International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com

Vol.6., Issue.3, 2018
May-June

RESEARCH ARTICLE

ISSN: 2321-7758

FABRICATION AND PERFORMANCE EVALUATION OF GROUND WHEEL OPERATED BOOM SPRAYER

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ABSTRACT

Pests and weed problems, in crop production are serious both in rain fed and irrigated farms in Ethiopia. Farmers are forced to spray insecticides, pesticides and herbicides frequently using manually operated machines, which are poor in application uniformity, laborious, time consuming, and dangerous in terms of operators' safety and health. The objectives of this research saw to manufacture and evaluate ground wheel operated boom sprayer. The materials used in fabricating the sprayer were selected based on the manufacturing drawing. The sprayer was tested both in laboratory and field for the uniformity of application, discharge rate, field capacity and field efficiency and had achieved an application rate of 281.3 l/ha with coefficient of variation (CV %)of2.80%among the nozzles discharge rate, effective field capacity of 0.83 ha/hr., theoretical field capacity of 1.04 ha/hr. and field efficiency of 82.7%.As compared to the manually operated knapsacks sprayer of 0.4 ha/day field capacity and 56%field efficiency the prototype sprayer had improved the effective field capacity and field efficiency. Based on the performance result the newly developed sprayer can cover one hectare of land within about an hour with a better spray uniformity.

Keywords: Boom sprayer, wheel barrow, wheel driven pump, design, performance evolution, effectiveness and efficiency

1. INTRODUCTION

Plant protection plays a significant role in optimizing the productivity of a given crop. Agricultural pests, which include organisms such as fungi, bacteria, viruses, insects, mites, nematodes, weeds, rodents and grain-eating birds, that live on and/or compete with plants determine, to a varying degree, if crops can be grown economically in certain situations. Usually 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 (Wolman and Fournier, 1987).

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 is the only fully mechanized farming operation. Machines previously developed for chemical application include the knapsack sprayers, the ultra-low volume sprayers and tractor boom sprayers (Liu, 2008).

However, pesticide use has enabled farmers to increase crop productivity without

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sustaining the higher losses likely to occur from an increased susceptibility to the damaging effect of pests. The concept of integrated pest/crop management includes a threshold concept for the application of pest control measures and reduction in the amount/frequency of pesticides applied to an economically and ecologically acceptable level. Often minor crop losses are economically acceptable; however, an increase in crop productivity without adequate crop protection is very difficult, pests (Cooke, 1998).

An effective chemicals use needs a scientific and effective way of handling rationing proper application method, aiming at eliminating pests, diseases and weeds, and ensuring stable and high yield of crops.. In general, equipment items 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).

Small and medium farmers mostly use knapsack sprayers to apply pesticides (FAO, 1994). More than 5 million hand operated sprayers are sold annually in the world and most of them are sold in Southeast Asia and Africa (Matthews, 1992). 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. 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). It was estimated that about 50-80% of applied pesticides wasted due to poor spray machinery and inappropriate application methods (Khan, et al., 1997).

According to (Hastings and Quick, 1988) to attain a good result during spraying the distance between the nozzle and tops of the plants should be maintained at around 30 cm. According to some studies, 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 (Garman and Navastor 1981). That means it is quite difficult to maintain a constant nozzle height during swing of the lance.

Tractor boom sprayer could be a possible solution but it has become very difficult for farmers to easily engage tractors even for the more laborious jobs of tillage. The cost of tractor hiring is very high and beyond the reach of the average farmer. Farmers, who could afford tractors, find it difficult to access attachment boom spraying equipment. And when they possibly do, there are spare parts and maintenance and calibrations still pose insurmountable problems. It is also uneconomical to deploy a tractor for small farm operations. 50 hectares is the minimum farm size for economic deployment of tractor (Takeshima and Salau, 2010). Thus a gap exists between the very small scale farms suited for knapsack and ultra-low volume deployment and the tractor boom spraying suitable for large scale farming. Taking the above into account the study was launched to manufacture and evaluate more efficient, bigger swath, which can a alleviate drudgery of spray and better adaptable six nozzle boom sprayer for small and medium levels.

