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Development and performance evaluation of small scale walk behind sprayer

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Abstract

Spraying agrochemicals on crop is essential to protect them from insects, pests and weeds. Different machine like knapsack, boom and aircraft are being commonly used worldwide to spray agrochemicals for crop protection. Knapsack sprayer is a common equipment used by the farming community in Pakistan.These sprayers have less field efficiency and can lead to operator discomfort and back pain. Tractor mounted boom sprayers and aircraft sprayers may also be used but these are very expensive equipments and small farmer cannot afford them. To address this farming community challenge, a small scale walk behind sprayer was designed and manufactured at Agricultural Engineering Workshop, University of Agriculture Faisalabad in 2020. This newly developed spraying machine is light weight and easy to operate in the fields. Performance of walk behind sprayer was evaluated in the term of effective field capacity, field efficiency and wheel slippage. Spraying machine can work for five hours after one recharge of a 12V battery.

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Pump produced pressure of 150 PSI and discharge rate of nozzles were 0.5 liters per minute. Overall machine has proven beneficial for the small farmer as it can easily spray 5 acres/day. The research findings showed that field efficiency of machine was 77.7% and slippage factor was 13.5%. It is concluded from the study that newly developed technology performed better as compared to knapsack sprayer therefore this machine is recommended to the farmers.

Keywords: Agrochemicals; Cost effective; Crop protection; Operator comfort; Small sprayer

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Introduction

Agrochemicals were introduced aiming at enhancing crop yields and at protecting crops from pests. Due to adaptation and resistance developed by pests to chemicals, every year higher amounts and new chemical compounds are used to protect crops, causing undesired side effects and raising the costs of food production (Carvalho 2006). The success of pest control operations depends on proper technique of application and the equipment used for applying pesticide. Manually operated equipment such as lever operated knapsack sprayers are commonly used by farmers. In case of operation of knapsack sprayer, the vertical position leads to an awkward posture which causes many discomforts in operator's head, neck and shoulder areas. Thus, battery operated walk behind type sprayer was developed to reduce the pain and time used for the spraying operation. Walk behind type sprayer is effective, more efficient and capable of spraying at faster rate. It is also beneficial for small-scale farmer and unskilled labour who can easily work without any problem (Mishra et al. 2023).

The small and marginal farmers in India are contributing about 51.2% into the total country production. Knapsack sprayers are commonly used on Indian farms by small and marginal farmers for pest control due to cost-effectiveness and ease of use but they have limited productivity. The physiological energy consumption and discomfort were reduced without compromising the output which was increased to 0.3 ha/hr using a solar powered sprayer (Sinha et al. 2018).

Assessing an electrically powered sprayer backpack, able to carry up to 10 liters of liquid, designed using local materials was the subject of the report. This is a terrifying heat-denying mechanism no longer in need of any energy consumption for air pressure control that is a default part of every knapsack sprayer. Another essential content are the tank, a 12 volt water pump, a 12 volt accumulator battery, the belt (strap), the feeding pipe, and finally a spraying-handle with lance and nozzle. The data which showed the flow rate, application rates and distribution rates of the method was conducted in both lab works and field trials. In determining flow rate, there was application of simple hydraulic principles. I then used the effective walking speed during agri-field to determine the application rate. Research carried out in the laboratory reported that the drop in liquid head resulted in slower flow rate. Other than the reduced output, it was also found that the efficiency dramatically decreased as the battery voltage dropped. The sprayer applying the chemical substance at a walking speed of 0.7 m/s can construe the possible application within a hectare of land, but the time taken can be termed as 4.17 hours. Loss of functionality may become a problem since the device will not be able to keep operating constantly due to the voltage drop after 2 hours. To overcome this challenge for using the drones in a large-scale spraying, we recommend that we should carry extra batteries to the farms to avoid interruptions while operating (Awulu & Sohotshan, 2012). The use of mechanization in nursery raising, out-planting, interculture, irrigation, plant protection, pruning, harvesting, and processing has a great impact on the whole production cycle (Khan et al. 2023).

A knapsack sprayer is a portable unit which one wears like a book bag. One hand carries the pump, while the other holds a spray nozzle. ATV Sprayers are also rather pricey, and it is a challenge to find one with all the features that minimize time, work and improvement. It is a 20-gallon tank sprayer with a 2.0-gpm motor and spray tips that are also connected to the garden hose having a spray nozzle attached to it (Niese 2018).

The extensive usage of pest control procedures depends mainly upon the appropriate use of techniques and the good quality of the equipment. Previously, with five liters capacity for the liquid and an integrated lever to operate the knapsack sprayer, old-fashioned being a dominant solution for farmers were lever-operated knapsack sprayers. Although the use of sprayers provides with ease and convenience in achieving those aerial targets, it may lead to pain in the operator's head, neck, and shoulder area because of the terrible posture that is needed during operation of the sprayer. These issues were diagnosed and methods to overcome were invented. For this purpose a walk-behind sprayer that operated on battery was developed. A mist-type of sprayer is preferred because it leads to these outcomes such as the wastage is reduced, it is costly to apply, and spraying is faster. Besides, the developing fact remains that it is beneficial both for small scale farmers and unskilled laborers as well, where for the sake of convenience, they don't have to be discomfort. It allows actual work time for post, which is powered either by 8AH or 12AH battery, to be approximately of 2 to 3 hours and 5 to 6 hours, respectively. These objectives explain the initial investment cost of Rs19165.80 per year on the battery-operated walk-behind sprayer, which calculates to Rs171,000 per season. In addition to this, sprayer’s emission factor per cumulative melting area is 2.21 years per year. In all, the battery-operated walk-behind sprayer definitely brings in a big change in means of pest control which is further making control of pest a lot easier. It is doing that by introducing efficiency, comfort for the user and cost-effectiveness (Mishra et al. 2023). Conventional machines are labor-intensive, time-consuming, and have high yield losses (up to 30%) (Husain et al, 2024).

