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DESIGN AND DEVELOPMENT OF A WHEEL SPRAYER

BY

KIRAN K. J. (2017-02-031)

MAYALEKSHMI K. M. (2017-02-032)

REHNA SALMA ALI (2017-02-036)

PROJECT REPORT

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR – 679573,

MALAPPURAM KERALA, INDIA

2021

DECLARATION

We hereby declare that this project report entitled **"DESIGN AND DEVELOPMENT OF A WHEEL SPRAYER"** is a bonafide record of project work done by us during the course and that this report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Place: Tavanur

Date : /03/2021

Kiran K. J. (2017-02-031)

Mayalekshmi K. M. (2017-02-032)

Rehna Salma Ali (2017-02-036)

CERTIFICATE

Certified that this project report entitled **"DESIGN AND DEVELOPMENT OF A WHEEL SPRAYER"** is a record of project work done jointly by **Mr. Kiran K. J., Ms. Mayalekshmi K. M.** and **Ms. Rehna Salma Ali** under my guidance and supervision and that it has not previously formed the basis for any degree, diploma, fellowship or associateship or other similar title of another University or Society.

Place: Tavanur

Date: /03/2021

Dr. PREMAN P.S.
Associate Professor (FPME)
Dept. of FMPE
KCAET, KAU

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KIRAN K. J. (2017-02-031)

MAYALEKSHMI K. M. (2017-02-032)

REHNA SALMA ALI (2017-02-036)

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SYMBOLS AND ABBREVIATION

Abbreviation/Notation	Description
/	Per
^{0}	Degree
^0C	Degree Celsius
%	Percentage
3D	Three dimensional
CAD	Computer aided design
cm^2	Square centimetre(s)
cm^3	Cubic centimetre(s)
et al.	And others
Fig.	Figure
h	Hour
ha	Hectare
hah^{-1}	Hectare per hour
hha^{-1}	Hour per hectare
i.e	That is
ID	Inner Diameter
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg	Kilogram

$kgfcm^{-2}$	Kilogram force per square centimetre
kgf	Kilogram force
$km\ h^{-1}$	Kilometre per hour
L	Litre
ls^{-1}	Litre per second
lha^{-1}	Litre per hectare
$l\ min^{-1}$	Litre per minute
mm	Millimetre(s)
mm^2	Square millimetre(s)
m	Metre(s)
m^2	Square meter(s)
m^3	Cubic metre(s)
ml	Millilitre
ms^{-1}	Metre per second
$m^3\ s^{-1}$	Cubic metre per second
MPa	Mega Pascal
MS	Mild steel
N	Newton
OD	Outer diameter
PVC	Polyvinyl chloride
rpm	Revolution per minute
Rs.	Rupees
s	Second

sm^{-2}	Second per square meter
UP	Uttar Pradesh

CHAPTER-I
INTRODUCTION

India is said to be an agriculture-based country where 75 per cent of the population of India is dependent on farming directly or indirectly. But still our farmers are doing farming in the same traditional ways for the ages (Raut, 2013). There is a need of development in this sector and most commonly on fertilizers and pesticides spraying technique, because it requires more efforts and time to spray by traditional way. In order to meet the requirement of food of growing population and rapid industrialization, there is a need of modernization of the agriculture sector. On many farms production suffers because of delay in sowing, improper distribution of pesticides and fertilizers, harvesting etc. One of the main reasons for lower productivity is insufficient power availability for the farms and very low levels of farm mechanization. Mechanization solves all the problems which are responsible for low production (Miller *et.al*, 2004). It conserves the input and precision in work and gets better and equal distribution. It reduces quantity needed for better response, prevent the losses and wastage of input applied. This results in higher productivity and cost effective utilization of agricultural implements.

A major share of agriculture in India is contributed by vegetables, cereals, pulses and spices. India has a bright future with respect to the production and export of spices. Pepper, cardamom, chillies and turmeric are some of the important spices produced in India. India is a great exporter of spices. Chilli is one among the valuable spice crop produced in India. The crop is grown largely for its fruits all over India. The major vegetable crops grown in India, which accounts for 11.2 per cent of global vegetable production, are potato, tomato, onion and okra. Tomato is one of the most important vegetable crop regarding both income and nutrition (Hussain and Abid, 2011).

Chilli (*Capsicum annuum* L.)is one of the important spice crop of India and widely cultivated throughout warm temperate, tropical and subtropical countries. Chilli is included in the family Solanaceae. It is used in India as a principle ingredient of various dishes. Chilli can be grown in all types of soil from light sandy to heavy soils. Chilli is not an annual crop and in the absence of winter crop can survive several seasons and grow into a large perennial shrub. While the species can tolerate most climates, it is highly productive in warm and dry climate. Chilli is growing under both rain fed and irrigated conditions. India is the major producer, consumer and exporter of chilli in the world. Pusa Sadabahar, Pusa Jwala, Ujwala are some of the important varieties of chilli grown in India. They are mainly cultivated in Andhra Pradesh, Karnataka, Maharashtra, U.P, Bihar and Tamil Nadu (Hussain and Abid, 2011).

Tomato (*Solanum lycopersicum* L.) is a very important vegetable used in almost all meals and is consumed in diverse ways. Tomato cultivation in India is one of the most profitable agribusiness. The expertise of growers, an ideal climate, and good soils contribute to production of tomatoes for processing. Extreme damage from diseases and insects can render tomatoes unusable. High value products require tomatoes to be free from blemishes caused by diseases and insects. Production of tomatoes for processing would be impossible without fungicides and copper bactericides to control diseases. Preventative applications of pesticides must be made to avoid or reduce losses from diseases (Dari *et.al*, 2015).

Plant protection plays a significant role in optimizing the productivity of a given crop. Agricultural pests inflict considerable damage to crops and represent a significant production constraint. Effective plant protection thus becomes essential to minimize the losses caused and to ensure that full benefit is drawn from other production inputs.

Chemical application has been very successful in pest control but must be handled properly, applied in rationed proportions and spray effectively. Specialized equipment is thus essential for chemical application as the only fully mechanized farming operation. Spraying pesticide is an important process in farming. The objective of the application of pesticide is to keep the pest under check. The pest population has to be kept suppressed to minimum biological activities to avoid economic loss of crop yield. The objective of pesticide application besides keeping the pest population under check should also be to avoid pollution and damage to the non targets. These herbicides, pesticides, and fertilizers are applied to agricultural crops with the help of a special device known as "Sprayer". The sprayer provides optimum performance with minimum efforts. The invention of a sprayer, pesticides, fertilizers, bring revolution in the agriculture or horticulture sector as well as enable farmers to obtain maximum agricultural output. Machines previously developed for chemical application include the knapsack sprayers, the ultra-low volume sprayers and tractor boom sprayers (Liu, 2008). In general, equipment used for spraying chemicals to protect crops against pests, diseases and weeds range from big tractor mounted sprayers to manually operated knapsack sprayers (Matthews, 2008).

Spraying techniques

Small scale farmers are very interested in manually lever operated knapsack sprayer because of its versatility, cost and design. But this sprayer has certain limitations like it cannot maintain required pressure; it lead to problem of back pain. However, this equipment can also lead to misapplication of chemicals and ineffective control of target pest which leads to loss of pesticides due to dribbling or drift during application. Moreover, the quality of a number of these sprayers, and their ability to be used to apply pesticides accurately and efficiently is of great concern due to their design and operation. Spray application technique has an effect on spray deposition. Sprayer design cause major differences in spray distribution. The majority of the sprayers performed poorly, indicating that they are poorly designed with poor materials and mishandled by the farmers, (Mamat and Omar, 1992). Another type of sprayer is fuel operated which requires expensive fuel i.e. Diesel or petrol. A difficulty of petrol sprayer is the need to purchase the fuel which increases the running cost of the sprayer; it produces more vibrations and noise that irritates the farmer.

According to Hastings and Quick, (1988) a chance of overlap or missed areas was observed during swing of knapsack sprayers' lance operation and the nozzle height was changed by 10% in each swing of lance. That means it is quite difficult to maintain a constant nozzle height during swing of the lance.

A pesticide sprayer has to be portable and with an increased tank capacity as well as should result in cost reduction, labor and spraying time. In order to reduce these problems, there isa number of sprayers introduced in the market, but these devices do not meet the above problems or demands of the farmers. Today we use various spraying and seed sowing technologies involving use of electrical energy, chemical energy of fuels. This fact makes us know that how large content of energy is getting used at such places where mechanical energy can be used instead of direct energy sources. In markets battery operated and fuel operated pesticide sprayer are available. But this requires some external source of energy and increases cost of production. In conventional methods, the pesticide sprayer is mounted on the back which causes back pain and also improper spraying of pesticides. The heavy tank containing pesticide is carried by the farmer and requires a lot of human efforts for spraying (Ahmad *et al*., 2018).

.In view of the above constraints, a manually operated wheel driven sprayer was proposed which is mainly designed to reduce human effort. It is focused on spraying pesticides at maximum rate in minimum time by using wheel operated mechanism. The target of users is smaller industries and small gardens. Usually gardeners will use the manual knapsack sprayer that is heavy and need to carry on their back to do spraying session. But, proposed wheel sprayer needs only a forward push to operate it in field. Besides this, with a single operator, the proposed wheel sprayer can apply spray solution on both sides of its forward motion.So that the time taken is less, more area can be covered and effort is less than that of normal knapsack sprayer.

Problems caused by traditional sprayers:

- Heavy weight of sprayer causes difficulty in carrying on backside or shoulder of operator.
- Fatigue to the operator due to heavy weight.
- Heavy weight reduces the efficiency of the operator.
- Big size of pump cause inconvenience to the operator.
- Poor selection and quality of equipment.

Considering the above views, the proposed study entitled on “DESIGN AND DEVELOPMENT OF A WHEEL SPRAYER” has been taken up with the following objectives.

1. To design and develop a multi-nozzle wheel sprayer suitable for spraying chemicals and fertilizers on vegetable crops.
2. To fabricate a wheel sprayer.
3. To analyze the performance of the developed wheel sprayer.

CHAPTER II

REVIEW OFLITERATURE

The past research works related to wheel operated sprayer and other parameters are reviewed in this chapter. A brief review of work done relevant to various aspects of the present development is reported here under respective headings. Also the review of works related to parameters of selected crop are also specified.

2.1 General sprayers

Miller *et al.* (2004), has worked on "Effects of multi-mode four-wheel steering on sprayer machine performance". A self-propelled agricultural sprayer with four-wheel steering (4WS) was developed. A digital controller was designed to control the rear steering angle based on that of the front wheels through electro hydraulic control valves. Three modes of steering were enabled and investigated. Experimental methods were developed to determine potential of 4WS in improving machine performance. Machine performance of the sprayer was evaluated by measuring turning radius and performance metrics in headland turning and lateral path shift procedures. Coordinated 4WS resulted in smaller turning radii than conventional two wheel steering (2WS). In the headland turning tests, significant mean increases in aligning distance of 5.58 m and significant mean decreases in rear wheel off-tracking area of 9.3 m^2 were observed in 4WS over 2WS. In lateral path correction tests, crab 4WS substantially decreased the area and magnitude of estimated application errors over conventional 2WS, while coordinated 4WS resulted in increased application errors. These results provide evidence that 4WS could enable improvement in sprayer machine performance.

