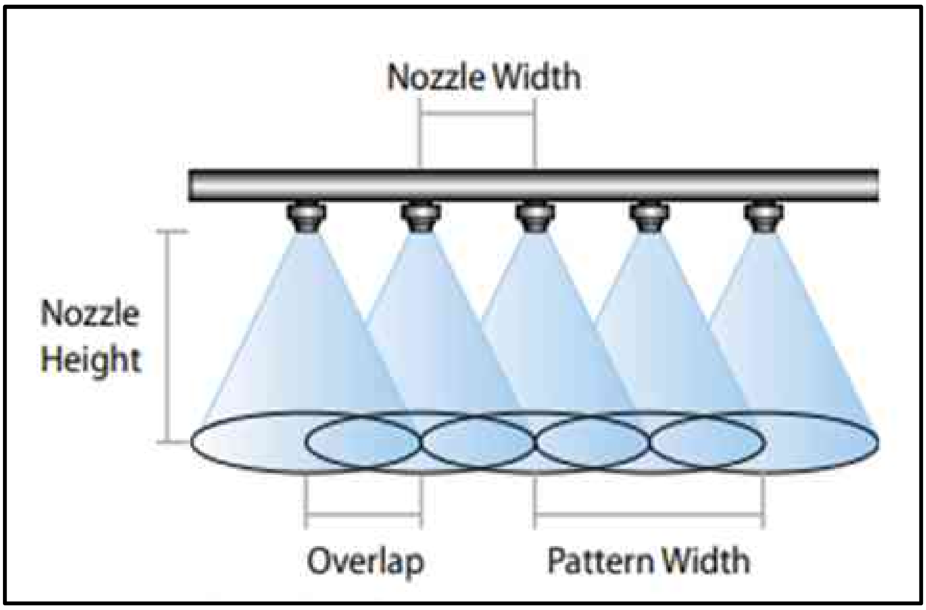


Plate 3.7 Spray overlapping and nozzle height

3.4.1.3 Spray overlap

The overlap is defined as the width covered by two adjacent nozzles divided by the width covered by a single nozzle, expressed in present. It mainly affects spray pattern of the sprayer it depends on the boom height and nozzle spacing.

The test was done on a test track using a dye. First the test track was cemented was used as a water shown on track to get a good contrast between the track and the spray solution. The test track was divided into the grid system for accuracy. The sprayer was tested for 54 cm boom height and 50 cm each nozzle spacing spray. The measurement was taken within 20 m distance at an interval of 5 m.

3.4.1.4 Volumetric efficiency

The volumetric efficiency in hydraulic pump refers the percentage of actual fluid flow out of the pump compared to theoretical fluid flow out of the pump.

$$\text{Volumetric efficiency (\%)} = \frac{\text{Actual suction capacity}}{\text{Theoretical suction capacity}} \times 100 \qquad \text{.....(3.6)}$$

3.4.2 Field performance

The field size, test duration, spray pressure, swath, discharge, speed of operation, field capacity and other relevant information were taken. The field test were conducted on 0.25 ha trial field at BSP unit of JNKVV.

3.4.2.1 Nozzle discharge rate

Nozzle discharge test was done to measure the amount of liquid discharge from each nozzle and to check the variation between the discharge rates of each nozzle during one minute time. The sprayer was operated at the field condition and discharge data was collected and time taken for each trial was recorded. Four experiments were undertaken for this test. The discharge from each nozzle was collected by using a plastic bag on each nozzle. The sprayer was operated for one minute and then sprayer was stopped and the discharge from each nozzle was collected from the plastic bags and measured with the help of measuring cylinder.

Plate 3.8 Field performance of developed sprayer

3.4.2.2 Speed of operation

Speed of operation of manually operated multi nozzle sprayer was measured the time required to cover 50 m distance. By recording speed was calculated by using following formula (RNAM procedure).

$$\text{Speed (km/h)} = \frac{3.6 \times \text{Distance traveled (m)}}{\text{time(s)}} \quad \text{....(3.7)}$$

3.4.2.3 Power requirement

Manual operated multi nozzle sprayer machine requires power to operate the machine by one man. The resistance an implement provides to forward movement will determine the draft force have to apply to achieve the required work. Draft forces can be measured with various types of dynamometer which are commonly based on expanding springs, hydraulic pistons or load cells. Draft was determined with the help of a load cell having range of 125kg in the field. The load cell was connected to the sprayer and pull out by a man and readings were taken to calculate the draft of machine.

Calculation of power is required to determine the efficient use of available man/animal power. It is the power requirement of the implement for average pushing force and operating speed to be made available by man. It is calculated by using the following formula (Michael and Ojha, 1966).

$$P = \frac{(D \times S)}{75} \quad \text{... (3.8)}$$

Where,

P = Power, hp

D = Draft, kgf, and

S = Speed, m/s.

Plate 3.9 Load cell

3.4.2.4 Application rate of chemical

There are many methods described for calibration of sprayer. The sprayer can be calibrated theoretically and practically in the field. It is good to frequently verify the correctness of theoretical calibration with field practical calibration. A very simple and easy to remember formula is

$$A = \frac{60000\,D}{S\,W} \qquad \ldots(3.9)$$

Where,

A = application rate (l/ha)

D = Quantity of liquid collected from all nozzle on the boom (l/min)

W = Spray swath width, (cm)

S = Speed, km/h

3.4.2.5 Field capacity

The field capacity includes theoretical field capacity and effective field capacity.

3.4.2.5.1 Theoretical field capacity

For calculating the theoretical filed capacity, working width of spray nozzle and travelling speed has been taken in to consideration. It is always greater than the actual field capacity. Theoretical field capacity is calculated by using following formula.

$$\text{Theoretical field capacity (ha h}^{-1}\text{)} = \frac{S \times W}{10} \qquad \ldots(3.10)$$

Where,

S = Speed of operation, km/h

W = Theoretical width covered by boom, m

3.4.2.5.2 Effective field capacity

For calculating effective field capacity, the time consumed for actual work and lost for other activities such as turning and filling the tank of spray. Effective field capacity was calculated by following formula.

$$\text{Effective field capacity (ha h}^{-1}\text{)} = \frac{A}{T_1 - T_2} \qquad \text{...(3.11)}$$

Where,

A = actual area covered, ha

T_1 = Total time require for operation, h

T_2 = non-productive time, h

3.4.2.7 Field efficiency

Field efficiency will be calculated by taking ratio of effective field capacity to theoretical field capacity. It is always expressed in percentage. It was calculated by following formula.

$$\text{Field efficiency} = \frac{\text{Effective field capacity}}{\text{theoretical field capacity}} \times 100 \qquad \text{...(3.12)}$$

3.5 Cost of operation for developed push type manually operated multi nozzle sprayer

3.5.1 Fixed costs for spraying operation

3.5.1.1 Depreciation

This cost reflects the reduction in value of a machine with use (wear) and time (obsolescence). While actual depreciation would depend on the sale price of the machine after its use, based on different computational methods depreciation can be estimated by straight –line method as given below.

$$D = \frac{P - S}{L \times H} \quad \dots (3.13)$$

Where,

D = depreciation cost, average per year;

P = purchase price of the machine;

S = residual value of the machine;

L = useful life of the machine in years; and

H = working hours per year, hours.

The depreciation cost per hour can be estimated by dividing D by the number of hours the machine is expected to be utilized in a year. Residual value if the machines may be taken as 10 percent of the purchase price.

3.5.1.2 Interest

An annual charge of interest was calculated taking 12 percent of average purchase price as basis. Average purchase price was calculated using the formula given below

$$I = \frac{P + S}{2} \times \frac{I}{H} \quad \dots (3.14)$$

Where,

I = Interest on capital ₹/h;

P = purchase price of the machine;

S = residual value of the machine;

i = interest rate in fraction; and

H = working hours per year, hours.

3.5.1.3 Insurance, taxes and shelter

Insurance and taxes were estimated taking 2% of average purchase price of machine into consideration.

3.5.2 Variable Costs for spraying operation

3.5.2.1 Repair and maintenance

It was taken as 6% of purchase price.

3.5.2.1 Wages and Labour charges

The cost of labour was estimated taking the prevailing rate of Rs. 250 per day for 8 hour.