The efficiency of tractor operated boom sprayer was measured on Chilly. The boom sprayer designed in the laboratory performed well at 0.90l/min nozzle discharge and 689.5 kPa operating pressure. The variation of droplet size, spray uniformity, and droplet density variate as the nozzle discharge rate and pressure was kept to be 0.45, 0.70, 0.90, and 1.35 l/min and 275.8 kPa, respectively. For nozzle 0.9 lpm and pressure 689.5 kPa, the Volume Median Diameter (VMD), Uniformity Coefficient (UC) and Droplet Density (DD) of the existing boom sprayer have 130.9-206.36 µm, 0.98-1.39 and 11-27 number of droplets/cm2, respectively. The new design of the boom sprayer with a working pressure of 689.5 kPa and a nozzle discharge rate of 0.90 l/min is distinctly superior in terms of discharge as well as nozzle pressure for each individual nozzle (Pramod et al. 2023).

Rear-mounted boom sprayer, power till type is new for cotton and row crops that will allow to spray efficiently with saving of the chemicals at the minimum. During field application, this nozzle heads will spray 16 cone nozzles, which are 40 cm apart and extending over a lane at 2 km onward the speed. This sprayer is a rational choice for farmers with a small area as it has the capacity to spray up to 0.72 ha/ hour which makes the treatment of crops timely and effective. The improved view along the vertical line due to this assembly helps the operator to perform operation accurately and safely. Controls which the operator can comfortably reach will give a chance of using them to spray the pesticides effectively without putting his health in danger. Besides, the operator adjusts the immediate surrounding of the boom by using clamps and pipes to avoid emission through convection especially-during horrendous weather conditions that lead to chemicals deposited on the canopy. It is also ensured that the application of chemicals is done properly, and therefore workers are protected from the risks that accompany exposure to chemicals. Those risks include firstly health-related problems. Such development will thus allow the farmers to easily use this sprayer to kill insects and caterpillars on cotton and other row crops, this directly leads to crop health improvement and productivity with a guarantee that farmers and applicators are safe from the health hazards of insecticide pests (Padmanathan & Kathirvel 2007). In Pakistan, harvesting is presently conducted through manual labor or with the utilization of outdated models with huge grain quality and quantity losses (Khan et al. 2024).

The spray should be spread uniformly over the bed only and no spray should be applied onto the paths between beds in case of bed-grown crops. The aim was to develop and apply a model that allows designing advantageous set-ups of nozzles on sprayer boom for bed-grown crops. Designs using fourfold nozzle bodies are presented to find best solutions for beds with widths between 1.1 m and 1.5 m for boom heights of 0.2 m to 0.6 above crop, allowing customized dose rate application depending on the canopy height range. Many possible configurations are simulated, but only a fraction of them fit the conditions that can be stipulated by the user (Holterman et al. 2018).

A semi-automatic boom sprayer was created to facilitate an easier application of pesticides on corn crops. The performance of the semi-automatic boom sprayer was compared with that of generally used knapsack sprayers in which a test was undertaken. Other components of this research included laboratory evaluation, field evaluation, and cost assessments. Based on 15 days and 30 days technical testing with corn, the semi-automatic boom sprayer capacity was recorded as 0.318 ha/h at operator speed of 0.316 m/s. The semi-automatic boom sprayer had a larger tank capacity as compared to that of the knapsack sprayer. The spraying effectiveness of the semi-automatic boom sprayer was better in comparison to the knapsack, specifically 86.033% against 85. 269%, respectively (Putri et al. 2022).

In the technological sense, automatic target spray technology based on real-time sensors and automatic target spray technology based on geographic information technology are discussed as far as sensing mechanisms are concerned; in terms of control systems, pressure flow regulation system, PWM (Pulse Width Module) control flow regulation system and liquid chemical concentration mixed regulation system are presented. In the area of spray technology, it primarily concerns the development and utilization of variable nozzles as well a projection on the development path and application potential for variable spray technology (Dou et al. 2018).

The farmers in Pakistan are poor and majority of them have less number of acreage essential for using hi-tech machinery. The currently used knapsack sprayers create health hazards and farming community demand for an alternative small scales sprayer suitable for their socio-economic conditions. Therefore, to development of a small scale walk behind pesticide sprayer was the need of hour.