Joshua *et al.* (2010) has worked on "Solar Sprayer - An Agriculture Implement". Now-a-days the concept and technology employing this non-conventional energy becomes very popular for all kinds of development activities. One of the major area, which finds number applications are in agriculture sectors. Solar energy plays an important role in drying agriculture products and for irrigation purpose for pumping the well water in remote villages without electricity. This technology on solar energy can be extended for spraying pesticides, fungicides and fertilizers etc., using solar sprayers. This paper deals how a 'Power Sprayer' which is already in use and works with fossil fuel can be converted into solar sprayers works without any fossil fuel. The concept of solar PV technology on solar sprayers was used as an energy alternative device for power sprayers.

Poratkar and Raut (2013) carried out their work in “Development of Multi nozzle Pesticides Sprayer Pump”. Small scale farmers are very interested in manually lever operated knapsack sprayer because of its versatility, cost and design. But this sprayer has certain limitations like it cannot maintain required pressure; it leads to problem of back pain. However, this equipment can also lead to misapplication of chemicals and ineffective control of target pest which leads to loss of pesticides due to dribbling or drift during application. This phenomenon not only adds to cost of production but also cause environmental pollution and imbalance in natural echo system. This paper suggests a model of manually operated multi nozzle pesticides sprayer pump which will perform spraying at maximum rate in minimum time. Constant flow valves can be applied at nozzle to have uniform nozzle pressure.

Rao *et al.* (2013) have worked on “Multiple power supplied fertilizer sprayer”. In their work, they have proposed a system of modified model of two stroke petrol engine powered sprayer which minimizes the difficulties of existing power sprayer such as operating cost, changing of fuel etc. The two stroke petrol engine has been replaced by a direct current motor and operated by electrical energy stored in the battery attached to the unit in which the battery can charged by solar energy. This could also be operated on direct current during rainy and cloudy weather conditions. The system has been tested and compared with theoretical values of charging time.

Raut *et al*. (2013) have worked on agricultural sprayer with weeder. They have claimed that modernization and mechanization in agriculture is important to meet the food requirements of growing population. Mechanization enables the conservation of inputs through precision in metering that ensure better distribution, reducing quantity needed for better response and prevention of losses or wastage of inputs applied. Agricultural machinery program has been one of the selective mechanization with a view to optimize the use of human, animal and other sources of power.

Dhete *et al.* (2015) has worked on “Agricultural fertilizer & pesticides sprayers”. In his work he emphasizes on different methods of spraying devices. Due to chemical fertilizers the fertility of soil is decreasing. Hence farmers are attracted towards organic farming. By mechanization in spraying devices fertilizers and pesticides are distributed equally on the farm and reduce the quantity of waste, which results in prevention of losses and wastage of input applied to farm. It will reduce the cost of production. Mechanization gives higher productivity in minimum input. Farmers are using same traditional methods for spraying fertilizers and pesticides. Equipment is also the same for ages. In India there is a large development in industrial sectors compared to agricultural sectors. Conventionally the spraying is done by labourers carrying backpack sprayer and fertilizers are sprayed manually. The efforts required are more and beneficial by farmers having small farming land.

Kshirsagar *et al*. (2016) claimed that the spraying of pesticides and insecticides is traditionally done by farm worker carrying backpack type sprayer which requires more human effort. Giving attention to these important problems an attempt is made to develop equipment which will be beneficial to the farmer for the spraying operations. Agricultural sprayer vehicle should be able to work with help of appropriate controls in order to spray effectively along the path as required to perform the required functions.

Deshpande *et al*. (2017), has worked on "Agricultural Reciprocating Multi Sprayer". In agricultural sector generally farmer uses traditional way by carrying backpack sprayer on back and spraying on crop. This becomes time consuming, costly and human fatigue is a major concern. These problems can be overcome by using agricultural reciprocating multi sprayer. It facilitates uniform spread of the chemicals, capable of throwing chemicals at the desired level, precision made nozzle tip for adjustable stream and capable of throwing foggy spray depending on requirement. In their project they have used slider crank mechanism to convert rotary motion into reciprocating motion to operate the pump, thus the pesticide is spread through the nozzle. This work gives continuous flow of pesticide at required pressure and height. A special arrangement is implemented in this project to adjust the pressure as high or low, also a weed cuter was used for removing unwanted plants. By using agricultural sprayer, spraying time, weeding time, human efforts can be considerably reduced and also results in cost reduction.

Thakkar *et al.* (2017) have suggested a machine that saves time and operational cost. The invention of a sprayer brings revolution in the agriculture or horticulture sector which enables farmers to obtain maximum agricultural output. There are many advantages of using sprayers such as easy to operate, maintain, and handle, that facilitates uniform spread of chemicals, capable of throwing chemicals at the desired level, precision made nozzle tip for adjustable stream and capable of throwing foggy spray, light or heavy spray, depending on requirement. In this work, they have proposed a multi nozzle agricultural sprayer with the objective of application of pesticides to reduce the pest population under check and also to avoid pollution and damage to the non targets.

Subbarayudu and Venkatachalapathi (2017) have worked on "Modeling and Development of Pedal Operated Agricultural Sprayer". This project concentrates to minimize the human effort and to increase the speed ratio between pedal operation and reciprocation of the pump and discharge rate in the sector of manual sprayers. In this project the foot sprayer can be modeled, developed and fabricated. This sprayer is also invented to easy operation and transport from the one field to another field. It can be operated by both the legs at a time so that the applying load will be distributed equally to both the legs of the operator. This pedal operated sprayer is implemented by introducing the crank mechanism which converts rotary motion into linear motion. Then the frame and reciprocating pump will be designed. The different parts are piston, push rod, plunger, crank mechanism, pedal mechanism, suction pipe with strainer and delivery pipe with gun or lance. This project will help formers in the agriculture for the purpose of pesticides and insecticides spray to control field crops and orchards.

According to literature published on flow control of agricultural spraying machine by Massey university New Zealand on different spraying mechanism are studied New Zealand relies heavily on its agricultural industry. A large portion of this industry is pastoral farming, where livestock are raised to graze on pasture. This includes beef, sheep and dairy farming. An important aspect of this style of farming is maintaining pasture quality. In order to increase growth fertilizers are often applied to the pastures. This increase yields in both meat and milk production. However, the increased application of fertilizer is linked with diminishing water quality. While the effects of nitrogen leaching and the best ways to manage fertilizer use are still being investigated, it is clear that control over the application will become more and more important. The Tow and Fert is a range of fertilizer machines designed and built in New Zealand by Metalform Dannevirke. The Tow and Fert range is capable of spraying a wide range of fertilizers including both soluble and non-soluble fertilizers. The Tow and Fert is unique in its ability to spray fertilizer slurries consisting of mixture ratios of up to three parts fine particle fertilizer to one-part water. This is achieved by the use of a recirculating system. Currently there is next to no control on the flow rate of the machines and the application rate is determined by the speed the operator maintains. The purpose of this thesis is to design and build a flow control system for the Tow and Fert product range and investigate the effect of the changing flow rate on the spray characteristics. The ability to spray such a wide range of fluids with drastically different properties presents many challenges.

2.2 Wheel sprayer

Shivarajakumar *et al.* (2014), have done work on "Development of wheel driven sprayer". A pesticide sprayer has to be portable and with an increased tank capacity as well as should result in cost reduction, labour and spraying time. In order to reduce these problems, there are a number of sprayers introduced in the market, but these devices do not meet the above problems or demands of the farmers. The conventional sprayer having the difficulties such as it needs lot of effort to push the liver up and down in order to create the pressure to spray. Another difficulty of petrol sprayer is the need to purchase the fuel, which increases the running cost of the sprayer. In order to overcome these difficulties, an equipment was proposed that is wheel driven sprayer, it is a portable device and no need of any fuel to operate, which is easy to move and sprays the pesticide by moving the wheel. This wheel operated pesticide spray equipment consumes less time and avoids the pesticide from coming out of the front of nozzles which will be in contact with the person who sprays pesticides. The mechanism involved in this sprayer is reciprocating pump, which is driven by the wheel.

Wayzode *et al*. (2016), carried out their work in "Design and Fabrication of Agricultural sprayers, weeder with cutter". Chemicals are widely used for controlling disease, insects and weeds in the crops. They are able to save a crop from pest attack only when applied in time. The chemicals are costly. Therefore, equipment for uniform and effective application is essential. Dusters and sprayers are generally used for applying chemicals. In this work they have proposed an equipment that is wheel and pedal operated sprayer, it is a portable device and no need of any fuel to operate, which is easy to move and sprays the pesticide by moving the wheel and also peddling the equipment. The equipment is purposely designed for farmers having small farming land. This will be more beneficial when it is subjected to moist soil for weeding purpose. In this equipment using reciprocating pump, there is an accumulator provided for the continuous flow of liquid to create necessary pressure for the spraying action. Weed management is one of the tedious operations in crop production. Because of labour costs, time and fully manual weeding is unfavorable. Hence effort is made to design and develop efficient farm equipment to perform weeding without using electric power.

Harendra Singh *et al.* carried out their work on “Mechanical Agricultural Sprayer Vehicle”. The traditional spraying is not so profitable and is also time-consuming. To increase the productivity the agricultural advancement is inescapable. But using bulky and expensive electrical sprayers is expensive and inefficient. To overcome these problems a mechanism mounted on a vehicle for spraying is introduced which can increase the productivity and is inexpensive compared to the electrical sprayers. It can be equipped with a space to carry agricultural tools and equipments. An experimental investigation of setup is done to advance the spraying method and to increase the spraying efficiency with the help of a mechanism which is designed and made to increase the advancement in agriculture. This is mainly used for the purpose of gardening and floriculture.

Shambhu Singh *et al.* (2020) have done work on “Design, Fabrication and Evaluation of Wheel Operated Sprayer”. Pests and weed problems, in crop production are serious both in rain fed and irrigated farms in Chhattisgarh. Farmers are forced to spray insecticides, pesticides and herbicides frequently using manually operated machines, This becomes time consuming, poor in application uniformity, laborious, costly and human fatigue is major concern, these problems can be overcome by using manually wheel operated sprayer The objectives of this research saw to manufacture and evaluate wheel operated 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 639.09 l ha^{-1}, with coefficient of variation (CV %) of 2.50% among the nozzles discharge rate, effective field capacity of 0.075 ha hr^{-1}, theoretical field capacity of 0.126 ha hr^{-1} and field efficiency of 56%. Based on the performance result the newly developed sprayer can cover one hectare of land within about an hour with a better spray uniformity.

2.3 Parameters for spraying

Smith and Stom (1976) stated that drift potential can be decreased by reducing the number of small droplets. The uniformity of row to row droplet density and mean diameter in target area is raised by increasing the size of droplets.

Winterfield and Boving (1980) found out that an asymmetrical nozzle array does not enhance uniformity of distribution and effective swath width is reduced compared with symmetrical nozzle array, which gave reasonably regular rate of variation.

Nozzles are designed to give different rates of discharge, angle of spray and spray pattern. Nozzles are classified according to the type of spray pattern (Singh, 2017).Hollow cone nozzle is used to apply insecticides or fungicides where plant foliage penetration and complete coverage of leaf surfaces is essential. According to Singh, (2017) they operate at pressures ranging from 0.28-0.69 MPa. The spray angle is adjustable between 30^0 and 120^0.

Athul *et al.* (2017) have emphasized in their work on different nozzles and their spray patterns suitable for spraying on crops. From the spray patterns they have found that solid cone nozzle could give a more uniform spray than flat fan nozzle. The flat fan nozzles showed an irregular pattern. A nozzle with lesser fluctuations in spray uniformity was required. Solid cone type nozzles had more uniform pattern at the required overlap. The overlapping was done such that the target spray area received equal quantity of spray.