CHAPTER - 4

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

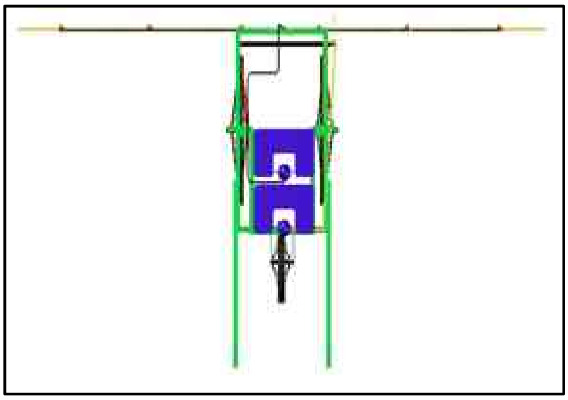
This chapter deals with the results and discussion of the experiments conducted to fulfill the objectives of the study. The prototype is fabricated at the workshop of the college of agricultural engineering J.N.K.V.V., Jabalpur (M.P.), during the year 2019–2020. The performance evaluation was conducted in the laboratory of the college of agricultural engineering, JNKVV. And the field testing was conducted in BSP research farm, JNKVV. To evaluate the performance of the machine and field trials were conducted in chickpea crop (variety J 11) fields and the layout of the experimental plots was made to test the requirements in medium field conditions with clay soil.

The field performance results described in this chapter The performance and result of the development of manually operated multi nozzles sprayer were expressed in terms of discharge rate, field efficiency, spray overlap, application rate. The results of the study has been reported and discussed under the following sub heads:

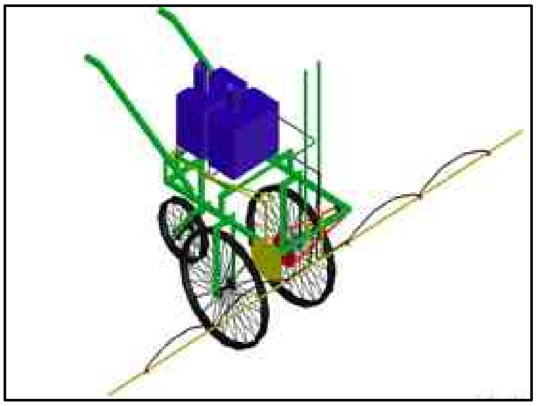
4.1 Development of push type manual operated multi nozzle sprayer.
4.2 Laboratory evaluation of push type manual operated multi nozzle sprayer.
4.3 Field performance of push type manual operated multi nozzle sprayer.

4.1 Development of push type manual operated multi nozzle sprayer.

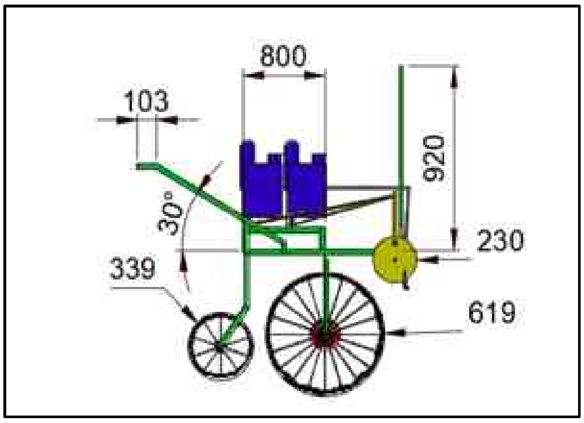
The push type manual operated multi nozzle sprayer was developed was trolley operated system by using this we can reduce maximum effort required for spraying Pesticides as well as we can Spray Pesticides in any direction or around the crops at any height of crops. The sprayer prototype is mainly consisted of mainframe, knapsack spray, traction wheel, boom, nozzles, and flexible rubber hose. The axle shaft is mounted on the mainframe which is driven by a traction wheel and carries above spray pump integration, and a boom assembly of 3.2 m length with six sprayer nozzles. The spray tank is connected to the boom with the help of distributing plastic rubber hose (diameter of hose is 20 mm) via the combined with a piston pump. The boom frame is attached to the front end of the mainframe. The boom frame is designed in the way that the boom height could be adjusted as per the crop height between 60 cm – 150 cm above the ground. The chemical in the spray tank is pumped to the flexible hose by the piston pump attached to the tank. The pump is driven by an offset slider-crank mechanism, which receives the power from the ground wheel. The ground wheel rotates and transmitting the power to the attached driving sprocket which in turn drives a smaller sprocket that is attached to a shaft through the chain drive. The rotary motion of the smaller sprocket then converted into the reciprocating motion by the single lever-crank mechanism, which actuates the single-acting reciprocating piston of the pump installed in the tank, the pump is pumping the chemical to the nozzles which is mounted on boom of sprayer. In fig. 4.1 all dimensions in mm.



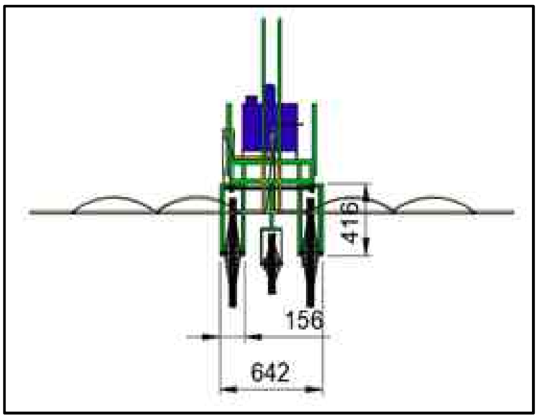
a. Top view



b. Isometric view



c. Side view



d. Front view

Figure 4.1 Auto Cad design of multi nozzle sprayer

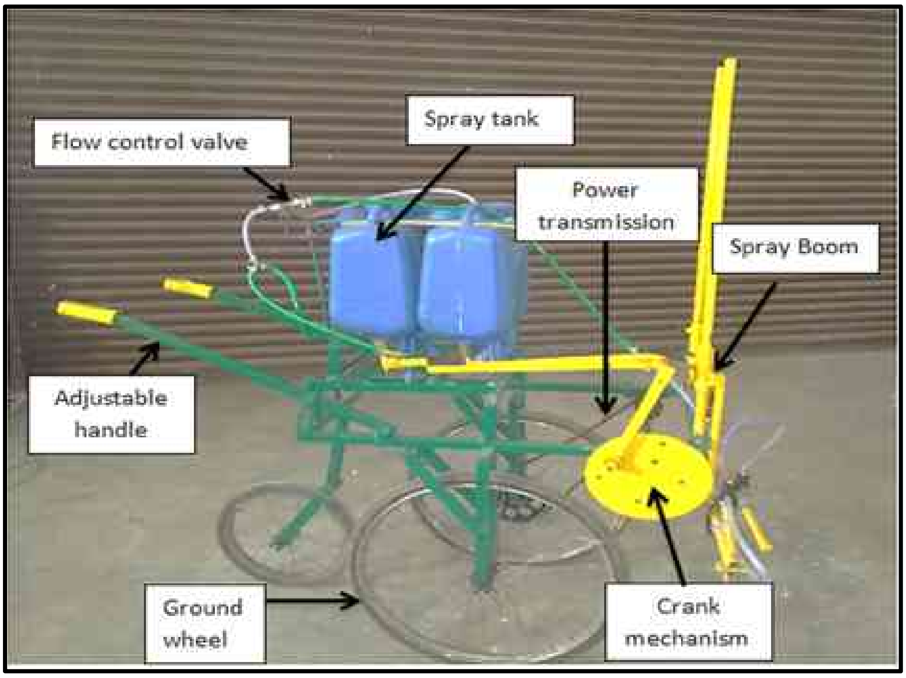


Plate 4.1 Developed push type manually operated multi nozzle sprayer

4.1.1 Selection of nozzles

The nozzles chosen for the research work were even flat fan and flood jet nozzles. The even flat fan nozzles and flood jet nozzles were placed at the boom of the sprayer.

4.1.2 Selection of nozzle tip

The discharge rate varied from 0.33 l/min to 0.6 l/min for even flat fan nozzles and 0.4 l/min to 0.5 l/min for flood jet nozzles respectively. The nozzle tips selected according to the discharge rate obtained were even flat spray XL/54P, and flood jet spray tip, XLP/WP/40. Their discharge rates lied in the mentioned range.

4.1.3 Selection of piston pump

These types of pumps operate by using a reciprocating piston. The liquid enters a pumping chamber via an inlet valve and is pushed out via an outlet valve by the action of the piston or diaphragm. Reciprocating pumps are generally very efficient and are suitable for very high heads at low flows. It is a positive displacement type of pump with a discharge rate varying between 1.5 -3.0 l min-1 and working pressure of 1-3 kg/cm2. The operating speed varied from 35 to 55 rpm.