Materials and Methods

Keeping in view the farmer needs, a small scale walk behind battery operated walk behind mobile pesticide sprayer was developed using locally available material and manufacturing facilities. The machine consist of main frame, storage tank, battery, battery charging system, DC pump, battery charging alarm system, nozzles, ON/OFF button, boom, height adjusting bar, handles and wheel system as shown in figure 1 and the actual machine is shown in figure 2. The detail of each component is given below;

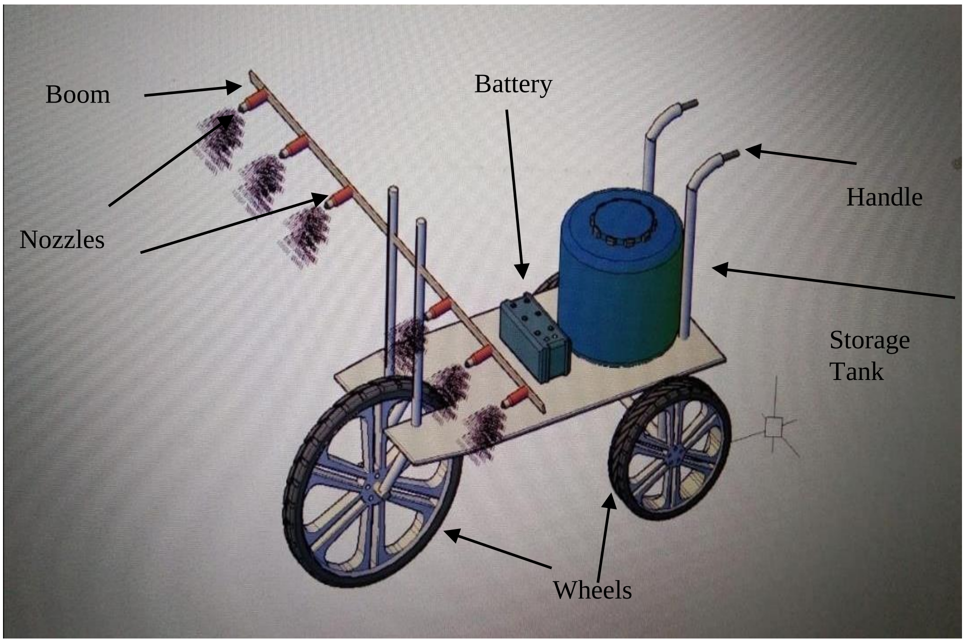

Figure 1. 3D view of walk behind pesticide sprayer

Main Frame
Main frame is made of mild steel pipes. This is the most important and mother part of this spraying equipment. Mild steel pipe which is used for the construction of main frame have dimensions of 25 mm width and 25 mm height. Pipes were joint together by the arc welding process in the mechanical workshop. This frame is supported by a front wheel and two rear wheels. Three wheel are used to maintain balance of the machine in the field conditions.

Storage Tank
It is made of plastic which is used to store mixture of agrochemical and water for spraying and installed on the main frame. As water is continuously contacted with the tank walls, this enhance the chances of rusting. To eliminate this risk, plastic material is used because it has more resistance against rusting or oxidization.

Pump
A diaphragm pump is used to generate pressure of the spraying liquid. Pump is mounted on the main frame with the help of nuts and bolts. A 12 volt battery is available for the

energy requirement of the pump. Pump suck mixture of chemical and water from the storage tank through suction pipe and then push it towards nozzles through delivery pipe.

Battery

A rechargeable dry battery is used as a power source for the pump operation, which is mounted on the main frame and connected with the pump with electrical wires. This is a 12 volt battery that can generate current up to seven amperes. Battery recharging time is approximately two hours and its discharging time is about five hours. A four ampere adopter is used to recharge the battery. Battery can work up to 5 hours in field and it is charged by an automatic battery charger.

Battery Charging System

A battery charger is used to charge the battery, which is an adapter having a small transformer and rectifiers in it. Rectifier is used to convert AC (alternating current) into DC (direct current). It take current from the outer source usually WAPDA home connection AC current and convert it to DC current to charge the battery. After charging the battery it automatically cutoff the current.

Battery Charging Alarm System

This circuit is installed on internal side of battery charger to control its charging. During charging it shows red light on its display, while battery is fully charged it disconnect the current from the source to battery and show green light.

Nozzles

Nozzles are used to discharge mixture of pesticide and water with optimum pressure. Different types of nozzles are in use now a days by the farmers. Different nozzles operates on different pressures and they made different flow patterns. Nozzles selection depends upon chemical being sprayed and the crop grown. Hollow cone nozzles have been used in small scale walk behind pesticide spraying machine. Factors that influence their performance include nozzle design, spray quality, and application rate (Jalu et al. 2023).

Power ON/OFF System

This button is mounted on the handle of the machine to control power supply from the battery to pump to facilitate operator in ease of operation (starting and stopping spraying). Safety parameters of using electric equipment were kept in mind therefore all live wire is covered with plastic pipe.

Boom Bar

Boom bar is designed in such a way that it has provision of folding up to 2 times of its width having the total swath of 2185 mm and it can be reduced to 711 mm. It is made up of mild steel and three pieces of steel pipe are used on which nozzles are mounted. These pipes were first drilled to make an opening to install nozzles on them and then they were welded from both ends and nozzles were mounted.

Each steel pipe is of 610 mm length and connected with each other by the mean of rubber pipes which helps them in folding. Boom of the small scale walk behind mobile pesticide sprayer is designed in way that it can fold and can reduce its width three times of its original width. In this shape the spraying equipment occupy minimum space and easy to handle when it is not in the field.

Boom bar Specifications

Width of the boom = 2185 mm

Diameter of Boom Pipe = 10 mm

Clamps are used to connect the rubber and steel pipes and nut bolts are used to tighten the boom on the desired height.

Height adjusting bars

These bar are made up of mild steel and connected with main frame through welding. Total height of these bars is 30 inches and these are used to support the boom on required height and to maintain its balance while spraying.

Handle

On the rear side of the main frame of this machine, there are handles to steer the machine and these handles are made up of mild steel pipes.

Wheel System

There are three wheels used in this design of the machine, a front wheel and two rear wheels. These wheels have a great role in machine balancing in the field.