2.4 Plant- spraying requirements

Hussain and Abid (2011) stated that chilli plays a very important role in commercial sector. Chilli extensively grown for dry chilli (powder) is also harvested green. There are about 25 varieties commonly cultivated throughout the world. Chilli is economically very important and valuable cash crop. It requires warm and humid climate for growth and dry weather during maturity. There are many nutritional, medicinal and economic benefits of its production. But the yield of chilli is reducing gradually every year due to different pests and pathogens which cause heavy losses. Due to the use of improper methods of drying, different fungi particularly *Aspergillus* sp. grow on chilli fruits and produce toxic compounds which are harmful for human health.

Dhanalakshmi *et al.* (2015) have worked on "Evaluation of insecticidal spray schedules against sucking pests of chilli". Chilli is used very widely in culinary, pharmaceutical and beverage industries throughout the world. Chilli is very famous for its pleasant aromatic flavor, pungency and high colouring substance. It is an important condiment used for imparting pungency and colour to the food being rich in vitamin C, A, B, oleoresin and red pigment. Chilli crop suffers from several foliage and sucking pests which are responsible for low yields. Fungal diseases are major problems affecting chilli crops. Fruit rot or die back; wilt, cercospora leaf spot and powdery mildew are among the many problems. Pests like fruit borer, thrips, and mites are also the other major challenges affecting chilli crop. Among the sucking pests, white fly (*Bemisiatabaci* Genn.) and thrips (*Scirtothirps dorsalis* Hood) are serious production constraints. Thrips and white fly are considered generally as the major pest of chilli crop and causes leaf curl disease. Hence spraying of the pesticides and fertilizers is of paramount importance in the cultivation and irrigation of chilli crops.

Dari *et al*. (2016) have worked on "Pesticide use in the production of Tomato (*Solanum lycopersicum* L.) In some areas of Northern Ghana". Tomato is a very important vegetable used in almost all meals and is consumed in diverse ways. In Ghana, farmers and consumers of fruits and vegetables face immense risk of exposure owing to the use of toxic chemicals that are banned or restricted in the country or in other countries. The objective of this study was to ascertain farmers' access and use of recommended agro-chemicals for the production of tomatoes in three sampled farming communities in Northern Ghana. Sixty semi-structured questionnaires were administered and data analyzed using Minitab Statistical package with T-test for significance. Various agro-chemicals were used by farmers which include: those not suitable for tomatoes production; unapproved or banned agro-chemicals and those suitable for tomatoes production. Communities which produced the "Burkina" variety used about 70% of the sampled pesticides compared with 30% for the "Wosowoso" variety. The agro-chemical most used (32.8%) was Dichlorodiphenyltrichloroethane (DDT) though banned from the Ghana registered list of pesticides. Farmers have access to, and use agro-chemicals for tomato production in the study areas. Farmers therefore need to be sensitized on the use of recommended and appropriate agrochemicals and the hazards associated with the use for the crop, farmer and environment.

Kerala Agricultural University has worked on "Package of Practices Recommendations: Crops" 14th Edition, 2011. In this work, package of practices of vegetables like cucurbitaceous, solanaceous, cool season and minor vegetables are furnished. Control of pests of tomato with the help of non-chemical insecticides and tips for tomato seed production are given. Different varieties, seed rate, raising of seedlings, time of planting, land preparation and transplanting, spacing of planting, irrigation after cultivation and plant protection techniques are included in this report. High yielding and bacterial resistant varieties of chilli (*Capsicum annuum*) along with techniques of raising the seedlings, time of planting, land preparation and transplanting, manuring, plant protection techniques, spray pattern are given in the same.

2.5 Software used

Ziden *et al.* (2012) carried out their work in "Effectiveness of AutoCAD 3D Software as a Learning Supporting Tool". The 3D AutoCAD software is more realistic than 2D software. Also, the 3D software give a positive impact on learning even for moderate level group. AutoCAD software in orthographic drawing has a positive impact on the understanding of users.

AutoCAD software was used for making the sketch of designed wheel sprayer as per the dimensions. Ogli (2020) suggested that the use of AutoCAD differs from any visual materials and posters, with the use of drawing, machine and construction drawing and the ease of use in several disciplines. AutoCAD is excellent and popular software that enables us to create high quality schemes and drawings of any type. It will also help the users get the most out of their creative abilities.

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CHAPTER III

MATERIALS AND METHODS

In this chapter, methodology adopted for the design, development and testing of wheel sprayer is briefly explained. Design parameters and procedures of the main components of wheel sprayer is explained. Cost analysis of the developed wheel sprayer is also described here.

3.1 Study area

3.1.1 Site selection

Field which is located near Vasudevapuram Temple in KCAET campus, Tavanur village, (10.8526^0 N and 75.9861^0 E) Malappuram District, Kerala was selected. Soil of the field selected was of lateritic with adequate drainage and sunlight.

Plate 3.1 Chilli field

3.1.2 Field layout

A field of 15000 x 10000 mm size is selected and 10 rows of continuous furrows with a spacing of 1000 mm are made. Ujwala variety of chilli seedlings of 1 month old are transplanted with a plant to plant spacing of 500 mm. The field layout for the testing of developed wheel sprayer is shown in Plate 3.2.

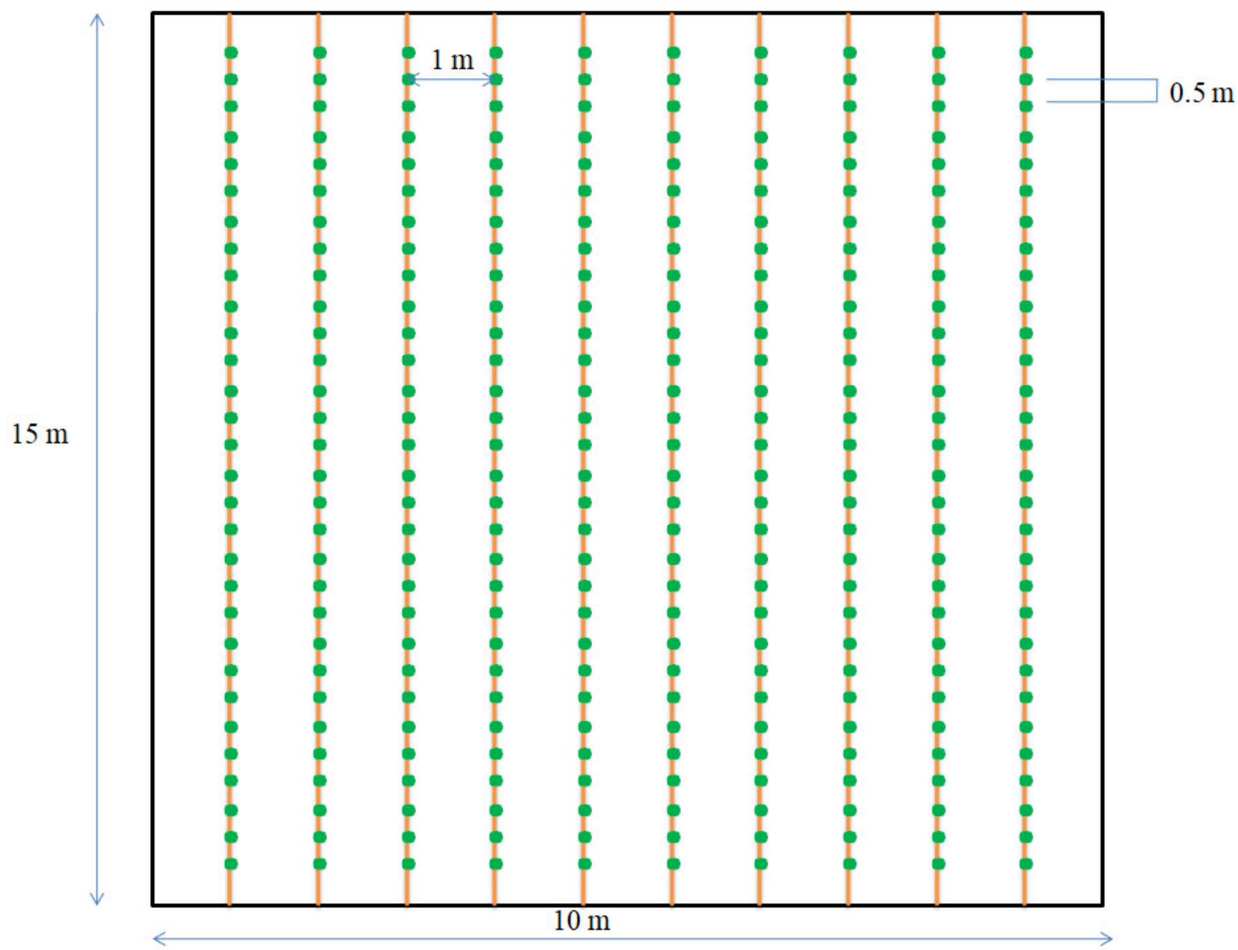


Plate3.2 Layout of the chilli field

3.1.3 Crop parameters

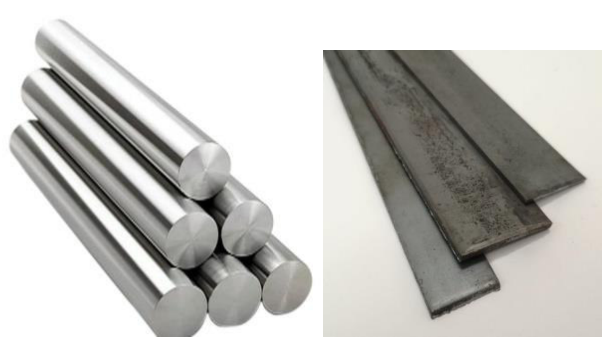
Ujwala is a bacterial resistant high yielding variety. The average height of the plant is 650 mm. The field measurements are measured using tape. Seeds are sown in the nursery and one month old seedlings are transplanted to the main field. Ujwala variety of chilli was cultivated on the field. This variety of chilli crop was raised in Kerala Agricultural University (KAU) as per the Package of Practices of KAU. Ujwala variety of chili is shown in Plate 3.3.

Plate3.3 Ujwala variety

3.2 Materials used

3.2.1 Mild steel

Mild steel is used to fabricate components of wheel sprayer. This material was chosen because it is more resistant to corrosion. It has high tensile as well as impact strength. Due to its good ductility and weldability, it is widely used for manufacturing of machine bodies. The frame as well as the shaft of the wheel sprayer is made of mild steel. Mild steel rod and mild steel flat bar are shown in fig.3.1.



(a) (b)

Fig.3.1 (a) Mild steel rod (b) Mild steel flat bar

3.2.2 Plastic

The knapsack sprayer tank is made of high density polyethylene (HDPE). It is one of the most versatile materials around the world. It is easy to process and a low cost material with good chemical resistance. It is also highly flexible and easily available. Plasticized PVC is used for manufacture of hose pipe. It is strong, flexible and light weight (Bhashkar *et al*., 2020).The material used for tank and hose are shown in fig.3.2 and fig.3.3 respectively.

Fig.3.2 Plasticized PVC Fig.3.3 HDPE

3.2.3 Rubber

Rubber is generally used to make tyres. Resilience also known as rebound is the ability of rubber to return to its original size and shape following a temporary deformation. The rubber withstand the weight of the sprayer and the whole assembly without distortion. The rubber used for wheel is shown in fig.3.4.

Fig.3.4 Rubber

3.2.4 Alloy steel

Alloy steels are made of iron, carbon and other elements such as vanadium, silicon, nickel, manganese, copper and chromium. When the other elements comprising metals and non metals are added to carbon steel, alloy steel is formed. Alloy steels are less expensive and easily manufactured compared to standard stainless grades. The driving and driven sprockets and the chain are made of alloy steel. Alloy steel material is shown in fig.3.5.