4.2 Laboratory performance of developed push type manually operated multi nozzle sprayer

For the laboratory studies were conducted to determine the effect of the selected parameters on the performance of the developed sprayer. The performance of the developed sprayer was evaluated for discharge rate and overlap present for two different type of even flat fan and flood jet nozzles.

4.2.1 Discharge rate of sprayer for even flat fan nozzles

The sprayer was operated on the test track and the discharge of flat fan nozzles for one minute shall be collected and measured (As per Indian standard 10134:1994). The average discharge of nozzles were 0.350 l min^{-1}, 0.355 l min^{-1}, 0.370 l min^{-1}l, 0.381 l min^{-1}, 0.366 l min^{-1}, and 0.356 l min^{-1} for N1, N2, N3, N4, N5, and N6 nozzles respectively. The average discharge from nozzles is 0.363 l min-1 at an average operating pressure of 1.6 bars. The valve of the coefficient of variation for the nozzles discharge was 3.336. This showed that the variation in discharges of the nozzle was below an acceptable variation of 10 per cent as per the recommendation (Gomez and Gomez, 1984).

Table 4.1 Discharge rate of individual flat fan nozzle in the laboratory

No of trail	Discharge (l/min)						Mean discharge (l/min)	CV, %
	Nozzles							
	N1	N2	N3	N4	N5	N6		
1	0.350	0.345	0.370	0.380	0.365	0.355	0.360	3.65
2	0.345	0.360	0.365	0.375	0.360	0.355	0.360	3.78
3	0.355	0.360	0.375	0.390	0.375	0.360	0.369	3.57
average	0.350	0.355	0.370	0.381	0.366	0.356	0.363	3.36

N1, N2, N3, N4, N5, N6 are six flat fan nozzles fitted on the boom at 40 cm spacing

This variation in the average discharge along the intervals is because the pump gets power from the ground wheel as it advances; therefore it takes some distance for the sprayer to attain optimal pressure at each nozzle along with the boom.

4.2.2 Discharge rate of sprayer for flood jet nozzles

The sprayer was operated on the test track and the discharge of nozzles in one minute shall be collected and measured. The average discharge of nozzles were 0.405 l min-1, 0.406 l min-1, 0.414 l min-1, 0.418 l min-1, 0.401 l min-1, and 0.406 l min-1 for N1, N2, N3, N4, N5, and N6 respectively. The average discharge for nozzles is 0.409 l min-1 at an average operating pressure of 1.6 bars. The valve of the coefficient of variation for the nozzles discharge was 3.13 per cent. Nozzles should be replaced when their liquid output increases by 5% above the catalogue output at a given pressure, or the variation between nozzles on the same boom exceeds ± 10% (Guidelines on Good Practice for Ground Application of Pesticides, FAO, 2001).

Table 4.2 Discharge rate of individual food jet nozzle in the laboratory

No of trail	Discharge (l/min)						Mean discharge (l/min)	CV, %
	Nozzles							
	N1	N2	N3	N4	N5	N6		
1	0.405	0.385	0.408	0.415	0.400	0.395	0.4013	3.03
2	0.390	0.420	0.410	0.420	0.415	0.425	0.4133	3.2
3	0.420	0.415	0.425	0.420	0.390	0.400	0.4117	3.31
average	0.405	0.406	0.414	0.418	0.401	0.406	0.409	3.13

N1, N2, N3, N4, N5, N6 are six flat fan nozzles fitted on the boom at 40 cm spacing

4.2.3 Spray overlap for flat fan nozzles

During the spray overlap test, the average overlap for nozzles was 35 per cent, 35.5 per cent, 37.5 per cent, 35.75 per cent and 35.75 per cent from N1N2, N2N3, N3N4, N4N5, and N5N6 respectively. The average overlap in nozzles is 35.81 per cent at an average operating pressure of 1.6 bars. The valve of the coefficient of variation for the overlapping of nozzles was 2.738 per cent, which shows a very small variability of overlap between consecutive adjacent nozzles. New spray nozzles generally have around 6% CV, producing a uniform spray distribution when properly overlapped (Phillips L. 2020). These mean that the uniformity and coverage of the spray were good. During the spray overlap test, the average per cent overlap between the nozzles varies from 35 % to 37.5% at a boom height of 50 cm and nozzle spacing of 40 cm, which was within the acceptable range of 30 – 100% for even flat fan nozzles.

Table 4.3 Spray overlaps for even flat fan nozzles

DAS Point	Overlap in cm					Mean average Overlap	CV per cent
	N1N2	N2N3	N3N4	N4N5	N5N6		
At 5 m	14	13	14.5	12.5	13.6	13.52	5.86
At 10 m	14.2	15	15.2	14.8	14	14.5	3.57
At 15 m	13.8	14.6	15	15.6	14.8	15.2	4.30
Average Overlap(cm)	14	14.2	14.9	14.3	14.133	14.407	4.58
Average Overlap (%)	35	35.5	37.5	35.75	35.32	35.81	2.74

N1- N2, N2-N3, N3-N4, N4-N5 and N5-N6 are the adjacent three flat fan nozzles fitted on the boom at 40 cm spacing and 50 cm nozzle height.

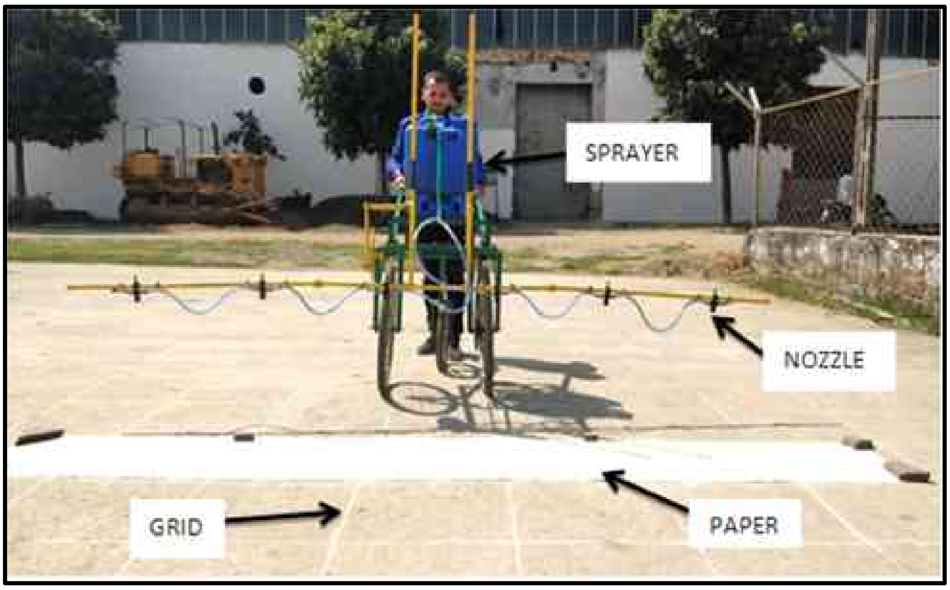


Plate 4.2 Spray overlapping test on test track

4.2.4 Spray overlap for flood jet nozzles

During the spray overlap test, the average overlap for flood jet nozzles were 45.16 per cent, 47.5 per cent, 49.17 per cent, 47.25 per cent and 46.83 per cent from N1N2, N2N3, N3N4, N4N5, and N5N6 respectively.

The average overlap in nozzles is 47.18 per cent at an average operating pressure of 1.6 bars. The valve of the coefficient of variation for the overlapping of nozzles was 3.03 per cent, which shows a very small variability of overlap per cent between consecutive adjacent nozzles.

Table 4.4 Spray overlaps for flood jet nozzles

DAS Point	**Overlap in cm**					**Mean average Overlap**	**CV Per cent**
	N1N2	N2N3	N3N4	N4N5	N5N6		
At 5 m	18	20.2	18	18.5	16	18.14	8.26
At 10 m	17.6	19.2	21	18.7	19.5	19.2	6.45
At 15 m	18.6	17.6	20	19.5	20.7	19.28	6.27
Average Overlap(cm)	18.06	19	19.66	18.9	18.73	18.87	3.03
Average Overlap (%)	45.16	47.5	49.16	47.25	46.83	47.18	3.03

N1- N2, N2-N3, N3-N4, N4-N5 and N5-N6 are the adjacent six flood jet nozzles fitted on the boom at 40 cm spacing and 50 cm nozzle height.