1.1. *OBJECTIVE*

The overall objective of the study was to avail a user friendly low cost sprayer suited small farms.

1.1.1. *Specific objectives*

- To fabricate ground wheel driven boom sprayer
- To evaluate the performance of ground wheel driven boom sprayer

2. MATERIALS AND METHODS

2.1. *Materials used*

The materials used to fabricate machine were selected based on the manufacturing drawing, the availability and the costof the material. Based on these considerations the materials used are listed in table1 with their dimensions, table 1.

Table1. List of materials used

No	Part Name	Dimensions	Material used
1	structural frame	$\emptyset \frac{3}{4} in\ X\ 164m$, 2 piece	Round steel pipe
2	tank	20 lit, 150 x180 x360	plastic
3	Piston pump	Ø34mm, stroke length 65mm	Brass, plastic
4	shaft	Ø24mm, 200mm	Milled steel
5	wheel	$\emptyset 65\ cm$	Pneumatic spoke wheel
6	hose	5m	Plastic
7	boom	2, 1.5m each	Galvanized steel pipe
8	nozzle	04 size	Tee Jet flat fan

9	chain	1155.7mm, pitch 12.7	standard
10	sprocket	Teeth no 42, Ø17.4 *cm*	standard
11	sprocket	Teeth no 14, Ø5.6*cm*	standard

2.2. Methods used

2.2.1. Manufacturing of the Sprayer

The machine was manufactured at Melkassa Agricultural Research Center workshop. Both the laboratory and field testing was also conducted in the research center using laboratory facility at the center. Part, assembly and manufacturing drawing were produced using CATIA.

Manufacturing of Main Frame

To manufacture the main frame 3/4" galvanized pipe was used. The pipe is bent in different three points at different angle and direction to form a wheel barrow shape, fig 1. Two symmetric wheel barrow shaped pipes were joined using RHS forming a wheel barrow profile.

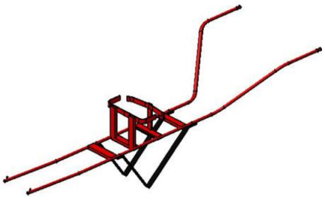

Fig1. Manufactured Frame

Wheel

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 as in fig 2.

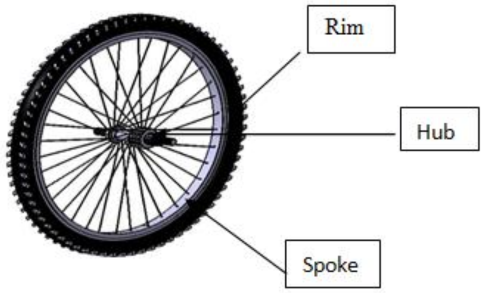

Fig 2.Wheel of the Sprayer

Tank and Pump

A standard 20 litter knapsack sprayer was dismantled and the tank with piston pump was integrated to the new design, fig 3.

Fig 3. Tank with Piston Pump Integration

Fabrication of Boom

The boom was manufactured from two separate galvanized pipes. Each boom has three nozzles with a nozzle adapter attached with screwed clamp. The booms are fixed to a common holder with clamps so that both booms move together as shown in fig 4. The boom holder in turn is fixed on a vertical frame using screw clamp, which the boom holder can slide up and down, that helps to adjust the spray height.

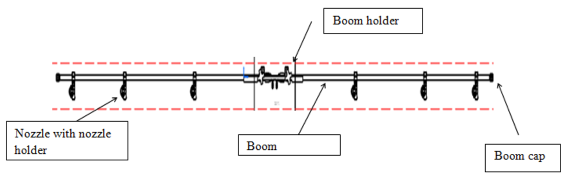

Fig 4. Boom, Nozzle and Boom Holder Assembly

Complete Sprayer Assembly

The sprayer main parts were assembled with bolt and nuts, straps to secure in place and some clamps. In assembling the sprayer parts only three different sized bolts and nuts were used. This makes easy maintenance and only few tools are needed. The main components of the sprayer are shown in fig 5.