Fig.3.5Alloy steel

3.2.5 Brass

It is the alloy of copper and zinc. Brass is the best material from which to manufacture many components are manufactured because of its unique combination of properties such as good strength, ductility, excellent corrosion resistance and high malleability and machinability. It is highly expensive. The boom and nozzle of the sprayer assembly is made of brass. The piston pump and connecting rod is also made of brass which is shown in fig.3.6.

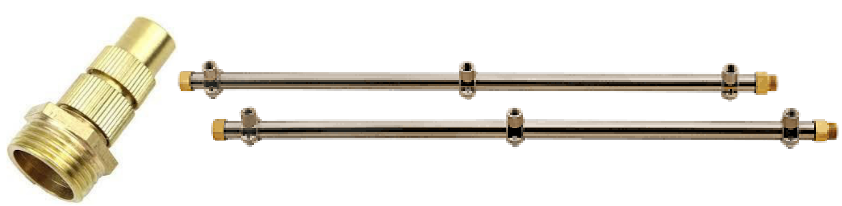


Fig.3.6 Brass

3.2.6 Cast iron

Cast iron is an alloy of iron that contains 2-4 % of carbon along with silicon and manganese, and traces of sulphur and phosphorous. With its relatively low melting point, good fluidity, castability, excellent machinability, resistance to deformation and wear resistance, cast irons are widely used as an engineering material in many fields. The bearing block used in sprayer assembly is made of cast iron and is shown in fig.3.7.

Fig.3.7 Cast iron

3.3 Development of wheel sprayer

The components of developed wheel sprayer are main frame, sprayer tank, wheel, driving and driven sprockets, boom assembly, nozzle, chain, piston pump, hose, shaft, plummer block bearing and connecting rod.

3.3.1 Main frame

The main frame is to carry whole assembly on it. The frame is made of cylindrical pipe of mild steel. The pipe is bent in different three points at different angle and direction to form a wheel barrow shape using sledge hammer. The height of the frame handle is designed as per the ergonomic considerations. Frame is made of mild steel bars of thickness 31 mm which can be easily welded. Main frame attached with wheel is shown in Plates 3.4 and 3.13. The length and diameter of the main frame pipe is selected as per design and values are 1420 and 31 mm respectively. The specifications and design calculations are given in Appendix I.

Plate3.4 Main frame with wheel

3.3.2 Wheel

Wheel is used to carry the whole assembly and move machine from one place to another by rotary motion of it. A typical modern wheel has a metal hub, wire tension spokes and a metal rim which holds a pneumatic rubber tyre. We use a tubeless tyre wheel. Tyres are used to move the sprayer more easily and give power transmission to pump. The rear wheel of a mountain bicycle is used with some modification on the sprocket hub. The sprocket hub is modified to hold a circular plate to attach a sprocket using bolts and nuts. The power is transmitted through the wheel to shaft. The plant to plant distance is 500 mm and the number of plants in a row covered by one rotation of wheel is 3. The wheel is shown in fig.3.8. These parameters were used for the selection and design of wheel. Hence, the designed rim and wheel diameters are 420 and 480 mm respectively. The respective design calculations are given in Appendix I.

Fig 3.8 Wheel

3.3.3 Sprayer tank

The sprayer tank is designed to carry spray solution. Considering low weight of plastic, a standard plastic 16 l capacity tank of knapsack sprayer is used to fabricate wheel sprayer. The dimensions of the selected tank is 420 x 360 x 180 mm. Its length to breadth ratio is 2:1.The selected spray tank is shown in Plate3.5.

Plate 3.5Sprayer tank

3.3.4 Pump

Pump converts the mechanical movement into hydraulic energy. It consists of a piston and cylinder. A lever is extending from the piston gives reciprocating motion. The pump assembly is kept inside the sprayer tank. During the upward motion of the piston, spray solution is sucked into the cylinder and pressurized. In the downward movement of the piston, sucked spray solution crosses the plunger and flows through hose and discharges as spray at nozzle. A single acting reciprocating cylinder is selected for the development of wheel sprayer, allows spray solution to enter only from one side of the piston. Selected pump is shown in fig.3.9. The pump diameter and stoke length are 60 and 50 mm respectively. The design calculations are given in Appendix I.

Fig 3.9 Pump

3.3.5 Frame of tank

A frame made of MS pipes of diameter 31 mm was welded to the main frame for inserting the tank. It was welded in a form of rectangular shape which covers almost one by third portion of the sprayer tank. Seven separate MS rods of diameter 6 mm are welded together to form the rectangular frame. Dimensions of frame are 350 x 230 x 220 mm. The fabricated frame for tank is given in Plate 3.6.

Plate 3.6 Frame for tank

3.3.6 Boom assembly

Sprayer boom assembly is a brass pipe attached with nozzles for distributing spray solution from the tank. Boom assembly has three nozzles. The boom holder is fixed on a vertical frame using ties, cannot slide up and down. The vertical frame is welded at an angle of 105^0 to the main frame. Length of boom is 800 mm. Boom assembly is shown in Plate 3.7.

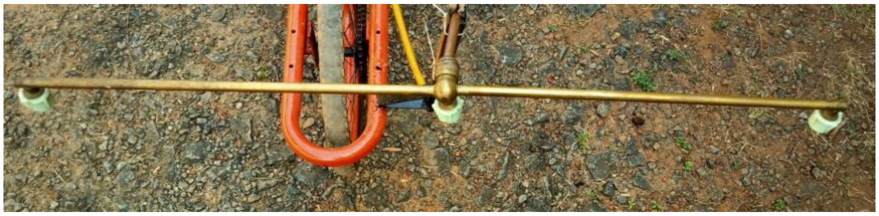


Plate 3.7 Boom assembly

3.3.7 Nozzle

Nozzle is a component on boom assembly which converts the pressure energy of fluid into kinetic energy and precisely disperse spray solution in fine droplets on plant surface. Three hollow cone type nozzles made of brass are selected and fitted on boom assembly at a spacing of 400 mm. Nozzles are covered with plastic cap. Hollow cone nozzle also referred to as disc and core type produce fine droplets. This type of nozzle is used to apply insecticides or fungicides where complete coverage of leaf surface is essential. Spray nozzle is given in Plate 3.8.

Plate 3.8 Spray nozzle

3.3.8 Driving sprocket

The name 'sprocket' applies generally to any wheel upon which radial projections engage a chain passing over it. The sprockets are distinguished from gears in such a way that it never meshed together directly as gears meshes directly. Similarly, sprockets differs from a pulley with teeth rather than smooth grooves in case of pulleys. It is made of alloy steel and is attached to the wheel, which provide driving force. Diameter of the driving sprocket is 140 mm and have 32 number of teeth. Selected driving sprocket is given in fig.3.10.

Fig.3.10 Driving sprocket

3.3.9 Driven sprocket

Sprocket is a profiled wheel with teeth that mesh with chain, track or other perforated or intended material. Driven sprocket is usually providing with the shaft import power. It is made of alloy steel and is attached to shaft. Diameter of the driven sprocket is 70 mm and has 16 number of teeth. The selected driven sprocket is shown in Plate 3.9.

Plate 3.9 Driven sprocket

3.3.10 Chain

Chain is a kinematic element which is used to transmit the power between two sprockets without slip and zero energy loss. Bicycle chain is used in the wheel sprayer for motion transmission between two sprockets. As per the data book, type of chain used is British standard Metric 08B roller chain. It is used to connect between bigger and smaller sprocket without any slip. It made of alloy steel. The calculations regarding motion transmission and speed reduction ratio are given in Appendix 1. Number of teeth in both driven and driving sprockets are determined and selected for design purpose. Number of connecting links and chain length are determined and selected based on design and values are 95 nos. and 1300 mm respectively. The design of chain is given in Appendix 1. The chain used for transmission is shown in fig 3.11.

Fig.3.11 Chain

3.3.11 Hose

It is a flexible hollow tube designed to carry fluids from one location to another. The hose pipe delivers spray solution from sprayer tank to nozzle boom by the reciprocating action of pump. The hose used in the wheel sprayer is made of plasticized PVC. Diameter of hose is 8.5 mm. The selected hose is shown in fig 3.12.

Fig.3.12 Hose

3.3.12 Plummer block

Plummer block gives friction free smooth rotation of the shaft. The casing is made of cast iron and bearing from chrome steel. Two plummer block bearings are used in the developed wheel sprayer. It is a pedestal used to provide support for a rotating shaft with help of compatible bearings and other accessories. The bearing blocks are bolted with frame. Designation number represents the different dimensions of the plummer block bearings used in wheel sprayer. The designation number of bearing used is UC204.The selected plummer block bearing is shown in Plate 3.10.

Plate3.10 Plummer block bearing

3.3.13 Shaft

Shaft is a rotating machine element used to transmit power from one part to another. Driven sprocket is attached to the shaft which is bolted to the connecting rod. Material used for shaft is mild steel. Shaft was machined to desired size by lathe operations. Diameter and length of shaft are 35 and 450 mm respectively. The shaft and turning of shaft are shown in Plate 3.11 and 3.12 respectively.

Plate 3.11 Shaft

Plate 3.12 Turning of shaft in lathe

3.3.14 Connecting rod

. This is used to connect the piston of sprayer pump to the shaft. Connecting rod is made of mild steel. Length is measured using measuring tape. Connecting rod is attached to the piston pump by using a pin and locked to avoid the detachment from the sprayer assembly. The length of connecting rod is 590 mm. Fig 3.13 shows the connecting rod.

Fig.3.13 Connecting rod

Plate 3.13 Frame after painting

3.4 Working principle

The mechanism involved in wheel sprayer and its working principle are described in the following sections.

3.4.1 Motion transmission by chain and sprockets arrangement

Chain drive is a way of transmitting mechanical power from one place to another especially when the distance between the centers of the shafts is short such as in bicycles, motor cycles, agricultural machinery, road rollers, etc. No slip takes place during chain transmission (Poratkar*et.al*, 2013).A roller chain which is extremely strong and simple in construction is used for the development of wheel sprayer. It gives good service under severe conditions. Sprocket with integral hub is used in chain drive.

3.4.2 Slider crank mechanism

A slider crank mechanism is used to convert straight-line motion to rotary motion, as in a reciprocating piston engine, or to convert rotary motion to straight-line motion, as in a reciprocating piston pump (Poratkar*et.al*, 2013).

In the developed wheel sprayer, rotary motion obtained to crank from chain drive is converted into reciprocating motion of the piston with the help of connecting rod. Thus the desired pressure is achieved by compression and spray solution is discharged from the nozzle. The crank is attached to one of the rotating wheel and other end is attached to the reciprocating pump. The wheels are fixed on main axle and cranking is on the other axle which pushes the piston rod in and out of the cylinder, pumping the air pressure into the tank. The spray tank fitted on the frame consists of spray solution and is connected on the protruded rod and jet is set for the required pitch. Operator by holding the handles of wheel sprayer, it is being pushed which causes the wheel to rotate. The chain sprocket arrangement is driven by the wheel, which in turn rotates the slider crank, creating pressure in piston pump. The final outcome of the machine is that the push force of the operator is converted finally to the pressure energy and the fluid is sprayed. This equipment has an air pump which compresses air into the tank and pressurizes the spray mixture. The pressure slowly drops as the liquid is sprayed. The amount of pressure created causes the spray solution to flow out of the tank. The spray solution propel out through the nozzle and sprayed on plant surface

3.5 Working of wheel sprayer

The operator pushes the handle of the developed wheel sprayer in forward direction. When the wheel rotates then the gear sprocket mounted on wheel also rotate at same speed. The chain drive transfers the motion of driving sprocket to driven sprocket. The driven sprocket and connecting rod is mounted on either side of same shaft. The rotary motion of shaft is converted into the reciprocating motion of pump with the help of crank and connecting rod mechanism.