4.2.5 Overlap per cent between even flat fan nozzle and flood jet nozzle

Fig. 4.2 shows the overlap per cent of adjacent nozzles for flat fan and flood jet nozzle in laboratory testing. The average overlap per cent was 47.18 % for flood jet nozzles and 35.81 % for flat fan nozzles. There should also be a 30% minimum overlap for spray uniformity along a boom (Lloyd Phillips, 2010), for producing a uniform spray distribution when properly overlapped.

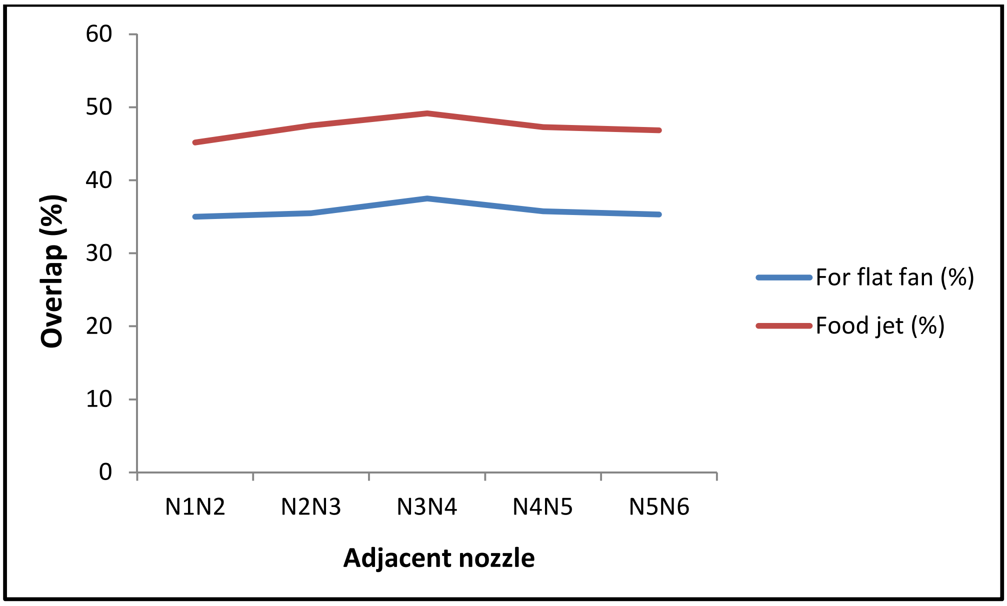


Figure 4.2 Spray overlapping for flat fan and flood jet nozzle

4.3 Field Performance of developed push type manually operated multi nozzle sprayer

The Performance trials were conducting at BSP research farm, college of agricultural engineering JNKVV, Jabalpur. The field size, test duration, spray pressure, swath, discharge, speed of operation, field capacity and other relevant information were taken during field testing.

Table 4.5 Test conditions for field performance

	Particulars	
a)	**Condition of field and soil**	
1	Location	BSP unit, JNKVV
3	Length (m)	50
4	Width (m)	50
5	Area (m^2)	2500
6	Type of soil	Clay (heavy soil)
b)	**Condition of crop**	
1	Name of crop	Chick pea
2	Variety	Vaibhav (JG 11)
3	Age in days after sowing	35

4	Sowing method	Seed drill
5	Row spacing (cm)	30
6	Hill distance (cm)	Continuous
7	Average height of plant (cm)	20
c)	**Condition of operation (sprayer)**	
1	Number of rows applied or swath width of application	10
2	Height of boom from plant canopy (cm)	50
3	Nozzle spacing(cm)	40
d)	**Condition of operator**	
1	Skill of operator	Semiskilled
2	Wage of operator ₹ per day	250

Table 4.6 Field performance data of developed push type manually operated multi nozzle sprayer

S. No	Performance Parameters	Values
1.	Average operating speed(km/h)	2.25
2.	No of nozzles	6
3.	Nozzle spacing (cm)	40
4.	Boom discharge for flat fan (l/ min)	2.03
5.	Boom discharge for flood jet (l/ min)	2.43
6.	Application rate for flat fan (l/ha)	225.55
7.	Application rate for flood jet (l/ha)	270.3
8.	Average theoretical field capacity (ha/h)	0.54
9.	Average actual field capacity(ha/h)	0.409
10.	Field efficiency (%)	75.74
11.	Draft (Kgf)	12.06
12.	Power (kW)	0.07

4.3.1 Discharge rate of sprayer for flat fan nozzles in field

The sprayer was operated on the field and the discharge of nozzles in one minute shall be collected and measured. The average nozzles discharge were 0.325 l min-1, 0.352 l min-1, 0.350 l min-1, 0.340 l min-1, 0.340 l min-1, and 0.325 l min-1 from N1, N2, N3, N4, N5, and N6 respectively. The average discharge from nozzles is 0.338 l min-1 at an average operating pressure of 1.6 bars. The average value of the coefficient of variation for the nozzles discharge was 4.365 per cent during the field testing.

Table 4.7 Discharge rate of individual flat fan nozzle in the field test

No of trail	**Discharge (l/min)**						**Mean discharge (l/min)**	**CV, %**
	Nozzles							
	N1	N2	N3	N4	N5	N6		
1	0.315	0.355	0.365	0.360	0.340	0.325	0.343	5.87
2	0.330	0.345	0.350	0.320	0.335	0.320	0.333	3.75
3	0.325	0.358	0.335	0.340	0.345	0.330	0.338	3.47
average	0.323	0.352	0.350	0.340	0.340	0.325	0.338	4.365

N1, N2, N3, N4. N5 and N6 are six flat fan nozzles fitted on the boom at 40 cm spacing

4.3.2 Performance of flat fan nozzles in laboratory and field evaluation

Fig. 4.3 shows the different trend lines in the figures account for the small changes and graphs in the discharge of nozzles in laboratory evaluation as compared to field performance. In the field, the graph shows more variation in discharge because the discharge of the nozzle is affected by the speed of operation on the field. The graph showed that discharge first increased, then attained a maximum value near the centre and then decreased towards the right and left for both cases.

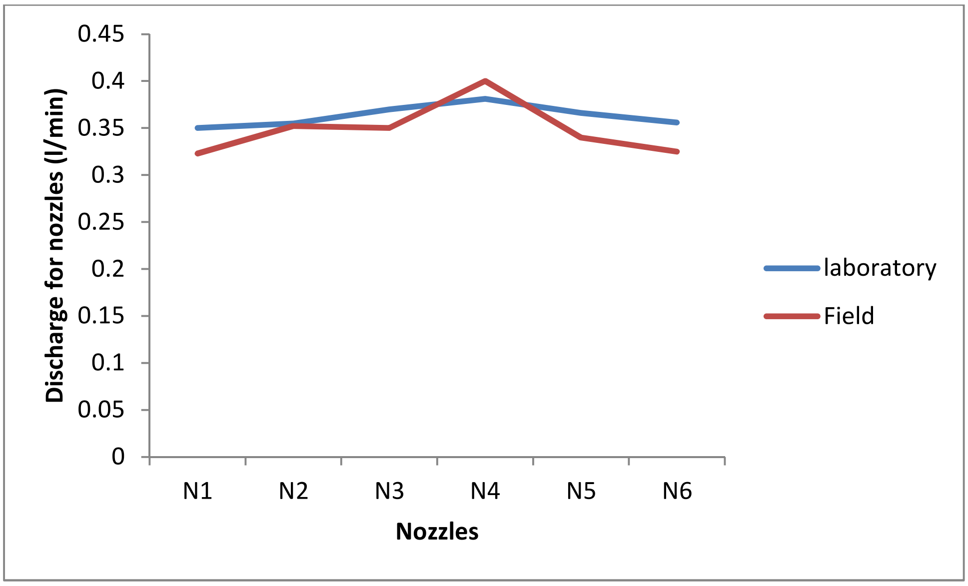


Figure 4.3 Discharge rate for even flat fan nozzle in laboratory and field evaluation

4.3.3 Discharge rate of sprayer for flood jet nozzles in field

The sprayer was operated on the field and the discharge of nozzles in one minute shall be collected and measured. The average nozzles discharge were 0.398 l min-1, 0.406 l min-1, 0.415 l min-1, 0.411 l min-1, 0.412 l min-1, and 0.395 l min-1 from N1, N2, N3, N4, N5, and N6 respectively. The average discharge from nozzles is 0.409 l min-1 at the average operating pressure of 1.6 bars. The average value of the coefficient of variation for the nozzles discharge was 1.947 per cent during the field testing.