Figure 2. Field testing of walk behind pesticide sprayer

Economic Depreciation of Walk behind Pesticide Sprayer

Depreciation of walk behind pesticide sprayer is the reduction in its value over the period of time. The value or price of the machine depends upon the age of the machine and how many hours it has worked in the field. Machine loses its value as it gets old with the passage of time. Depreciation value of walk behind mobile pesticide sprayer was calculated as;

$$D_C = (P-S) / L$$

Where

Dc is stand for net depreciation value

P is Purchasing cost

S is salvage cost (Regain or recoverable value)
L is total usage of the machine in years
Salvage value is the price of the machine after the life of the machine i.e. after the full depreciation it will still have some cost.

Results and Discussions

Laboratory and field testing of small scale walk behind mobile pesticide sprayer were carried out at University of Agriculture, Faisalabad. Theoretical and effective field capacities of walk behind spraying machine were calculated. Storage tank discharging time, battery charging and discharging time were also noted. Nozzle calibration of walk behind pesticide sprayer was carried out to adjust the discharge rate of each nozzle.

Theoretical Field Capacity

Theoretical field capacity depends upon the walking speed of the operator and the swath width of machine. The speeds of the walk behind pesticide sprayer were noted while the swath width of the machine is 2184 mm.

W = 86 inches (2.18 m)

The theoretical field capacity was calculated;

TFC = (S × W)/10
TFC = (2.63 × 2.18)/10
TFC = 0.57 ha/hr.
TFC = 1.40 acre/hr.

The maximum theoretical field capacity of small scale walk behind pesticide sprayer was measured in the third trial which was 0.59 hectare per hour while minimum theoretical field capacity was found in the first trial which was 0.54 hectare per hour while the average TFC for machine is 0.57 ha per hr as shown in figure 3.

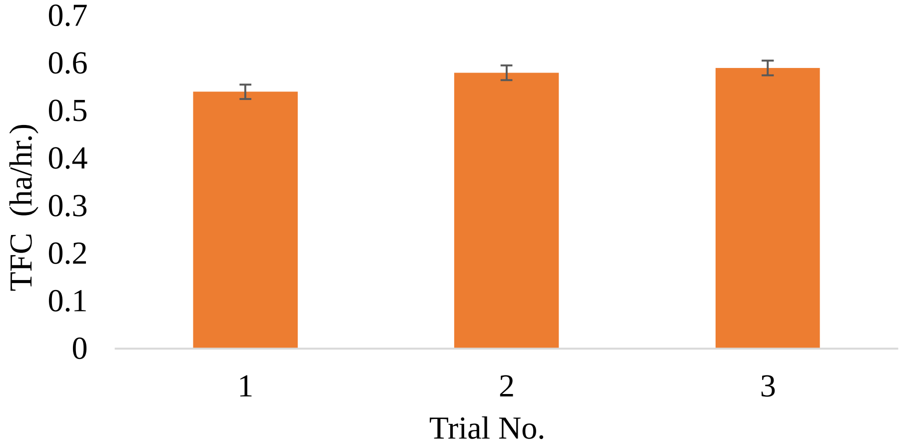

Figure 3. Result of theoretical field capacity of sprayer

Calibration of Spray Nozzles

The newly fabricated walk behind small scale pesticide sprayer have six hollow cone nozzles on its boom. Each nozzle have distance of 406 mm between them and they can operate from 20 PSI to 50 PSI pressure while nozzle discharge rate is 0.51 L/min.

Figure 4 illustrates, nozzle number 1 and 6 have less discharge as compared to Nozzle number 3 and 4 but this difference is negligible while the nozzle number 2, 4 and 5 have similar discharge rates. The average discharge rate of all nozzles was found to be 0.53 l/min. Over all machine distribution efficiency is good and all nozzles operates on constant pressure and discharge rate.

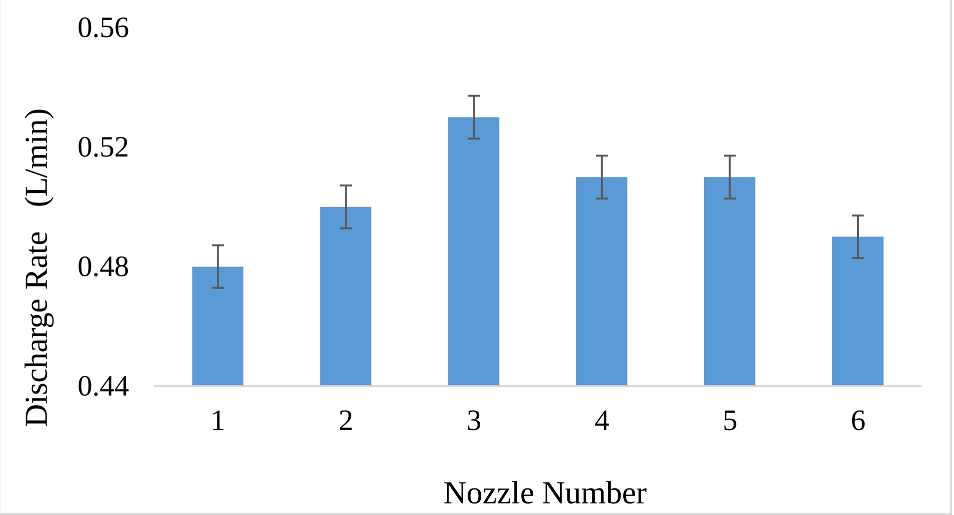

Figure 4. Discharge rate of different nozzles

Battery Discharging Time

A 12 volt battery is used as a power source for the operation of diaphragm pump. Battery timing is very important factor in this walk behind sprayer design. Figure 5 illustrate the results for battery discharging trials;

According to results, it is estimated that battery can work continuously in the field for about five hours. Battery discharging time for all the three repetitions were nearly same as shown in the Figure 26. As per TFC, machine can spray on an area of 1.33 acres per hour which means that after one full charge of the battery, 3.7 acres can be sprayed by the help of this machine.