The reciprocating motion of piston pump produces desired pressure for spraying the spray solution through nozzles. Since the wheel, sprockets and chain are of bicycle type, the spraying of the pump occurs only in the forward motion of developed wheel sprayer by the operator. When the wheel sprayer moves in the forward direction, the piston pump reciprocates which causes the spray solution to discharge through the boom assembly and droplets are sprayed on plant surface by the spray nozzles.

3.6 Design procedures

The design of the components of developed wheel sprayer are carried out as follows:

3.6.1 Motion transmission

Motion transmission allows a transfer of mechanical energy from one object to another without changing the nature of movement. The motion transmission of the driving and driven sprockets is rotational to rotational. Gear ratio is calculated by dividing the number of teeth on the driving sprocket to the number of teeth on the driven sprocket.

$$Gear\ ratio(R) = \frac{No: of\ teeth\ on\ the\ driving\ sprocket}{No: of\ teeth\ on\ the\ driven\ sprocket}$$

$$R = \frac{T_1}{T_2}; [T_1 > T_2]$$ (Kumar *et.al*, 2014)

Where

T_1 =No of teeth of driving sprocket

T_2 =No of teeth of driven sprocket

So considering the gear ratio

$$Gear\ ratio = \frac{diameter\ of\ driven\ sprocket}{diameter\ of\ driving\ sprocket}$$ (Kumar *et.al*, 2014)

Chain length is determined by using the formula,

$$Length\ of\ chain = [\pi \times (r + R)] + \frac{[2 \times (R - r)]}{C} + (2 \times C)$$

Where

R- radius of driving sprocket

r- radius of driven sprocket

C- centre to centre distance between two sprockets(Kumar *et.al*, 2014)

Pitch line velocity of sprocket (v)is determined using the formula,

$$V = \frac{(\pi DN)}{60}$$ (Kumar *et.al*, 2014)

Where

D - diameter of sprocket

N - rpm of sprocket

The calculations are given in Appendix I.

3.6.2 Sprayer assembly

Frame is made of mild steel bars which can be easily welded. It could support the load and take the weight of the tank easily. Rest of the frame was designed considering its strength, stability and ergonomics. The basic dimensions are measured using measuring tape and scale and the total length of frame is determined.

Length of frame = Centre distance between two sprockets + wheel radius + frame handle length+ excess length (Kumar *et.al*, 2014)

Weight of the frame and the complete sprayer assembly is weighed using digital electronic balance (0-500 kg).

Total load is determined by multiplying total weight of the complete assembly with acceleration due to gravity.

Total force acting is determined using the formula:

$$\text{Force required for motion} = \mu \times W$$

Where,

$\mu = 0.45$ for wet mud

W = total load on the complete assembly

The calculations are given in Appendix I.

3.6.3 Wheel

The diameter of the wheel is determined from the field and crop parameters. Spacing between plant to plant and number of plants covered by the wheel sprayer in one rotation of the wheel are determined. Thus the distance covered by the sprayer in one rotation of wheel is calculated. Then it is equated as follows:

Distance covered by sprayer in one rotation of wheel = Perimeter of wheel

$$= 2 \times \pi \times r$$

Where, r = radius of the wheel

Hence, diameter of the wheel is determined.

Velocity of the wheel can be determined by the formula,

$$Velocity\ of\ the\ wheel\ = \left(\frac{2\pi N r}{60}\right)$$ (Kumar *et.al*, 2014)

Where, N = rpm of wheel

Section height is determined by using the formulae:

Wheel diameter = Rim diameter + (2 x section height) (Kumar *et.al*, 2014)

Aspect ratio

Aspect ratio is an important sizing calculation in tire fitting, and should be considered with wheel diameter with the best tyre and wheel combinations. Lower aspect ratio typically indicates a high performance tire, with better lateral stability. It is calculated as the ratio of section height and section width. It is denoted in percentage.(Kumar *et.al*, 2014)

$$Aspect\ ratio\ (\%) = \left(\frac{section\ height}{section\ width}\right) x\ 100$$

The respective calculations are given in Appendix I.

3.6.4 Pump

Discharge of pump can be determined from the formula:

$$Q = \frac{ALN}{60}$$ (for single acting reciprocating pump)

$$Q = \frac{2ALN}{60}$$ (for double acting reciprocating pump)

Where,

Q = Discharge of pump

L = Stroke length of pump

N = Speed of piston in rpm (Kumar *et.al*, 2014)

A single acting reciprocating pump is best suited for the functioning of the wheel operated sprayer which consists of a piston of which only one side engages the fluid being displaced.

The area of piston is calculated using the following formula:

$$A = \left(\frac{\pi}{4}\right)D^2$$

Where,

A = Area of piston

D = Bore diameter of piston

Thus discharge required for single acting reciprocating pump is determined. The calculations are given in Appendix I.

3.7 CAD drawing

CAD or computer- aided design and drafting (CADD) is the technology for design and technical documentation, which replaces manual drafting with an automated process. CAD software is used to increase the productivity of designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. The software enables us to create drawings of any type and make orthographic images from 3D drawings. The sketches can be drawn to dimensions with specialized tools. Window of AutoCAD is shown in fig 3.14.

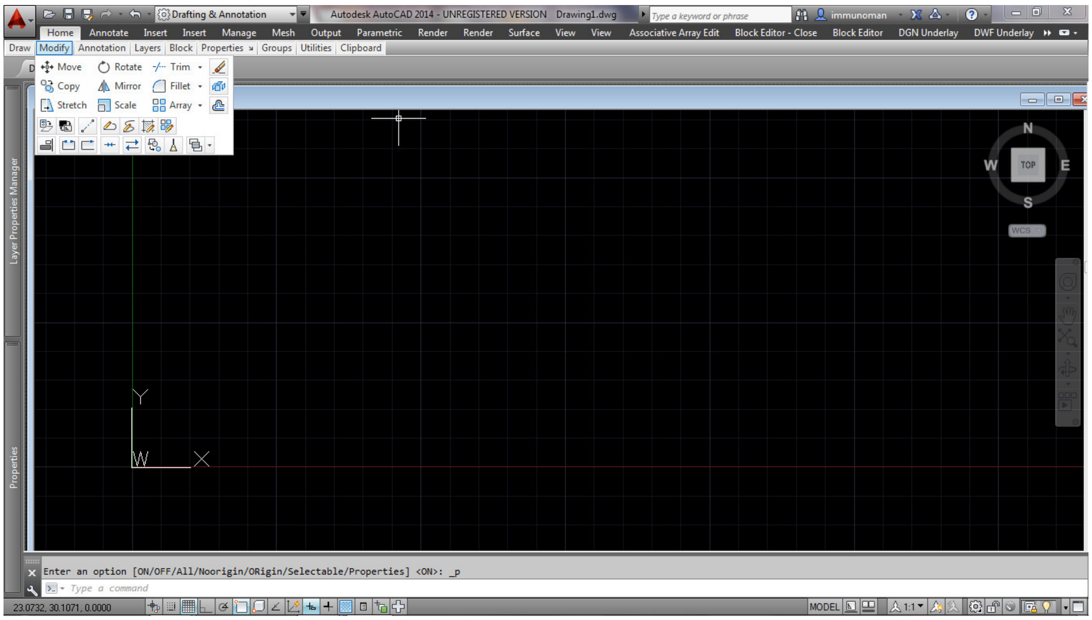


Fig.3.14 AutoCAD window

The drawing has been done in the AutoCAD software with the help of manual drawing done based on the design parameters. The top view, front view and side view of the designed wheel operated sprayer is drawn in AutoCAD. Drawing of wheel sprayer with dimensions is shown in plate 3.14.

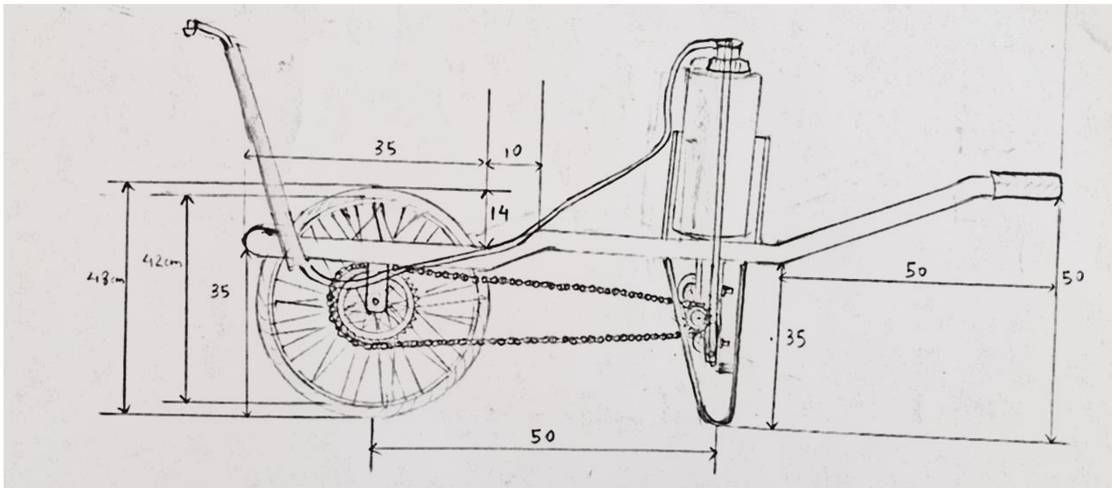


Plate 3.14 Drawing of wheel sprayer

3.8 Performance evaluation

The performance of developed wheel sprayer was evaluated in a field where chilli crop was grown with respect to time taken per row length, discharge rate, volume of water sprayed per row, field capacities and field efficiencies.

The wheel sprayer was operated in the field in between two rows so that it sprays on crops present in two rows on either side of wheel sprayer simultaneously. The time taken to spray the fluid in the entire row length is recorded using stop watch. The volume of water used for spraying crops in each row was determined from the graduations marked on the sprayer tank. The length of each row was measured using measuring tape. The time loss due to turning is also considered while calculating the actual field capacity. The total area of field of spraying was measured. The table showing the respective readings of volume and time for each row is given in Appendix II.

3.8.1 Discharge calculations

Time taken per row length as well as the volume of water sprayed per row is observed and the readings are given in Appendix II. From Appendix II, the discharge rate of the sprayer boom (consisting of 3 nozzles) is determined by calculating the amount of water discharged per unit time. The discharge of sprayer boom is calculated using the formula:

$$Discharge\ rate = \frac{Volume\ of\ water\ sprayed\ in\ each\ row}{Total\ time\ taken\ to\ spray\ it\ in\ each\ row}$$

Discharge rate is expressed as m^3s^{-1} or lh^{-1}

3.8.2 Theoretical field capacity

It is the function of speed of wheel sprayer and the width of operation expressed in ha hr^{-1} The calculation of theoretical field capacity from the field is given in Appendix III. It was calculated by the following equation:

$$TFC = \frac{w \times s}{c}$$

... (Metha et al., 1995)

Where,

TFC = Theoretical field capacity, ha h^{-1}

w = Operating width of the wheel sprayer, m

s = Spraying speed, km h^{-1}

c= Constant, 10

$$Operating\ speed\ of\ sprayer\ (ms^{-1}) = \frac{Distance\ covered\ by\ sprayer\ (m)}{Time\ taken\ for\ spraying\ (s)}$$

$$\text{Operating speed in km h}^{-1} = \frac{18}{5} \times Operating\ speed\ of\ sprayer\ (ms^{-1})$$

3.8.3 Actual field capacity

The actual or effective field capacity is the actual rate of coverage by the machine i.e., area covered, based upon the total working time and it can be calculated by the following equation:

$$AFC = \frac{A}{T}$$

... (Mehta et al., 1995)

Where,

AFC = Actual field capacity, ha h-1

A= Total sprayed area, ha

T= Total operating time for spraying, h

To calculate effective field capacity, the width of overlap is also considered and then the calculation is done. The time loss due to turning is also considered in determining actual field capacity. Total time is determined by adding up the total operating time and time loss due to turning. Then actual field capacity is determined by the taking the ratio of total sprayed area to total operating time for spraying. The calculations are given in Appendix III.