Table 4.8 Discharge rate of individual nozzle in the field test

No of trail	**Discharge (l/min)**						**Mean discharge (l/min)**	**CV, %**
	Nozzles							
	N1	N2	N3	N4	N5	N6		
1	0.395	0.400	0.415	0.408	0.410	0.390	0.403	2.83
2	0.410	0.415	0.420	0.410	0.420	0.400	0.413	1.83
3	0.390	0.405	0.410	0.415	0.405	0.395	0.413	2.25
average	0.398	0.407	0.415	0.411	0.412	0.395	0.406	1.95

N1, N2, N3, N4. N5 and N6 are six flood jet nozzles fitted on the boom at 40 cm spacing

4.3.4 Performance of flood nozzles in laboratory and field evaluation

Fig. 4.4 shows the discharge rate of the flood jet nozzle. The maximum discharge rates obtained 0.418 l/min for N4 nozzles and minimum discharge rates obtained 0.395 l/min for N6 nozzles. The trend shows the variation in the discharge of the nozzle is more in the field evaluation. The discharge first increased, then attained a maximum value for the centre nozzle and then decreased towards for the outer nozzles in both cases.

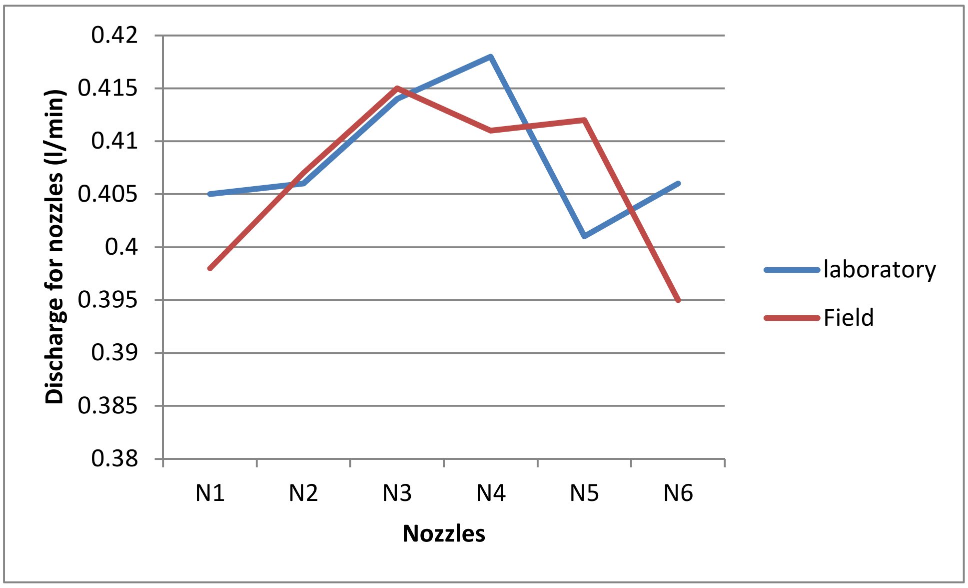


Figure 4.4 Discharge rate for even flood jet nozzle in laboratory and field evaluation

4.3.5 Power requirement

Draft was determined with the help of a load cell having range of 125 kg in the field. The load cell was connected to the sprayer and pull out by a manually. The average draft of the developed machine was found to 12.06 kgf (118.3 N) and the average speed of operation of machine was found to be 2.25 km/h (Appendix: A).

The power requirement for the operation of developed sprayer machine was calculated at the average draft (12.06 kgf) and speed (2.25 km/h).The average power requirement for operated the developed sprayer was found to be 0.10 hp or 0.07 kW (Appendix: A).

Plate 4.3 Draft measurements during field evaluation

4.3.6 Field capacity

The field capacity depends upon the working width of sprayer and speed of operation. During the field operation many factors influence the field capacity of sprayer i.e. turning losses, filling losses and field conditions of field and the speed of operation. The six number of nozzles fitted on boom at nozzle spacing was 40 cm, then the working width was 240 cm and the average speed of operation of machine was found to be 2.25 km/h.

Field capacity includes theoretical field capacity and effective field capacity. The average theoretical field capacity and actual field capacity of sprayer was observed to be 0.54 ha h^{-1} and 0.42 ha h^{-1} respectively. The field efficiency of the developed machine was found to be 78.46 per cent (Appendix: A).

The theoretical field capacity of the developed sprayer is 0.54 ha/h and 0.054 ha/h for knapsack sprayer (Zilpilwar, et al., 2018). The fig. 4.5 shows the theoretical field capacity of the developed sprayer is more as compare to hand operated knapsack sprayer because the developed sprayer was having more swath width (2.4 m) for a spray.

Fig. 4.6 shows the actual field capacity of the developed sprayer is more as compare to hand operated knapsack sprayer. The developed sprayer takes 2.38 h to cover and 18.42 hours to cover 1 ha land.

Fig.4.7 shows the field efficiency of the developed sprayer is less as compare to hand operated knapsack sprayer. The developed sprayer was taking more time to turn and tank refilling in the field that increasing the non-productive time in the field.

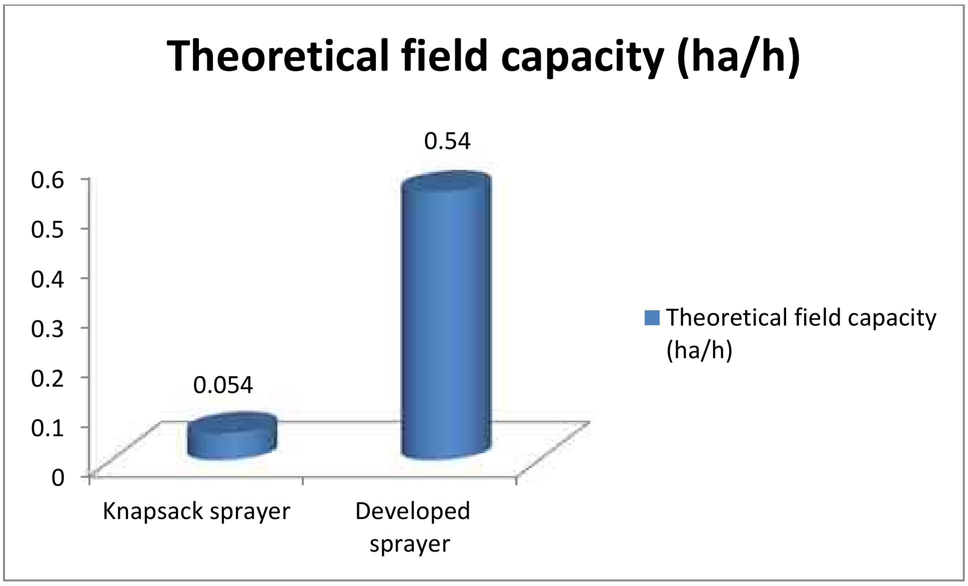


Figure 4.5 Comparison of theoretical field capacity between developed sprayer and knapsack sprayer

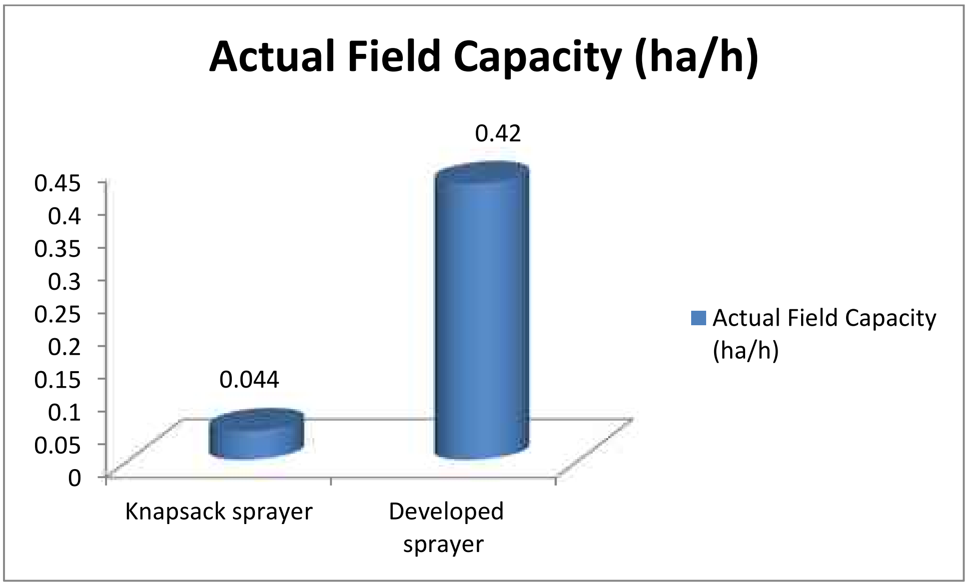


Figure 4.6 Comparison of actual field capacity between developed sprayer and knapsack sprayer