One power cycle of battery = 3.7 acres sprayed

Battery Charging Timing

Batteries were fully discharged and recharged for three times to check the average recharging time of battery.

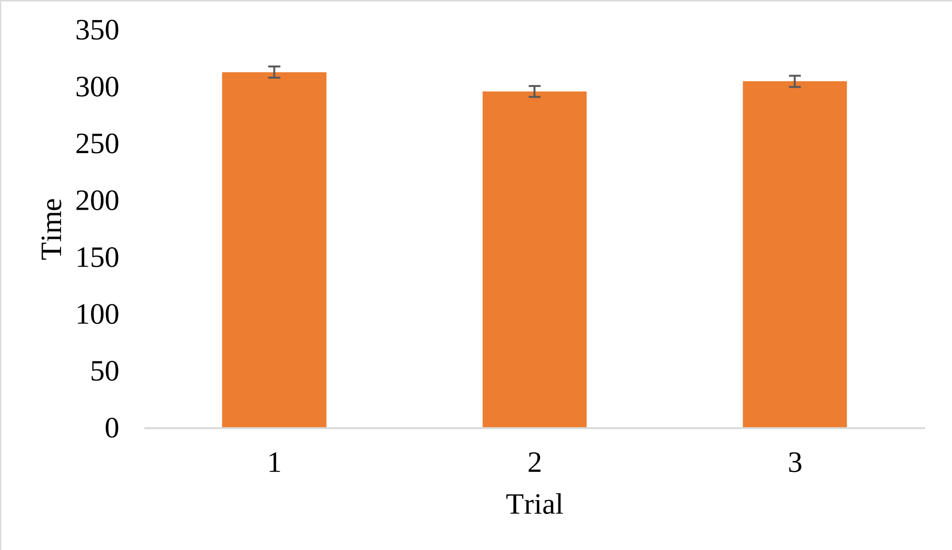

Figure 5. Results of battery discharging time

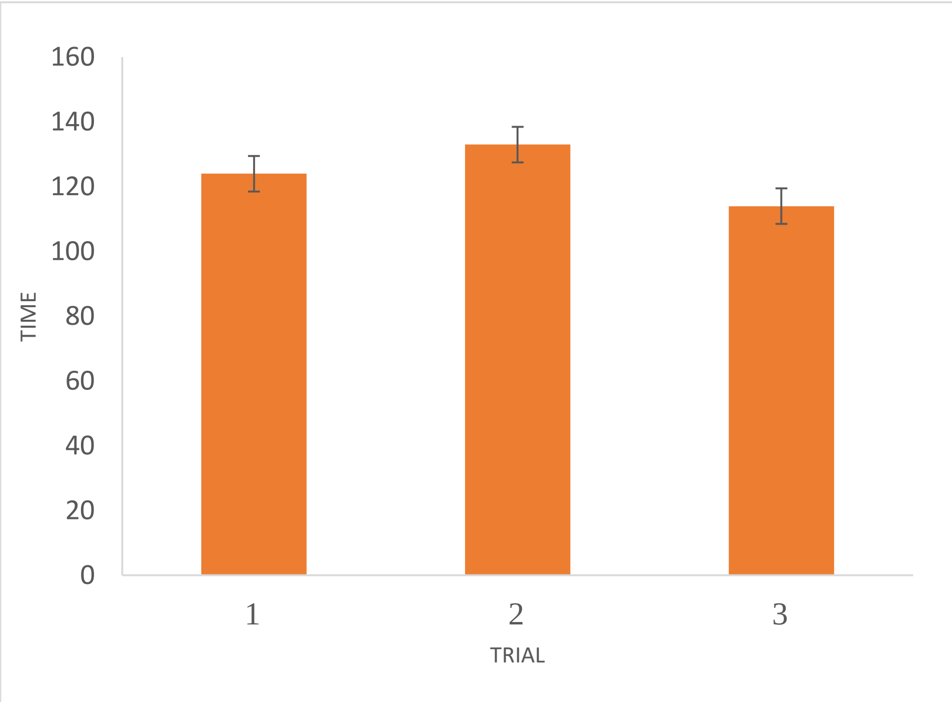

Figure 6. Results of battery charging time

Figure 6 explain that battery of small scale walk behind pesticide sprayer took maximum time of 133 minutes to fully recharge. In third trial battery took minimum time of 114 minutes but the average charging time of battery is around 120 minutes.

Storage Tank Discharging Time

Storage tank is fixed on the main frame of the spraying equipment. Storage tank discharging time were measured three times and the results obtained were noted. Figure 7 shows the results of tests carried out to evaluate the storage tank discharging time.