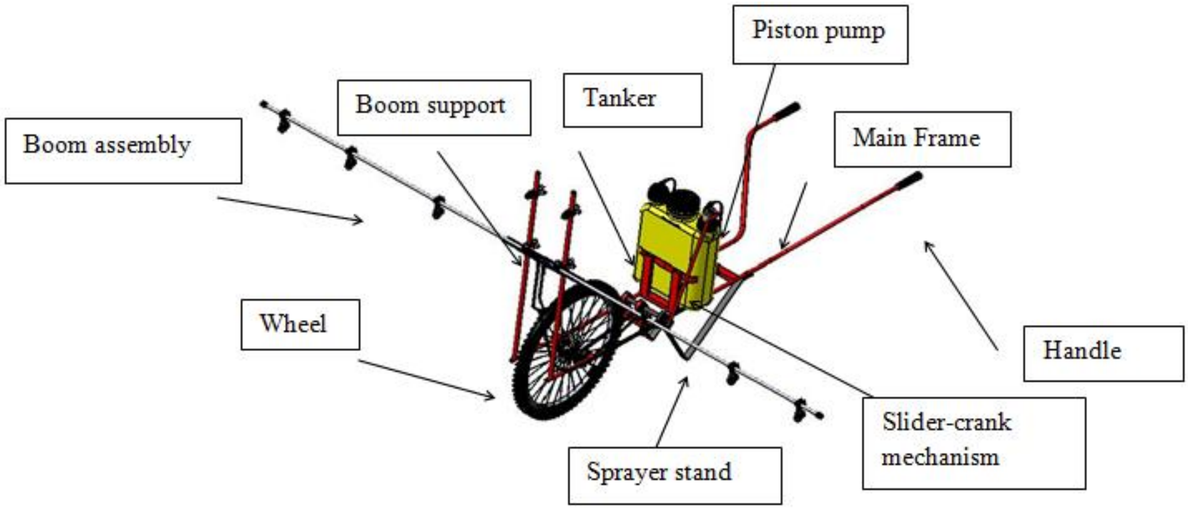

Fig 5. Complete Sprayer Assembly Parts

Fig6. CAD Model of the Sprayer

Operation of the Machine

The sprayer prototype is made basically of the main frame, spray tank, pump/prime mover, traction wheel, boom, nozzles and flexible rubber hose. The main frame is mounted on the axle shaft with single traction wheel and carries the spray tank and pump integration, and a boom assembly of 3m length with six sprayer nozzles. The spray tank is connected to the boom with distributing flexible plastic. The boom frame is bolted at the front end of the main frame in the way that the boom height could be adjusted as per the crop height between 30cm – 120cm above the ground. The pump is actuated by an offset slider-crank mechanism, which gets the power from the ground wheel through chain and sprocket transmission. During the operation the operator simply puts the boom in a horizontal position and pushes the sprayer it into the rows of the crop, fig 7.

Fig 7. Sprayer prototype

2.2.2. Performance Evaluation of the Sprayer

Sprayer performance is evaluated by the uniformity of coverage and spray patterns(Ajit, etal.,2012). The sprayer was evaluated both in laboratory and field and accordingly the following data were collected and analyzed.

Laboratory Test

Uniformity of Nozzle Discharge Rate

The discharge rate from each nozzle was measured to determine the amount and check the variation between the discharge rates of each nozzle within 5 meter intervals of 20m. In each 5m interval the discharge from each nozzle was collected using a bag and measured using a measuring cylinder as in fig 8. The time taken to cover each interval also recorded to calculate the discharge rate. The trial for each interval was replicated three times and coefficient of variation (CV %) was used to analyze variation of discharge rate among the nozzles for each 5m interval.