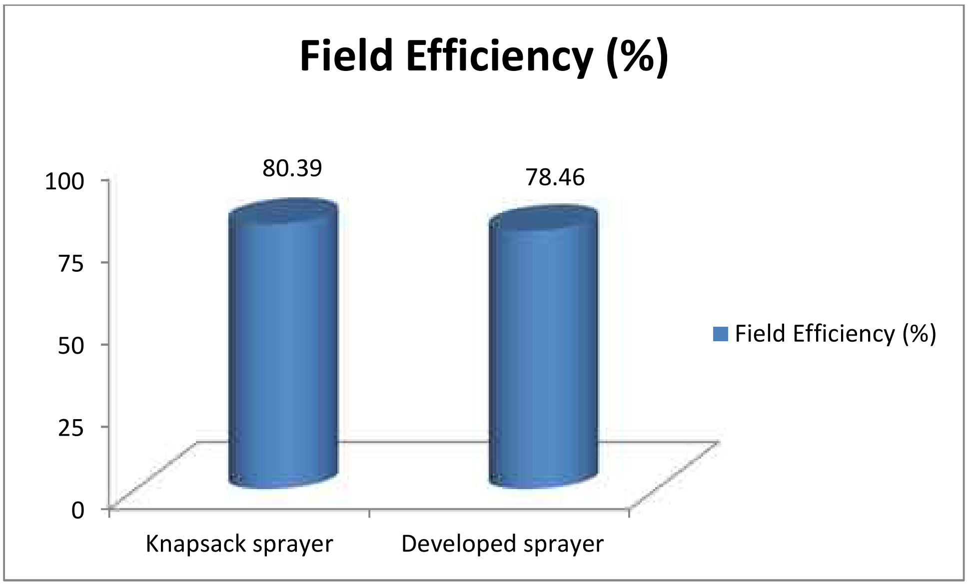


Figure 4.7 Comparison of field efficiency for developed sprayer and knapsack sprayer

4.3.7 Sprayer Application Rate

The rate of application should be uniform over the whole of the field area. Too much application as well as too less application rate is both undesirable. There are many methods described for calibration of sprayer. The sprayer can be calibrated theoretically and practically in the field. It is good to frequently verify the correctness of theoretical calibration with field practical calibration.

Application Rate for flat fan nozzle,

A very simple and easy to remember formula is:

Quantity of liquid collected from all nozzle on the boom (D) = 2.03 (l/min)

Spray swath width (W) = 240 (cm)

Speed (S) = 2.25 km/h

$$\text{Application rate (l/ha) } A = \frac{60000\ D}{S\ W}$$

$$= \frac{60000 \times 2.03}{2.25 \times 240}$$

Application rate = 225.55 l/ha

Application Rate for flood jet nozzle,

A very simple and easy to remember formula is:

Quantity of liquid collected from all nozzles on the boom (D) = 2.433 (l/min)

Spray swath width (W) = 240 (cm)

Speed (S) = 2.25 km/h

Application rate (l/ha) A = $\frac{60000\ \mathrm{D}}{\mathrm{S\ W}}$

$$= \frac{60000 \times 2.43}{2.25 \times 240}$$

Application rate = 270.33 l/ha

Practical calibration for sprayer,

For this practical field calibration a small area is demarked, say 100 m2 (10 x 10 m). The sprayer is filled with a known volume of water, say 10 litres. Then the operator sprays this area uniformly and evenly. Afterward, the quantity of water still remaining in the sprayer is measured by a jar. The quantity of water sprayed can be found out. In this case, 2.6 litres by flat fan nozzle and 3 litres by flood jet nozzle were sprayed in 100 m^2. For one hectare or 10,000 m^2 volume needed is 260 litres for flat fan nozzle and 300 litres for flood jet nozzle. The application rate can be affected by the nozzle discharge rate, swath width, and the walking speed of the operator on the field.

The application rate of the developed sprayer was lower than the knapsack sprayer, which shows the reduction of excess uses of chemicals on the field.

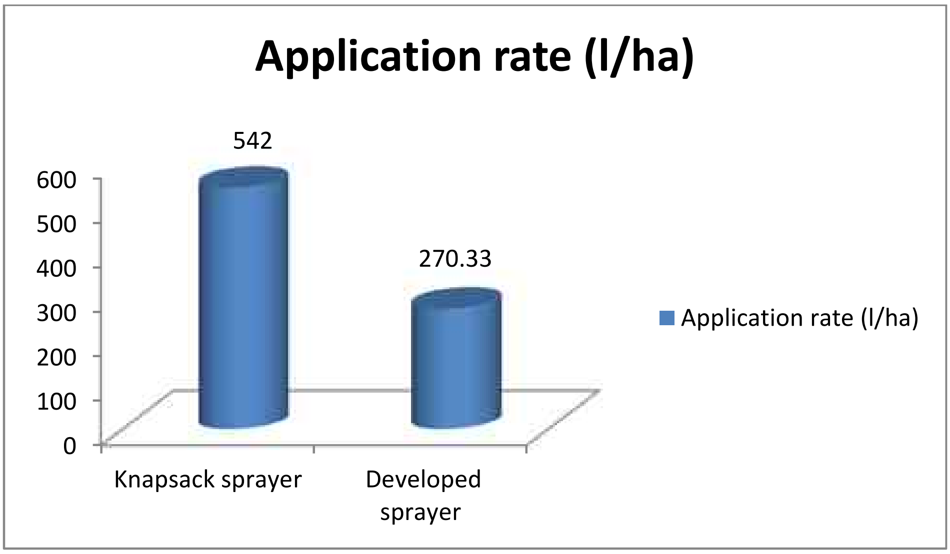


Figure 4.8 Comparison of application rate for developed sprayer and knapsack sprayer

4.4 Cost economics of manually operated multi nozzle sprayer

The total cost of the machine includes the cost of material, fabrication, and assembling of push type manually operated multi nozzle sprayer machine was calculated and it was found to be ₹ 8500/. The life of the machine has been considered as 8 years and annual use 150 hours. Assuming an appropriate rate of depreciation, interest, housing insurance and taxes, labour charge, repair, and maintenance charge, the cost of operation of manually operated multi nozzle sprayer machine was calculated per hour and per hectare. The cost of operation for spraying was found to be 182.49 ₹/ha. The cost economics for push type manually operated multi nozzle sprayer machine is given in table 4.9.

Fig. 4.9 shows the cost of operation per hectare was 182.49 ₹/ha for the developed sprayer and 1467.55 ₹/ha for the knapsack sprayer (appendix B), which found that the cost of operation is less for the developed sprayer because the time required in spraying for the developed sprayer is less to cover 1 ha land as compare to knapsack sprayer.

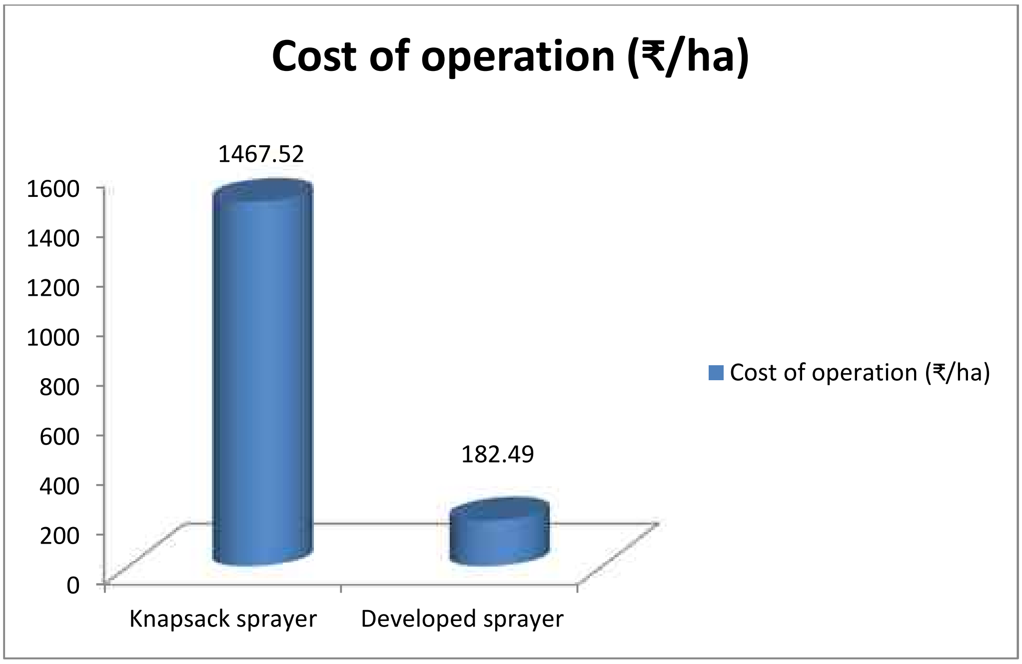


Figure 4.9 Cost of operation for developed sprayer and knapsack sprayer

Table 4.9 Cost economics of push type manually operated multi nozzle sprayer machine