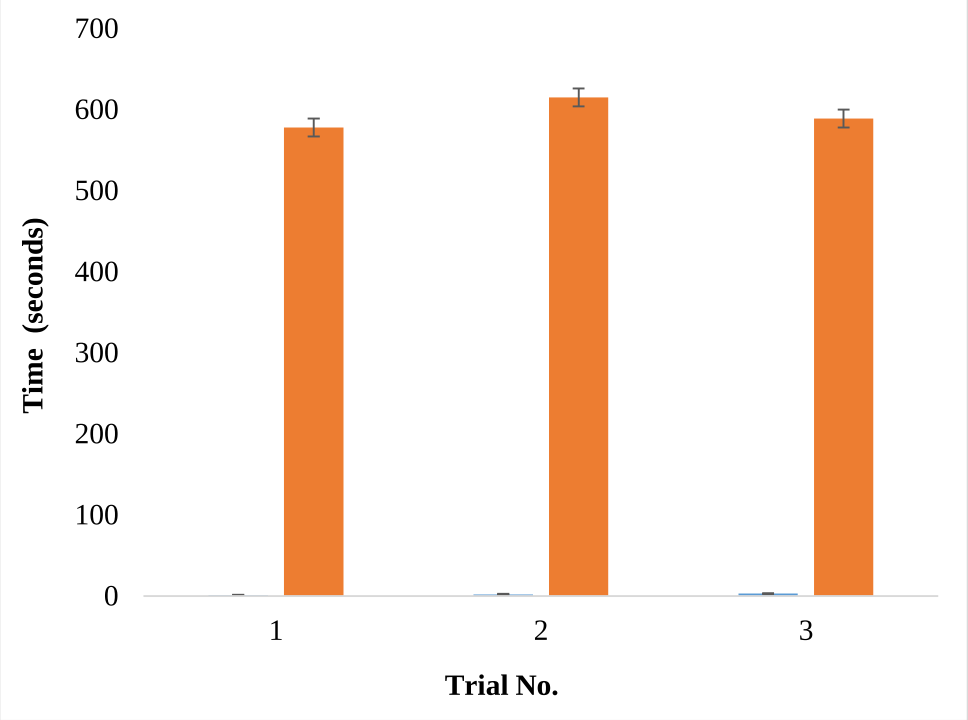

Figure 7. Storage tank discharging time

It was observed after three trials that storage tank fully discharged after10 minutes of operation and operator had to recharge the storage tank. For 120 liters of agro chemical spraying on one acre, storage tank will have to be refilled for four times.

Effective Field Capacity

Effective Filed Capacity of the walk behind small scale pesticide sprayer was calculated by the given formula;

EFC = Area/Time

Area = (60.9 × 6.09) m^2

= 371 m^2

Time = 315 seconds

= 0.087 hours

EFC = 371 / 0.087

= 4264.36 m^2/hr.

= 4264.36/ 10,000 ha/hr.
= 0.42 ha / hr.
= 1.03 acre/hr.

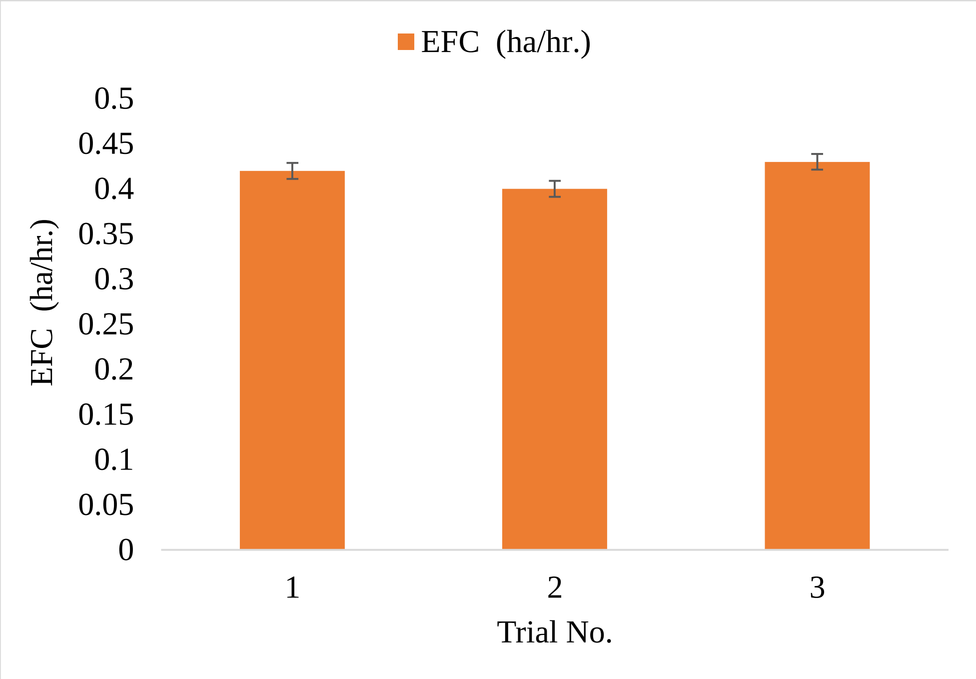

Figure 8. Trial results of effective field capacity

Figure 8 illustrates that the results of all three trials of EFC were nearly same. The maximum EFC of 0.43 ha/hr was found in the third trial while the minimum EFC 0.40 ha/ha was found in the second trial. The average EFC of the machine is about 0.41 hectare per hour. It is highly dependent on the operator's speed in the field and the actual field conditions.

Field Efficiency of the Sprayer

Field efficiency of the machine can be determined by the TFC and EFC of the machine. It was calculated by using formula;

Field Efficiency = (TFC/EFC) × 100
Field Efficiency = (0.42/0.54) × 100
= 77.77 %

It was found that the Field efficiency of the walk behind pesticide sprayer is 77%. It can vary as per variation in operator's walking speed and field conditions.