3.8.4 Field efficiency

It is the ratio between the productivity of a machine under field conditions and the theoretical maximum productivity. It is simply the percentage ratio of actual field capacity to theoretical field capacity. Field efficiency can be calculated by the following equation:

$$E_f = \left(\frac{AFC}{TFC}\right) \times 100$$

... (Mehta et al., 1995)

Where,

E_f = Field efficiency, %

AFC = Actual field capacity, ha h^{-1}

TFC = Theoretical field capacity, ha h^{-1}

The calculation of field efficiency is given in Appendix III.

3.9 Cost Estimation

It is necessary to consider the cost analysis of wheel operated sprayer during its design and development. The main objective is to make the analysis of rates economically feasible. The cost estimation mainly includes the determination of analysis of rates of each materials and the estimation of total cost. Analysis of rates includes the estimation of quantity of item used and cost of materials per unit. Total cost is estimated by multiplying the cost per unit with quantity of the item used.

$$Total\ cost\ (Rs) = Rate\ of\ material \times Quantity\ of\ material\ used$$

Labour charges and miscellaneous charges are also included in the cost estimation. In the cost estimation of wheel sprayer the miscellaneous charge is taken as 3 percentage of total cost obtained. Grand total amount is obtained by adding this miscellaneous charge with total cost.

CHAPTER IV

RESULTS AND DISCUSSIONS

This chapter deals with the experiments done on the field for the evaluation of wheel sprayer. It also considers the details and specifications of the developed wheel sprayer and cost analysis. Results of field tests conducted are briefly explained in this chapter.

4.1 Development of wheel sprayer

A wheel operated sprayer suitable for applying spraying solution on vegetable crops using designed values was developed as explained in sections 3.2 and 3.3. The wheel sprayer comprises main frame, tank, wheel, driving and driven sprockets, boom assembly, nozzle, chain and sprocket, piston pump, hose, shaft, bearing and connecting rod. The developed wheel sprayer is shown in plate 4.2.

The selection of materials and dimensions of the main components used to develop the wheel sprayer are given in Table 4.1 below.

Table 4.1Specifications of the components of the developed wheel sprayer

Sl. No.	Name of parts	Dimensions	Materials used
1	Main Frame	Diameter-31 mm Length-1420mm	M.S pipe
2	Tank	Capacity 16L 420x360 x 180 mm	Plastic
3	Wheel	Rim diameter- 420 mm Wheel diameter- 480 mm	Steel plated with nickel Rubber

4	Driven sprocket	16 teeth Diameter -70 mm	Alloy steel
5	Driving Sprocket	32 teeth Diameter-140 mm	Alloy steel
6	Boom	Diameter- 8 mm Length- 800 mm	Brass
7	Nozzle	Diameter 7.6 mm Nozzle hole diameter 2 mm	Brass
8	Chain	Length 1300 mm	Alloy steel
9	Piston Pump	Diameter 60 mm Stroke length 50 mm	Brass
10	Hose	Diameter 8.5 mm Length 960 mm	Plasticized PVC
11	Shaft	Length 450 mm Shaft diameter 35 mm	Mild steel
12	Bearing	ID 20 mm OD 42 mm	Cast iron
13	Connecting rod	Length 590 mm	M S rod

4.2 Design procedures

Based on the design procedures and the formulas, the design calculations are done and given in the Appendix I. The results obtained from the design of wheel operated sprayer are within the permissible limit and given below.

4.2.1 Motion transmission

The gear ratio of the motion transmission assembly is determined as 2:1. From 140 mm diameter of one sprocket, diameter of the other sprocket is designed as 70 mm. Bicycle chain type is used in the wheel operated sprayer. The type of chain selected from the design is British standard Metric 08B roller chain. The pitch selected as 12.7 mm from data book. The maximum roller diameter is 8.51mm. Transverse pitch is selected as 13.92mm. This has a breaking load of 1820 kgf. Length of chain is determined as 1300 mm. Velocity of both sprockets are 0.1 m s^{-1}.

4.2.2 Sprayer assembly

Frame is made of mild steel bars of thickness 31 mm which can be easily welded. It can support the load and take the weight of the tank easily. Weight of the tank is 4.6 kg. Total weight of frame is 16.5 kg. Therefore total weight of the complete assembly is 21.10 kg. Total load on tire is calculated as 207 N. Force required for motion of wheel is 93 N. Length of frame is designed as 1420 mm.

4.2.3 Wheel diameter

Diameter of wheel is calculated as 480 mm. For this wheel diameter, a wheel rim of 420 mm diameter is conveniently fitted in it. The velocity of wheel is 0.679 m s^{-1}. The section height of tyre is determined as 30 mm. Hence the aspect ratio is calculated as 75 per cent. So, the tyre is suitable and safe for the developed wheel sprayer.

4.2.4 Reciprocating pump

A single acting reciprocating pump is most suited for the wheel sprayer assembly. Diameter of piston is60 mm. Length of stroke is about 50 mm. Area of piston is determined to be 2826 mm^2. Desired discharge of the single acting pump is 3 l min^{-1}.

4.3 CAD drawing

With the help of AutoCAD software, the design drawing has been done for the development of wheel spryer. Wheel operated sprayer is developed based on the three views (top view, side view, front view) drawn in AutoCAD. The respective top view, front view and side view of wheel sprayer developed on AutoCAD is shown in Plate 4.1. The complete wheel sprayer assembly is shown in Plate 4.2.

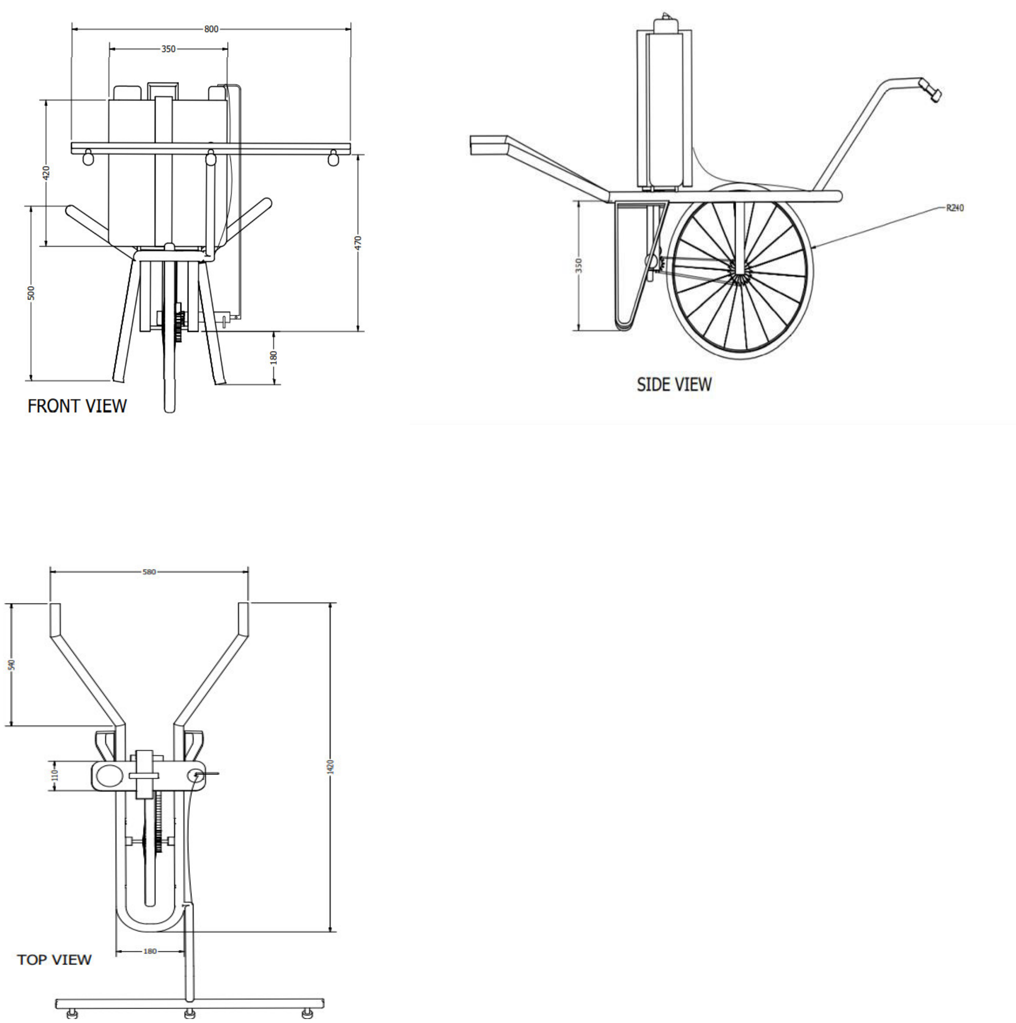


Plate 4.1 CAD drawing

Plate 4.2 Developed wheel sprayer

4.4 Performance evaluation

The developed wheel sprayer in the field was evaluated by spraying solution on chilli. The actual discharge is determined. The readings are observed and the discharge rate of wheel sprayer is calculated. Simultaneously, the theoretical field capacity as well as actual field capacity were calculated. Field efficiency is calculated in order to analyze and evaluate the performance of wheel sprayer.

4.4.1 Discharge calculations

Spraying of wheel sprayer is done on 9 rows and observations are recorded. Actual discharge of the sprayer is determined from the field tests and found to be as 0.045 L s^{-1} i.e. 2.72 L min^{-1}. Actual discharge is found to be within the permissible design limit (3 L min^{-1}). There are 3 nozzles attached to the boom of the wheel sprayer. The nozzle discharge rate of wheel sprayer is calculated as 0.907 L min^{-1}.

4.4.2 Theoretical field capacity

The theoretical width of operation is found to be as 800 mm. The operating speed of the wheel sprayer is determined as 0.679 m s^{-1} i.e. 2.444 km h^{-1}.Theoretical field capacity is calculated as 0.196 ha h^{-1}.

4.4.3 Actual field capacity

The entire plot (15 x 10 m) was grown with 10 rows of chilli in which spraying operation is done. Time loss in turning for 1 row is 2 s. Total time loss in turning is found out to be 18s. Thus, effective field capacity is determined as 0.17 ha h^{-1} by assuming the overlapping width of spraying as 100 mm. Time taken for spraying is determined as 5.85 h ha^{-1}.Time loss in turning is calculated as 0.334 h ha^{-1}.Total time taken for spraying in the field is found out to be 6.184 h ha^{-1}.Actual field capacity is determined as 0.162 ha h^{-1}.

4.4.4 Field efficiency

Field efficiency is the important parameter to analyze and evaluate the performance of a sprayer. The field efficiency of wheel operated sprayer is found out to be as 82.5%.Field evaluation of the developed wheel sprayer is shown in Plate 4.3.