S.No	Particulars	Amount
1	Cost of manually operated push type two row onion seed plant machine, ₹	8500
2	Life of the machine (y)	8
3	Annual use (h)	150
4	Depreciation, ₹/h	6.375
5	Interest, ₹/h	3.75
6	Insurance, taxes and shelter ₹/h	0.62
A(4+5+6)	Fixed cost (₹/h)	**10.745**
7	Repair and maintenance cost, ₹/h	3.4
8	Wage of 2 labour , ₹/h	62.5
B(7+8)	Variable cost (₹/h)	**65.9**
A+B	Total operating cost, (₹/h)	**76.645**
C	Cost of operation, ₹/ha	182.49

CHAPTER - 5

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

5.1 Summary

Agriculture is the backbone of India. The agriculture sector is required to enhance and increase the productivity of the field crop. This project deals with improving design, improve the spraying methods, increase crop productivity, and reduce the farmer's effort with skill implementation in the agriculture sector.

Agriculture, with its allied sectors, is the largest source of livelihoods in India. 70 per cent of its rural households still depend primarily on agriculture for their livelihood, with 82 per cent of farmers being small and marginal (www.fao.org, India at a glance). The economic conditions of average Indian farmers are poor and hence they cannot afford costly mechanization methods high improved machines. Spraying is an essential component of farming as it is important to spray the pesticides to improve the efficiency in spraying for increasing yields and meet the growing food requirements of India.

The average Indian farmer is using conventional methods for spraying of crops, these methods include the knapsack sprayer which has to be mounted on the back and requires the lever to be operated manually to spray. Continuous weight on the back of the farmer leads to back pain and manual pumping leads to wastage of efforts of the farmers. There is a need to reduce these efforts, and speed up the spraying application in the field. The agriculture sector is facing problems with capacity issues, shrinking revenues, and labor shortages and increasing consumer demands. The prevalence of traditional agriculture equipment intensifies these issues. Thus, a significant opportunity rests with understanding the impact of a sprayer in an agriculture field.

The prototype of the sprayer has mainly consisted of various components like mainframe, knapsack spray, traction wheel, boom, nozzles, and flexible rubber hose. The basic principle of operation is the ground wheel rotates and transmitting the power to the attached driving sprocket which in turn drives a smaller sprocket that is attached to a shaft through the chain drive. The rotary motion of the smaller sprocket is then converted into the reciprocating motion by the single lever-crank mechanism, which actuates the single-acting reciprocating piston of the pump installed in the tank, the pump is pumping the chemical to the nozzles which are mounted on the boom of a sprayer.

For the laboratory studies were conducted to determine the effect of the selected parameters on the performance of the developed sprayer. The performance of the developed sprayer was evaluated for discharge rate and overlap present for nozzles.

For the field evaluation of the push type manual operated multi nozzle sprayer was operated on a field. The field size, test duration, spray pressure, swath, discharge, speed of operation, field capacity and field efficiency were taken during field evaluation.

Based on the results obtained from performance tests at laboratory and at field level following conclusions are drawn:

1. The average discharge rate on laboratory evaluation was 0.363 l/min 0.409 l/min for flat fan and flood nozzles respectively.
2. The average overlap per cents were 35.81 per cent and 47.18 per cent for flat fan and flood jet nozzles respectively.
3. The average discharge rate on field evaluation was 0.338 l/min 0.406 l/min for flat fan and flood nozzles respectively.
4. The draft required for operating the machine was observed to be average 12.06 kgf (118.3 N).
5. The power requirement for the operation of the developed sprayer machine was found to be 0.1hp (0.07kw) at the average draft 12.06 kgf and speed 2.25 km/h.
6. The theoretical field capacity and actual field capacity of the machine were observed to be 0.54 ha h-1 and 0.42 ha h-1 for spraying operation respectively.
7. The field efficiency of the sprayer was observed to be averagely 78.46 per cent.

8. By theoretical field calibration, the application rate for sprayer was observed to be 225.5 l ha-1 and 270.33 l ha-1 for flat fan and flood jet nozzles.
9. In practical field calibration, the application rate for sprayer was observed to be 260 l ha-1 and 300 l ha-1 for flat fan and flood jet nozzles.
10. The cost of operation for spraying was found to be 182.49 ₹/ha.

5.2 Conclusions

The following conclusions drawn from the study are as follow

1. The selection of the type of knapsack sprayer was based on the literature survey and the most commonly used by the farmers.
2. Based on the results of the laboratory evaluation, the manual operated multi nozzle sprayer was developed, which has Overall dimensions (Length x Width x Height) and weight of the developed sprayer was found to be 1.2 m x 0.52 m x 1.52 m and 50 kg, respectively.
3. The developed manual operated multi nozzle sprayer was evaluated in the actual field conditions. The field capacity and field efficiency of the developed machine for spraying was found to be 0.42 ha/h and 78.46 %, respectively at the average operational speed of 2.25 km/h.
4. The cost of operation for spraying one hectare of land by the developed manual operated multi nozzle sprayer, the cost of operation came to ₹ 182.49 ₹/ha. For spraying one hectare of land by knapsack sprayer was, the cost of operation came to ₹ 1467.52/ha.
5. The performance of the developed machine was found satisfactory for a selected crop in the field. It will be useful for small and marginal farmers.

5.3 Suggestions for future work

The following suggestion are given for future research

1. Development of the manual operated multi nozzle sprayer with self-propelled mode by adding a small engine.
2. In developed, manual operated multi nozzle sprayer may improve by using a battery operated sprayer pump at the place of knapsack sprayer.
3. Ergonomically study of push type manual operated multi nozzle sprayer.

4. The developed machine may be demonstrated in a larger area and on the farmer's fields for their valuable recommendations before commercialization.

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APPENDICES

APPENDIX: A

Field performance of manual operated multi nozzle sprayer

1.1 Operating speed

Distance covered by planter operator per unit time. Seed calculated given formula.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} \times 3.6, \text{ km/h}$$

Table A.1 Operational speed measurement of planter in field

s. no.	Distance (meter)	Time (second)	Speed (km/h)
1	50	80	2.25
2	50	76	2.36
3	50	83	2.16
Average	50	79.66	2.25

1.2 Theoretical field capacity

Nominal width of developed sprayer was

Size of boom of sprayer (w) = 6 × 40 cm (2.4m)

Average speed of operation (s) = 2.25 km/h

Theoretical field capacity $F_t = \frac{W \times S}{10}$, ha/h

$$F_t = \frac{2.4 \times 2.25}{10}, \text{ ha/h}$$

= 0.54 ha/h

1.3 Actual field capacity

Test field size = 50 × 50

Area of field = 2500 m^2 = 0.25 ha

Average value for total time taken for field completion 40 min = 0.67 h

Average value for total non-productive time taken for total field completion 5 min = 0.08 h

Effective field capacity (ha h^{-1}) = $\frac{A}{T_1 - T_2}$

Where,

A = actual area covered, ha

T_1 = Total time require for operation, h

T_2 = non-productive time, h

$$(F_c) = \frac{.25}{0.67 - 0.08}$$

$$(F_c) = 0.42 \text{ ha/h}$$

1.4 Field efficiency of sprayer

Field efficiency = $\frac{Fc}{Ft} \times 100$, %

Field efficiency = $\frac{0.42}{0.54} \times 100$

Field efficiency = 78.46 %

1.5 Total time per hectare

Time taken for complete per hector, It is a reciprocal of actual field capacity

Time = 1/actual field capacity

= 1 / 0.42

Time = 2.38 h/ha

1.6 Power requirement

Power = $\frac{\text{Draft} \times \text{Speed}}{75}$

= (12.06 × 0.0.625)/75

= 0.10 hp

= 0.07 Kw

APPENDIX: B

1. Cost of operation of manual operated multi nozzle sprayer

Cost Economy

Cost of operation of sprayer

Fixed cost,

Initial cost of sprayer P = ₹ 8500

Salvage cost (s) of machine = 10% of initial cost of sprayer

Assumed life of machine = 8 years

Annual use hour = 150 h

Repair and maintenance cost = 6% per initial cost of sprayer

Fixed cost,

Depreciation = $\frac{P-S}{L \times H}$

$= \frac{8500-850}{8 \times 150}$

= 6.375 ₹/h

Interest (@12% per annum)