Wheel Slippage of the Spraying Equipment

Wheels performance of spraying machine varies in different field conditions. Speed of the sprayer with load and without load were tested and wheel rotations of the machine were counted three times.

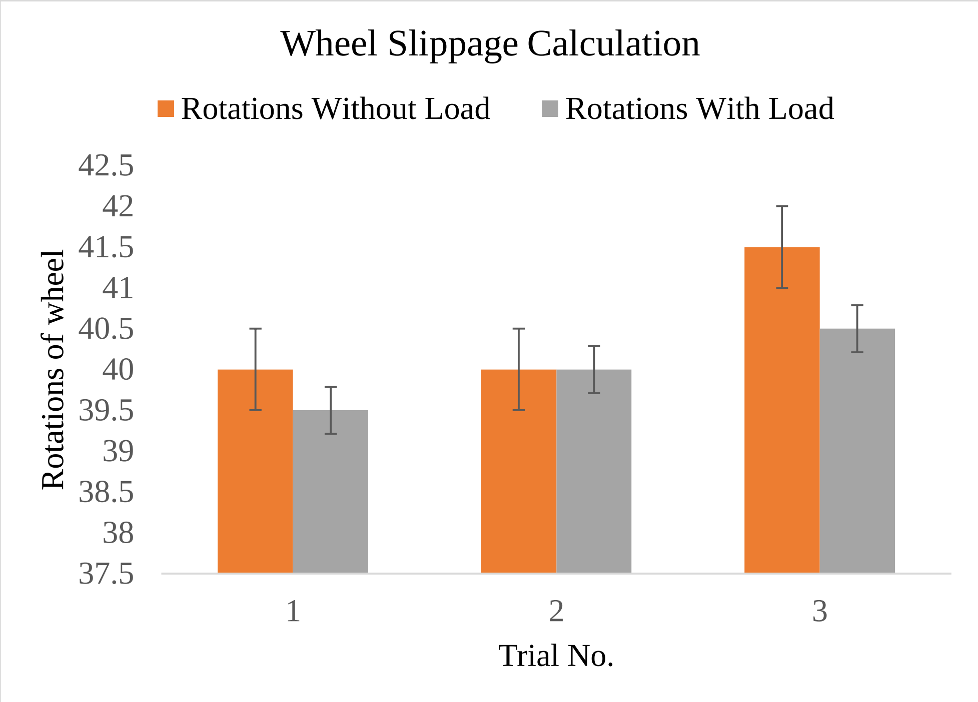

Figure 9. Results of wheel slippage calculation

Figure 9 illustrate that small scale walk behind pesticide sprayer covered the measured distance of 20m all the time with nearly same number of rotations of wheel with load and without load. The maximum no. of rotations 41.5 were observed in third trial without load while the minimum no. of rotations were 39.5 in the first trial of machine when it was loaded. The average difference between the rotations of wheel with load and without load was only half rotation. Wheel slippage of walk behind pesticide sprayer was calculated as below;

Wheel Slippage = $((R_{wol} - R_{wl}) / R_{wol}) \times 100$

$R_{wol} = 40.5$

$R_{wl} = 40$

Wheel Slippage = $((40.5 – 40) / 40.5) \times 100$

Wheel Slippage = 1.23 %

Nozzle Canopy and Overlapping

Nozzles which are used in the walk behind pesticide sprayer are hollow cone nozzles having operating pressure of about 30 psi and discharge for each nozzle is 0.5 liters per minute. Nozzles are 16 inches away from each other and the canopy of the nozzles reached about 10 inches away from the discharging point. The width of the cone was 254mm while the overlapping was of 4 inches.

Canopy Width = 254 mm

Overlapping = 101 mm (25%)

Spray pattern = Hollow cone

Spray angle = 85º

Economic Analysis of Walk behind Pesticide Sprayer

Cost analysis of the walk behind pesticide sprayer is depend upon two factors, first is fixed cost and second is variable cost. Both factors are discussed below

Total purchase cost of the sprayer, P = PKR 25000.
Total life of the sprayer = 10 years
Yearly usage of sprayer = 30 days
Daily working hours = 8 hours
Total working hours per year = 30 × 8
= 240 hours per year
Total life of the sprayer in hours = 240 × 10
= 2400 hours
Salvage value of the sprayer, S = 10% of P
= PKR 2500

Fixed Cost of Walk behind Pesticide Sprayer

Fixed cost of walk behind mobile pesticide sprayer includes

1. Depreciation cost
2. Interest
3. Insurance
4. Taxes
5. Housing and shelter

Depreciation Cost (Dc)

The depreciation cost of walk behind pesticide sprayer was calculated as;

$$D_c = \frac{\mathrm{P} - \mathrm{S}}{10}$$

$$D_c = \frac{25000 - 2500}{10}$$

So, the depreciation cost was calculated to be PKR 2250 per year which is PKR 9.37 per hour.

Interest, Insurance, Tax and Housing

This machine is small in size and has low initial cost, so interest, insurance, tax and housing are not taken into account in this case.

Total Fixed Cost

The total fixed cost can be calculated as sum of the above parameters i.e.

Total Fixed Cost = Dc + Ir + Is + Tx + H&S

Thus, the total fixed cost was calculated to be PKR 9.37 per hour.