Fig 8.SprayerDischarge Rate Test on Test Track

Uniformity of coverage

The uniformity of coverage is determined by (a) the type of nozzle, (b) the nozzle spacing, (c) the boom height, and (d) the angle of the spray nozzle. The most uniform coverage is produced with a flat-fan nozzle with a wide angle, with the boom height set at the minimum recommended height. Raising or lowering the boom results in over- or under-application. For narrow spray angle nozzles, the spray pattern is much more sensitive to changes in boom height(Ajit, et al.,2012).

Spray Overlap

The overlap is defined as the width covered by two adjacent nozzles divided by the width covered by a single nozzle, expressed in percent. It mainly affects spray pattern and coverage of the sprayer it depends on the boom height and nozzle spacing(Ajit, et al., 2012).

The test was done on a test track using a dye. First the test track was painted with light blue color and then a black dye was used as a water solution to get a good contrast between the track and the spray solution, in fig 9. The sprayer was tested for 50cm boom height and 50cm nozzle spacing spray and the measurement was taken within 30m distance at an interval of 5 m.

Fig 9. Spray Overlap Test on Test Track

Field Test

Application Rate, Field Capacity and Field Efficiency of the Sprayer

The field test were conducted on 0.25 ha trial field in this test nozzle discharge was done to evaluate the amount of discharge from each nozzle and to check the variation in discharge rates among the nozzles within 30 meter. The discharge from each nozzle was collected by tying a plastic bag on each nozzle as shown in fig 10. After each 30 minterval the sprayer were stopped and each liquid collected from the nozzle was measured using measuring cylinder. Three replications were undertaken to check the uniformity of discharge from each nozzle and coefficient of variation was used to analyze variation of discharge rate among the nozzles for each trial. The total amount of liquid sprayed and time taken to complete the field were recorded to calculate the application rate per hectare (l/ha), the field capacity and field efficiency of the sprayer.

Fig10. Field Test of the Sprayer

3. RESULT AND DISCUSSION

The results were as indicated in the following tables and figure

Table2. Performance of the Prototype Sprayer

	parameters	values
No	Functional parameters	
1	Number of nozzle and spacing, mm	6 x 500
2	Swath width, m	3.00
3	Mean pressure, bar	1.80
4	Discharge rate/nozzle, ml/min	882.00
	Performance parameters	
5	Quantity of solution sprayed, l	70.25
6	Effective time, (min)	14.75
7	Lost time, min	1.67
8	Total time, min	16.42
9	Field size or Area treated, ha	0.25
10	Forward speed, km/hr.	4.00
11	Field capacity, h/hr.	0.83
12	Field efficiency, %	82.7

*3.1.**Laboratory test result***

Uniformity of nozzle discharge

During the laboratory test on the test track, with in 20m and an interval of 5m,the nozzles average discharge rate was 10.68 ml/sec, 13.55

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Vol.6., Issue.3, 2018
May-June

ml/sec, 14.32 ml/sec and 14.71 ml/sec in the 1st, 2nd, 3rd and 4th intervals respectively at an average bar pressure of 1.8 bars, table3.

Table3. Average Discharge Rate of Individual Nozzle on the Test Track within 20m in 5m Interval

Intervals	Average Discharge rate, ml/sec						Mean average discharge in ml/sec	CV%
	Nozzle No							
	N1	N2	N3	N4	N5	N6		
1st	10.55	10.66	10.94	11.00	10.66	10.27	10.68	3.20%
2nd	13.55	13.61	13.72	13.61	13.33	13.50	13.55	2.19%
3rd	14.33	14.00	14.26	14.80	14.13	14.40	14.32	1.31%
Average	14.88	14.68	14.60	14.64	14.64	14.81	14.71	1.32%

N1- N2, N2-N3 … are the adjacent six flat fan nozzles fitted on the boom at 50cm spacing

The coefficient of variation for the average of nozzle discharges rate among the nozzles was 3.20%, 2.19%, 1.31% and 1.32% in 1st, 2nd, 3rd and 4th intervals respectively, which was below acceptable variation of 10% as per the recommendation (Gomez and Gomez, 1984)and decreases from 3.20%, in the 1st interval to 1.32% in the last 4th interval, this shows the variability in discharge rate decreases significantly within 20m and attains an optimal discharge rate of 14.71ml/sec.