Plate.4.3 Field evaluation of the developed wheel sprayer

4.5 Cost Estimation

The analysis of rates and the cost estimation is done in order to evaluate the economic feasibility of the developed wheel sprayer. The estimated total cost for the fabrication of wheel operated sprayer is found out to be Rs. 4950/-. The total cost included the cost of fabrication of all components of the wheel sprayer as well as the painting and labor charges. By considering miscellaneous cost as 3% of wheel sprayer, the grand total cost for the fabrication of wheel sprayer is determined as Rs. 5100/-.

CHAPTER V

SUMMARY AND CONCLUSION

Chilli (*Capsicum annuum L.)* is one of the important spice and vegetable crop which belongs to the family Solonaceae. It is an important commercial as well as an export oriented crop in India. Chilli can be cultivated throughout warm temperate, tropical and subtropical countries. It grows well in warm and humid climate and at a temperature of 20^0 to 25^0 C. Chilli is grown both as rainfed and irrigated crop. Chilli is sown in the Kharif season in the month of May to June and for the Rabi season in the month of January. Thrips and white fly are considered generally as the major pest of chilli crop and causes leaf curl disease. Spraying of the pesticides and fertilizers is of paramount importance in the cultivation of chilli crops. The objective of the application of pesticide is to keep the pest attack under control. Fertilizers are applied to agricultural crops as foliage application with the help of sprayers. Farmers use traditional methods like knapsack sprayer which requires more effort, time consuming and operator exposure. There is a need for modernization in this sector of agriculture. Hence an effort was done with the objective of development of a wheel sprayer which apply the spraying solution by moving wheel sprayer in forward direction. Main objective is to reduce the drudgery of operator in spraying of fertilizers.

An area of 3.71cent (0.015 ha) field of chilli crop was selected for the study of wheel sprayer. Study area was located in KCAET campus, Tavanur (10.8526^0 N and 75.9861^0 E) which has laterite type soil. Ujwala variety of chilli was transplanted in this field.

The wheel sprayer is designed and developed for applying spraying solutions on vegetable crops. The developed wheel sprayer consists of a main frame, wheel, chain, sprayer and sprockets, a shaft, bearing, sprayer tank, piston pump, boom and three nozzles. Main frame made of MS pipe having a diameter of 31 mm was chosen for assembling the main parts in it. Wheel rim with a tyre having a diameter of 480 mm was selected. British standard Metric 08B roller chain (95 no. of links) was used as a connecting link between two sprockets. Sprayer assembly contains a standard 16 L capacity plastic knapsack sprayer tank with reciprocating piston pump attached with it. For spraying in the field, a boom with 3 nozzle assembly having a diameter of 7.6 mm was selected. Hollow cone type nozzle was used for producing fine droplets of spray. Two sprockets, one driven sprocket (16 teeth, 70 mm diameter) attached to the shaft and the other a driving sprocket (32 teeth, 140 mm diameter) of larger diameter connected to the wheel are used. High pressure power spray hose of operating pressure 150-200 kgf $cm^{-2}$for carrying the liquid sprays from tank to the suction end of boom was provided.

In this wheel sprayer, two types of motion transmission take place within the system. Chain drive is used to transmit rotational motion between two sprockets. Rotary motion obtained to crank from chain drive is converted into reciprocating motion of the piston with the help of connecting rod. When the sprayer is pushed forward, the nozzles discharges spray fluid on chilli plants.

For design calculations, the gear ratio was calculated as 2:1. Total weight of the complete sprayer assembly was determined as 21.10 kg. Force required for motion of wheel is 93 N. Length of frame is designed as 1420 mm. Diameter of wheel is calculated as 480 mm and velocity of wheel is 0.679 m s^{-1}.Considering section width and height, the aspect ratio is calculated as 75 per cent. So the tyre is suitable and safe for the developed wheel sprayer. A single acting reciprocating pump was chosen and required discharge of 3 L min^{-1} was obtained.

While doing performance evaluation of wheel sprayer on 9 rows of the field, the nozzle discharge rate of wheel sprayer was calculated as 0.907 L min^{-1}. Theoretical field capacity was calculated as 0.244 ha $h^{-1}$and actual field capacity is determined as 0.206 hah^{-1}. The field efficiency of wheel operated sprayer is found out to be as 84.5 per cent. The analysis of rates and the cost estimation is done in order to evaluate the economic feasibility of the developed wheel sprayer. The total cost of fabrication of wheel sprayer is determined as Rs. 5100/-.

Suggestions for modifications:

- The number of nozzles in the boom can be increased from 3 to 6 to increase the field capacity.
- Two supporting wheels can be attached for more easy movement, maneuverability and turning through clayey and wet soils. Turning time loss can be reduced by using these wheels.

- The height of spray boom with respect to crop height can be adjusted by providing sliding slots with nut and bolt arrangement.
- A cut off valve can be installed in boom assembly to stop discharge of spray solution while the wheel sprayer making turnings at the headlands.

REFERENCES

Ahmad, M.A., Borkar, S.H., and Ghatole, S.D. 2018. Review Manually Operated Multi-Nozzle Pesticide Sprayer Pump. *Int. J. Innovative. Res. Sci. Eng. Technol*. 7(3): 223-227.

Athul, C.K., James, S.P., and Bovas, J.J.L. 2017.Developing Attachments for Four-Wheel Riding Type Rice Transplanter**.** *Lambert Academic Publishing,* 74p.

Bhashkar, A., Tiwari, S., and Vajpayee, P. 2020. Design and fabrication of multi nozzle wheel spray pump. *Int. J. Eng. Sci. Res. Technol.* 9p.

Dari, L., Addo, A., and Agbeko K.D. 2015.Pesticide use in the production of Tomato (*Solanumlycopersicum* L.) in some areas of Northern Ghana.*Afr. J. Agric. Res. Vol.* 11 (5): 352-355.

Dekeyser, D., Foque, D., Duga A.T., Verboven P., Hendrickx N., and Nuyttens D. 2014. Spray deposition assessment using different application techniques in artificial orchard trees. *Crop Protection*. 64: 187-197

Gaodi, M.A., Lonkar, A.S., Wankhede, A.S., and Gandate, S.D. 2016.Development of multipurpose sprayer.*Int. Res. J. Eng. Technol.* 3 (3): 540-542.

Hussain, F., and Abid, M. 2011. Pests and diseases of chilli crop: A Review. *Int. J. Biol. Biotechnol.* 8 (2): 325 – 332.

Joshua, R., Vasu, V., and Vincent, P. 2010. Solar Sprayer - An Agriculture Implement.*Int. J. Sustain. Agric*. 2 (1): 16-19.

KAU (Kerala Agricultural University) 2011. Package of Practices Recommendations: Crops(14^{th} Ed.). Kerala Agricultural University, Thrissur, 360p.

Kepner, R.A., Bainer, R., and Barger E.L. 1955.Principles of farm machinery.(2nd Ed). Westport, Conn, Avi Pub. Co. 468p.

Kumar, S., and Parameswaramurthy, D. 2014.Development of wheel driven sprayer. Int. J. Eng. Res. 2 (3): 79-85.

Laukik, P.R., Smit, B.J., and Nitin, Y.M. 2013.Design, development and fabrication of agricultural pesticides sprayer with weeder.*Int. J. Appl. Res. Stud.* 2 (11): 8p.

Liu, G.Q., and Zhang, G., and Li, J. 2008. Source and distribution characteristic of atmospheric organo-chlorine pesticides in the Pearl River estuary and adjacent South China Sea.*Int. J. Environ. Sci.* 29 (12): 3320-3325.

Matthews, G. A. 1992. *Pesticide Application Methods*.Longman Scientific and Technical, New York, (2ndEd), 405p.

Mehta, M.L., Verma, S. R., Misra, S. K., and Sharma, V.,K. 1995. *Testing and evaluation of agricultural machinery.*Natonal Agricultural Technology Information Centre, Ludhiana.

Miller, M.A., Steward, B.L., and Westphalen, M.L. 2004. *Effects of multi−mode four−wheel steering on sprayer machine performance*.American Society of Agricultural Engineers. 47 (2): 385-395.

Poratkar, S.H., Raut, D.R. 2013.Development of Multinozzle Pesticide Sprayer Pump.*Int J. Mod. Eng. Res.* 3(2): 864-868

Singh, R.H., Akadiyawala, A., Khokar, J., and Ingole, G.B. 2019. Mechanical Agricultural Sprayer Vehicle. Int. J. Advance. Res. Ideas.Innovations. Technol. 5(1): 476-479.

Singh, S., Padhee, D., Sonwani, S. and Sahu, T. 2020.Design, Fabrication and Evaluation of Agricultural Sprayer.*Int. J. Curr. Microbiol. App. Sci* 9 (1): 1649-1659.

Singh, T. P. 2017. *Farm Machinery*.Ashoke K Gosh publishers, PHI learning Pvt. Ltd., Delhi, 236p.

Subbarayudu, T., and Venkatachalapathi. 2017. Modeling and Development of Pedal Operated Agricultural Sprayer. *Aust. J. Basic Appl. Sc.* 11(11): 122-131.

Thakkar, K., Pathak, H., Soni, Z., and Joshi, D. 2017. Multi Nozzle Agricultural Sprayer.*Int. J. Adv. Res. Innovative.Ideas. Educ.* 3(2): 4154-4159

Wayzode, P.B., Umale, S.R., Nikam, R.R., Khadke, A.D., and More, H. 2016. Design and Fabrication of Agricultural Sprayer, Weeder with Cutter.*Int. J. Res. Advent Technol.* 340-344.

Winterfield, R. G. and Boving, P. A. 1980. Testing Selected Nozzles for Deposit Efficiency in Aerial Application of Spray. *Transactions of the ASAE*. 23(1): 36-42.

Ziden, A.A., Zakaria, F., and Othman, A.N. 2012.Effectiveness of AutoCAD 3D Software as a Learning Supporting Tool.*Int. J. Eng. Technol.* 7 (2): 57 – 60.

Appendix-I

Design Calculations

1. Motion transmission

No of teeth of driving sprocket (T_1) =32

No of teeth of driven sprocket (T_2) =16

$$Gear\ ratio(R) = \frac{No:of\ teeth\ on\ the\ driving\ sprocket}{No:of\ teeth\ on\ the\ driven\ sprocket}$$

$R=\frac{T_1}{T_2}= 2:1$; [$T_1>T_2$]

For every rotation of driving gear, the driven gear makes 2 rotations.

D_1= diameter of driver sprocket

The larger sprocket attached to wheel has a diameter of 140 mm

So considering the gear ratio

D_2= diameter of driven sprocket

$$Gear\ ratio = \frac{diameter\ of\ driven\ sprocket}{diameter\ of\ driving\ sprocket}$$

Therefore diameter of driven sprocket = $\frac{140}{2}$= 70 mm

No of connecting links = 95

Centre to centre distance between two sprockets (C) = 470mm

In case of chain design, bicycle chain type is used in the wheel operated sprayer.

Type of chain = British standard Metric 08B roller chain

So, selecting the pitch = 12.7 mm from data book;

For that, maximum roller diameter = 8.51mm

Transverse pitch = 13.92mm

Breaking load = 1820 kgf

Total number of links =m = 95

R- radius of driving sprocket = 70 mm

r- radius of driven sprocket = 35 mm

C- centre to centre distance between two sprockets = 470 mm

Therefore

$$Length\ of\ chain = [\pi \times (r + R)] + \frac{[2 \times (R - r)]}{C} + (2 \times C)$$

= [3.14× (0.035 + 0.07)] + ([2×(0.07 – 0.035)])/0.47 + (2 x 0.47)

=129.67 cm ≈ 1300 mm

Rpm of driving sprocket (N_1) = 27

Since, $N_1T_1 = N_2T_2$

Rpm of driven sprocket (N_2) = 54

Now, Pitch line velocity of sprocket;

$$V = \frac{(\pi DN)}{60}$$

$$V_1 = \frac{3.14 \times 0.07 \times 27}{60} = 0.0989\ m\ s^{-1} \approx 0.1\ m\ s^{-1}$$

$$V_2 = \frac{3.14 \times 0.035 \times 54}{60} = 0.0989\ m\ s^{-1} \approx 0.1\ m\ s^{-1}$$

Where, N - rpm of sprocket

Velocity of both sprockets = 0.1 m s^{-1}

2. Sprayer assembly

Weight of Tank = 4.6 kg x 9.8 =45.08 N

Frame is made of mild steel bars of thickness 31 mm which can be easily welded.