Interest = $\frac{P+S}{2} \times \frac{I}{H}$

$= \frac{8500+850}{2} \times \frac{12}{100 \times 150}$

= 3.75 ₹/h

Housing, insurance and Tax = $\frac{P+S}{2} \times \frac{2}{100 \times 150}$

$= \frac{(8500+850)}{2} \times \frac{2}{100 \times 150}$

= 0.62 ₹/h

Variable cost,

Repair and maintenance cost = $\frac{8500 \times 6}{150 \times 100}$

= 3.4 ₹/h

Labour cost for sowing (@250/day for 8h)

No of labour required = 2

= 250×2/8

= 62.5 ₹/h

Total cost of operation (₹/h) = (6.375+3.75+0.62+3.4+62.5)

= 76.645 ₹/h

Operation cost per hector

Operation cost per hector = $\frac{\text{Total cost of operation}}{\text{field capacity}}$

$= \frac{76.645}{0.42}$

= 182.49 ₹/ha

2. Cost of operation of manual operated knapsack sprayer

Cost Economy

Cost of operation of sprayer

Fixed cost,

Initial cost of sprayer P = ₹ 1250

Salvage cost (s) of machine = 10% of initial cost of sprayer

Assumed life of machine = 8 years

Annual use hour = 150 h

Repair and maintenance cost = 6% per initial cost of sprayer

Fixed cost,

Depreciation = $\frac{P-S}{L \times H}$

$= \frac{1250-125}{8 \times 150}$

= 0.93 ₹/h

Interest (@12% per annum)

Interest = $\frac{P+S}{2} \times \frac{I}{H}$

$= \frac{1250+125}{2} \times \frac{12}{100 \times 150}$

= 0.55 ₹/h

Housing, insurance and Tax = $\frac{P+S}{2} \times \frac{2}{100 \times 150}$

$$= \frac{(1250+125)}{2} \times \frac{2}{100 \times 150}$$

= 0.091 ₹/h

Variable cost,

Repair and maintenance cost = $\frac{1250 \times 6}{150 \times 100}$

= 0.5 ₹/h

Labour cost for sowing (@250/day for 8h)

No of labour required = 2

= 250×2/8

= 62.5 ₹/h

Total cost of operation (₹/h) = (0.93+0.55+0.091+0.5+62.5)

= 64.571 ₹/h

Operation cost per hector

Operation cost per hector = $\frac{\text{Total cost of operation}}{\text{field capacity}}$

$$= \frac{64.571}{0.044}$$

= 1467.52 ₹/ha

APPENDIX: C

Table C. 1 Field performance of developed sprayer

	Particulars	1st trial	2nd trial	3rd trail	Average
	Date of test	12/02/2020	14/02/2020	02/03/2020	
1.	Area (ha)	0.25	0.25	0.25	0.25
2.	Actual operating time (min)	38	42	40	40
3.	**Time lost owing to**				
I.	Turning at headland (min)	3	3.3	4	3.1
II.	Resting time (min)				
III.	Refilling of liquid chemicals (min)	1.2	2	1.4	1.5
4.	Total nonproductive time (min)	4.4	5.1	5.5	5
5.	Travelling speed (km/h)	2.36	2.16	2.25	2.25
6.	Working width of Sprayer (m)	2.4	2.4	2.4	2.4
7.	Theoretical field capacity (ha h^{-1})	0.57	0.52	0.534	0.54
8.	Actual field capacity(ha h^{-1})	0.45	0.407	0.43	0.43
9.	**Field efficiency (per cent)**				
	Developed sprayer	78.94	78.26	80.52	79.24
10..	**Discharge rate for boom (l/min)**				
I.	For flatt fan nozzle (l/min)	2.06	2.0	2.03	2.03
II.	For flood jet nozzle (l/min)	2.418	2.48	2.42	2.433
11.	**Application rate (l/ha)**				

I.	Application rate for flat fan nozzle (l/ha)	228.9	222.2	225.5	225.5
II.	Application rate for flood jet nozzle (l/ha)	268.67	275.55	268.89	271.03
12	Draft (N)	120.5	116.4	118	118.3
13	Power requirement (hp)	0.107	0.09	0.1	0.1
14	**Labour requirement**				
	No of labors	2	2	2	2

Table C. 2 Comparison of performance between developed sprayer and knapsack sprayer

S.NO	Parameters	Knapsack Sprayer	Developed Sprayer
1.	Time for Spray(h/ha)	18.42	2.5
2.	Speed of operation (km/h)	1.18	2.25
3.	Swath width (m)	0.46	2.40
4.	Theoretical field capacity (ha/h)	0.054	0.54
5.	Actual Field Capacity (ha/h)	0.044	0.40
6.	Field Efficiency (%)	80.39	75.74
7.	Application rate (l/ha)	542	270.33

APPENDIX: D

Specification of load cell

1. Capacity upto 125kg with Beam and diaphragm combination.
2. Tension, compression and bi-directional options.
3. Maximum error in axial force component measurement is limited to 0.25% within a 3° angle swept through 360° around the load cell axis. Its various end-fixing options are all inert and easily modified for direct inclusion in mechanical assemblies.
4. Integral 4 to 20mA or ±10V output amplifiers can be fitted as an option.
5. Parameter Value Unit are given below:
    i. Non-linearity - Terminal ±0.05 % RL
    ii. Hysteresis ±0.05 % RL
    iii. Creep - 20 minutes ±0.05 % AL
    iv. Repeatability ±0.02 % RL
    v. Rated output - Rationalized 2.0 mV/V
    vi. Rationalization tolerance (applies to single direction calibrations) ±0.1 % RL
    vii. Output symmetry ±0.3 % AO
    viii. Zero load output ±4 % RL
    ix. Temperature effect on rated output per ºC ±0.002 % AL
    x. Capable rod ends and suitable for indicator as specification below:

    Power source 6V sealed lead rechargeable battery bridged supply 5V dc fixed, calibration check internal shunt resistor, and accuracy ±0.02 %

Calibration of load cell

1. While powering **ON**, hold **MENU** switch and power **ON**.
2. You will get '**CAL-?**' on display.
3. Press **ENTER** switch.
4. Display will show **CAL-0** and after few second display will show **LOAD** automatically.

5. Now apply standard **WEIGHT / FORCE** on the sensor (20% to 30% of full capacity).
6. Press **ENTER** switch, display will show you numeric value. Now enter the value of applied **WEIGHT / FORCE** using **UP arrow** and **SIDE arrow** switches.
7. Now press **ENTER** switch, display will show **CAL F** and **UNLOAD** after sometime (Avoid touching the sensor during this time).
8. Remove **WEIGHT / FORCE** from the sensor and press **ENTER** switch again. Now system is calibrated and ready to you.

CURRICULAM VITAE

VITAE

Er. Vikas Lilhore S/o Shri Kishorilal Lilhore was born on 31st May 1996 at Vill.-Borgaon, Dist.- Betul, Madhya Pradesh, 460666. He did his high school from Sarswati Shishu Vidhaya Mandir, Betul, (M.P.) under Madhya Pradesh Board of Secondary Education securing 82.83%. He also completed H.S.C by securing 68.8 % from Sarswati Shishu Vidhaya Mandir, Betul, (M.P.) under Madhya Pradesh Board of Secondary Education.

He admitted to 'Bachelor of Technology' at A. K. S. University, Satna, M.P. He successfully completed the degree in the year 2018 with a CGPA of 8.28 at 10.00 point scale.

In the year 2018, he joined 'Master of Technology' two years post graduate degree programme in the Department of Farm Machinery and Power Engineering at College of Agricultural Engineering, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, (M.P.). After completing the entire prescribed course work successfully, he has submitted the thesis entitled "Development of Push Type Manually Operated Multi Nozzle Sprayer" in partial fulfillment of the requirements for the award of degree of 'Master of Technology'.