Variable Cost of Walk behind Sprayer

The variable cost of machine includes:

1. Labor cost
2. Repair and maintenance cost
3. Fuel cost

Labor Cost (Lc)

Labor is required to operate the small scale walk behind mobile pesticide sprayer. In Pakistan labor charge the money according to storage tanks consumed while spraying. As per discussed earlier, walk behind pesticide sprayer have 30 liter of storage tank.

In an hour sprayer cover the area = 1 acre

In one acre storage tank refill = 4 times

Labor cost for 1 storage tank = PKR 60

Total cost per hour = PKR 240 per hour

Repair and Maintenance Cost (R&M)

Repair and Maintenance for every machine is required due to wear and tear during the field operation. Maintenance cost is estimated to be 80% of initial cost and is calculated as;

Maintenance cost = 25000 × 0.8

= PKR 20000 for 10 years.

Maintenance cost per year = 20000 / 10

= PKR 2000 per year

Maintenance cost per hour = 2000/240

= PKR 8.33 per hour

Fuel Cost (Fc)

No fuel is required for the operation of walk behind pesticide sprayer. However, the battery is charged after five hours of working. The battery consumed 1 unit of electricity for every recharge.

Cost of one unit of electricity = PKR 10

No. of recharging per year = 240/5

= 48 times per year

Total cost of battery charging in a year = 48 × 10

= PKR 480 per year

Thus, the battery charging cost per hour was calculated to be PKR 2 per hour.

Total Variable Cost

The total variable cost is calculated to be as sum of the above parameters;

Total Variable Cost = Lc + R&M + Fc

The total variable cost was calculated to be PKR 250.33 per hour.

Total Cost of Walk behind Pesticide Sprayer

Total cost of the small scale walk behind pesticide sprayer is the sum of fixed cost and variable cost.

Total Cost = Fixed cost + Variable cost

= 9.37 + 250.33

= PKR 259.7 per hour

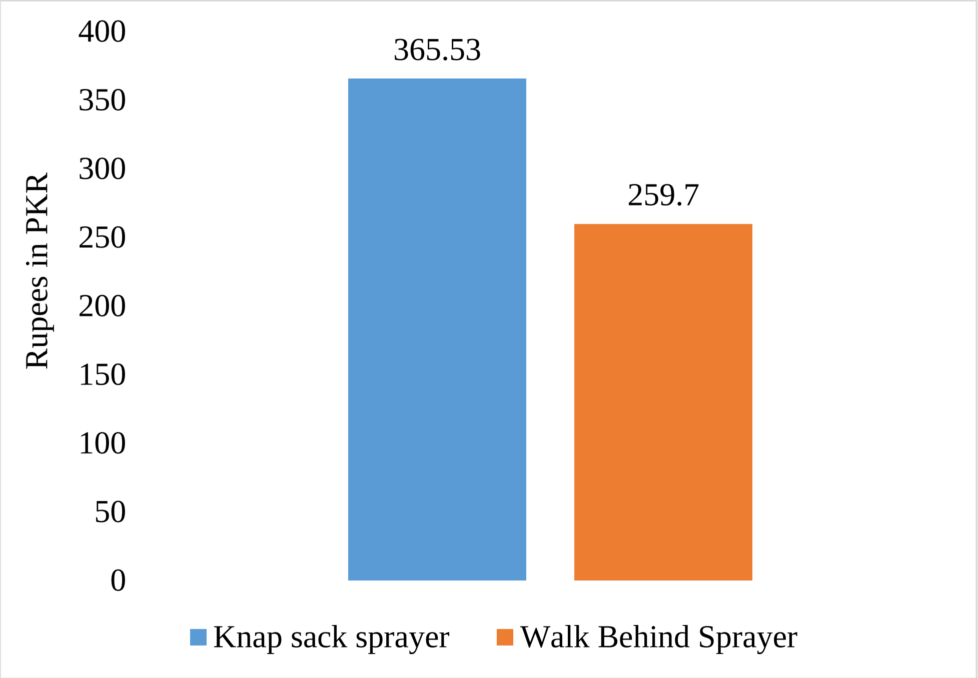

Figure 10. Illustrates that small scale walk behind pesticide sprayer is very much cheaper machine as compared to traditional knap sack sprayers.

Difference of per hour cost between knap sack and walk behind pesticide sprayers.
Knap sack sprayer = PKR 365.53
Walk behind sprayer = PKR 259.70
Difference = PKR 105.83
Saving per hour = PKR 105.83.
Working hour in year = 240 hours
Total saving in an year = 240 × 105.83
= PKR 25399 per year

The newly developed small scale walk behind pesticide sprayer saves more than 25 thousands rupees per year. It is more than its initial cost. So the payback period of walk behind sprayer is almost 1 year.

Conclusions

After the comprehensive testing of walk behind pesticide sprayer it was concluded that effective field capacity, wheel slippage and field efficiency of this machine was one acre/hour, 1.23% and 77% respectively. The battery capacity of sprayer was measured to be five hours. About four to six storage tanks of agro chemicals were required to spray one acre. It has proven to be more cost effective as compared to knapsack sprayer.

Limitations and Future Recommendations

The following recommendations and suggestions are made to improve the performance of small scale walk behind pesticide sprayer;

1. This newly developed machine have fixed spacing of wheels. An adjustable wheels mechanism should be developed for this spraying machine. It will enhance its capabilities of spraying in different row to row spacing.
2. This machine have fixed height of spraying nozzles. An adjustable nozzles mechanism should be developed, so that nozzles can be adjusted according to position of plants.

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