It can support the load and take the weight of the tank easily.

Rest of the frame was designed considering its strength, stability and ergonomics.

Length of frame = Centre distance between two sprockets + wheel radius + frame handle length + excess length

` =470+240+500 + 210

=1420mm

Maximum Height of frame = 500 mm

Maximum Width of frame = 580mm

Total weight of frame = 16.5 kg = 161.7 N

Therefore total weight of the complete assembly = 21 kg

Total load on tire = 161.7 + 45.08 = 206.78 N ≈ 207 N

Therefore,

Force required for motion of wheel = $\mu \times$ W

μ = 0.45 for sandy loam

Total force (F) = 0.45 × 207 = 93 N

Total torque to be applied at the handle = r × F

r – height of frame = 500 mm

Therefore, total torque = 0.5 × 93

= 46.5 N m

3. Calculation of Wheel Diameter.

Distance between two plants = 1.64 feet = 500 mm.

No of plants covered by one rotation of wheel = 3

$50 \times 3 = 1500$ mm

$150 = 2\pi r$

$r = \frac{150}{2\times\pi}$

$r = 240$ mm

Diameter of wheel = 480 mm

For this wheel diameter, a wheel rim of 420 mm diameter is conveniently fitted in it.

The rpm of the wheel (N) is measured as 27 rpm.

We know,

$Velocity\ of\ the\ wheel\ = \left(\frac{2\pi Nr}{60}\right) = 0.679\ m\ s^{-1}$ or $2.44\ km\ h^{-1}$

We know,

$$Wheel\ diameter\ = Rim\ diameter\ + (2\ \times\ section\ height)$$

Therefore, $section\ height = \frac{Wheel\ diameter\ -\ Rim\ diameter}{2}$

$= \frac{48 - 42}{2}$

$= 30$ mm

Aspect ratio (%)= $\left(\frac{section\ height}{section\ width}\right) \times\ 100$

$= \left(\frac{3}{4}\right) \times\ 100 = 75\ \%$

4. Selection of reciprocating pump

A single acting reciprocating pump is best suited for the functioning of the wheel operated sprayer which consists of a piston of which only one side engages the fluid being displaced.

Required discharge;

$Q\ = \frac{ALN}{60}$ for single acting reciprocating pump

Speed of piston = 21 rpm

D=diameter of piston = 60 mm

L = Length of stroke= 50 mm

Where, A = Area of piston = $\left(\frac{\pi}{4}\right) D^2$= 2826 mm^2

Thus,

Discharge required, Q = 3 $lmin^{-1}$

Appendix-II

Performance evaluation

No of observations	Plant to plant spacing (cm)	Row to row spacing (cm)	Volume of water sprayed in each row (L)	Time taken for each row (s)	Discharge rate (L s^{-1})
1	50	100	1	25	0.040
2	50	100	1	23	0.043
3	50	100	0.9	22	0.041
4	50	100	1	27	0.037
5	50	100	1.05	23	0.046
6	50	100	1	17	0.059
7	50	100	0.97	20	0.048
8	50	100	1.1	21	0.052
9	50	100	1	24	0.042

Sample calculations:

$$Average\ discharge\ rate = \frac{Total\ discharge\ rate}{No\ of\ observations}$$

$$= \frac{0.041 + 0.043 + 0.040 + 0.037 + 0.045 + 0.059 + 0.048 + 0.052 + 0.042}{9}$$

$$= \frac{0.407}{9}$$

$= 0.045$ L s^{-1}

Therefore the discharge rate of the wheel operated sprayer = 0.045 L s^{-1} × 60

= 2.72 L min^{-1}

Since there are 3 nozzles attached to the boom of the wheel sprayer,

the nozzle discharge rate of wheel sprayer can be calculated as

$$Discharge\ of\ spray\ nozzle = \frac{Total\ discharge\ rate\ of\ boom}{No\ of\ nozzles}$$

$$= \frac{2.72}{3}$$

$$= 0.907 \text{ l min}^{-1}$$

Therefore spray nozzle discharge rate is 0.907 l min^{-1}.

Appendix-III

Determination of field efficiency

Theoretical field capacity can be calculated as follows:

$$TFC = \frac{w \times s}{c}$$

Where,

TFC = Theoretical field capacity, ha h^{-1}

w = Operating width of the wheel sprayer, m

s = Operating speed, km h^{-1}

c= Constant, 10

$$Operating\ speed\ of\ sprayer = \frac{Distance\ covered\ by\ sprayer\ (m)}{Time\ taken\ for\ spraying\ (s)}$$

$$= \frac{15}{22.1}$$

= 0.679 m s^{-1}= 2.444 km h^{-1}

Theoretical field capacity = $\frac{(0.8 \times 2.44)}{10}$

= 0.196 ha h^{-1}

Actual field capacity can be calculated by the formulae

$$AFC = \frac{A}{T}$$

Where,

AFC = Actual field capacity, ha h^{-1}

A= Total sprayed area, ha

T= Total operating time for spraying, h

Time loss in turning for 1 row = 2 s

Number of rows = 10

Total time loss in turning = (10-1) × 2 = 18 s

Overlapping width of spraying = 10 cm = 0.1 m

Thus, effective field capacity $= \frac{(0.8-0.1)\times 2.44}{10}$

$= 0.17$ ha h^{-1}

Time taken for spraying $= \frac{1}{0.17} = 5.85$ h ha^{-1}

Time loss in turning (s m^{-2}) $= \frac{18}{10\times 15} = 0.12$ s m^{-2}

Converting the time loss in turning to h ha^{-1} $= \frac{(0.12\times 10^4)}{(60\times 60)}$

$= 0.334$ h ha^{-1}

Total time taken = 5.85 + 0.334

= 6.184 h ha^{-1}

Actual field capacity $= \left(\frac{1}{total\ time\ taken}\right)$

$= \frac{1}{6.184}$

$= 0.162$ ha h^{-1}

Field efficiency can be calculated by using the formulae

$$E_f = \left(\frac{AFC}{TFC}\right)\times\ 100$$

Where,

E_f = Field efficiency, %

AFC = Actual field capacity, ha h^{-1}

TFC = Theoretical field capacity, ha h^{-1}

i.e , Field efficiency = $\left(\frac{0.162}{0.196}\right) \times 100$

= 82.5 %

Thus the field efficiency of the wheel sprayer is 82.5%.

Appendix-IV

Cost Estimation

SL No	Description of items	Materials used	Quantity	Unit	Rate (Rs per unit)	Total cost (Rs)
1	Main frame	MS Rod - hollow	10	kg	50	500
2	Shaft	MS Rod - solid	1	kg	50	50
3	Knapsack sprayer tank including pump	Plastic	1	No	1200	1200
4	Wheel rim	Steel plated with nickel	1	No	300	450
	Tyre	Rubber	1	No	150	
5	Driven Sprocket	Alloy steel	1	No	90	90
6	Driving Sprocket	Alloy steel	1	No	150	150
7	Boom assembly (3 nozzles)	Brass	1	No	1200	1200
8	Hose	Plasticized PVC	1	m	80	80
9	Chain	Alloy steel	1.3	m	100	130
11	Paint (200 ml)	-	1	No	48	48
12	Primer (200 ml)	-	1	No	52	52
13	Labour charge	-	2	No	500	1000
					Total	**= 4950**
14	Miscellaneous	-	3	Per cent		148.5
					Grand total Rs	**= 5098.50**

DESIGN AND DEVELOPMENT OF A WHEEL SPRAYER

BY

KIRAN K.J (2017-02-031)

MAYALEKSHMI K.M (2017-02-032)

REHNA SALMA ALI (2017-02-036)

ABSTRACT OF THE THESIS

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR – 679 573, MALAPPURAM

KERALA, INDIA

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ABSTRACT

The research paper depicts the design and development of a wheel sprayer for applying spraying solution on vegetable crops. India is an agriculture-based country. Majority of the population primarily depend on agriculture. Our farmers follow the same traditional way for ages. There is a need of mechanization in the agriculture sector. This results in higher productivity and precision in Agriculture. Plant protection plays a significant role in optimizing the productivity of a given crop. Agricultural pests inflict considerable damage to crops. Spraying of chemicals is an effective way of pest control. Traditional methods of spraying include use of knapsack sprayer, foot sprayer, hand sprayer etc. which requires more effort and is time consuming. Heavy tank containing pesticides and chemicals is to be carried by the farmer. This causes severe health hazards.

An ideal pesticide sprayer has to be portable with an increased tank capacity, cost effective, labour friendly and low spraying time. Manually operated wheel driven sprayer is designed to reduce human effort. The target of application is small fields and small gardens. The main objective is to reduce the effort made by farmer in carrying the backpack sprayer and to design and fabricate a multi-nozzle wheel sprayer suitable to spray pesticides on vegetable crop. Ujwala variety of chilli crop was grown in the selected field. Analysis and performance evaluation of the developed wheel sprayer was done. The developed wheel sprayer was tested at Kelappaji College of Agricultural Engineering and Technology campus, Tavanur village (10.8526^0 N and 75.9861^0 E) Malappuram, Kerala. The soil of the field selected was of lateritic type and testing was conducted on an area of 3.71 cents. Field contains 10 number of rows and each row contain 30 number of chilli crops.

Operator pushes the handle of developed wheel sprayer in forward direction causes the wheel to rotate. Push force of the operator is converted finally to pressure energy and the fluid is sprayed. When the wheel sprayer moves in forward direction, pump reciprocates which cause the working fluid to transfer through the boom assembly and sprayed by nozzle. Since the wheel, sprockets and chain are of bicycle type, the spraying of the pump occurs only in the forward direction. Chain drive transmits the rotary motion between two sprockets. Rotary motion obtained from chain drive is converted into reciprocating motion of the plunger with the help of connecting rod. One end of shaft is attached to the reciprocating pump and the driven sprocket is

mounted on shaft. The chain- sprocket arrangement is driven by the wheel, this in turn rotates shaft, creating pressure in pump. Due to the pressure developed, the fluid is discharged through nozzles.

In case of performance evaluation, theoretical field capacity, actual field capacity and field efficiency of the developed wheel sprayer was determined. Spray overlap and time loss due to turning is also considered in determining actual field capacity. The developed wheel sprayer has proved to be more user friendly than traditional methods of spraying. It requires less effort and time for spraying. Low operator exposure towards chemicals is one of the main advantages of the developed wheel sprayer. The wheel sprayer is economically feasible for small fields. Actual field capacity obtained was 0.206 ha h^{-1}. Field efficiency of 84.5 percent was obtained for the developed wheel sprayer. Total cost of the wheel sprayer was Rs 5100/-.Some of the modifications which can be applied in the future includes the increasing number of nozzles for coverage of larger area, attaching of supporting wheels for easy turning, maneuverability and balancing. Boom height can be made adjustable with respect to varying plant height and cut off valve can be installed in boom assembly to stop the discharge of spray solution on plants while wheel sprayer making turnings at headlands.