Spray Overlap

During the spray overlap test the average% overlap between the nozzles varies from 31.69%to32.86 at boom height of 50cm and nozzle spacing of 50cm, which was within the acceptable range of 30 – 100%.

Table4. Spray Overlaps between Nozzles

Data points	Overlap in cm				Mean average overlap	CV%
	N1-N2	N2-N3	N4-N5	N5-N6		
at 5 m	24.70	25.00	23.50	24.30	24.38	
at 10m	24.50	24.80	24.50	24.50	24.58	
at 15m	25.00	23.50	22.80	25.00	24.08	
at 20m	23.50	24.50	23.50	23.60	23.77	
Average overlap	24.42	24.45	23.58	24.35	24.20	
average % overlap	32.83	32.86	31.69	32.73	32.53	1.7307

N1- N2, N2-N3 … are the adjacent six flat fan nozzles fitted on the boom at 50cm spacing

The coefficient of variation (CV %) of percentage overlap between the adjacent nozzles were1.73%, which shows very small variability of overlap between consecutive adjacent nozzles indicating a good uniformity of coverage as shown in table 4.

3.2. Field Performance Test Result

Application Rate, Field Capacity and Field Efficiency

During the field test the average discharge rate between the nozzles varies from 13.34 to 12.67 ml/sec with the mean average discharge rate of 13.04ml/sec at an average operating pressure of 1.8bars and forward speed of 4 km/hr.

Table5. Discharge Rate of Individual Nozzle in the Field Test

Rep	Discharge in ml/esc						Mean discharge in ml/sec	CV%
	Nozzle No							
	N1	N2	N3	N4	N5	N6		
1	12.90	12.90	12.58	12.42	12.58	12.9	12.71	
2	13.63	13.03	13.03	13.03	12.72	13.33	13.13	
3	13.48	13.48	13.18	13.18	12.72	13.64	13.28	
Average	13.34	13.13	12.93	12.88	12.67	13.29	13.04	2.80%

N1, N2 … N6 are six flat fan nozzles fitted on the boom at 50cm spacing

The result in table 5, above shows that the amount of fluid sprayed was 70.32 litters on 0.25 hectares of land, which gave an application rate of 281.3 l/ha.

Field Capacity of the Sprayer

Actual field capacity as calculated in (Sharma, et al., 2010).

For calculating actual field capacity the time consumed for real work and that lost for other activities such as turning, filling of tank were taken into consideration.

Actual field capacity was calculated by

$$Actial\ fiel\ capacity = \frac{A}{T_{tota}}$$

$$T_{total} = \text{time for turning} + \text{time for refilling} + \text{time for actual work}$$

$$6 \sec x\ 17 + 25 \sec x\ 4 + 15min = 0.30hr$$

Where

A = area covered, 0.25 ha

T_{total} = total time taken, = 0.3hr

$$= \frac{0.25ha}{0.30hr}$$

$$0.83\frac{ha}{hr}$$

Theoretical Field Capacity

Theoretical field capacity was calculated by (Sharma, et al., 2010).

$$TFC = \frac{Speed\ x\ boom\ Width}{10}$$

$$= \frac{4\frac{km}{hr}\ x\ 3m}{10}$$

$$= 1.04$$

Field Efficiency

Field efficiency is the ratio of actual field capacity to the theoretical field capacity; field efficiency is expressed in %, (Sharma, et al. 2010).

$$Fiel\ efficiency = \left(\frac{Actual\ field\ capacity}{Theoretical\ field\ capacity}\right) x\ 100$$

$$\frac{0.83}{1.04}\ X\ 100$$

(0.83/1.04) X 100

82.7%

4. CONCLUSION

Based on result above the sprayer has managed to maintain an average nozzle pressure of 1.8 bar during both the field and laboratory test at an average speed of 4km/hr. The average nozzles discharge rate variation along travel distance reduced and attained an optimum discharge rate among the nozzles within 15-20m distance. The prayer is manufactured with tank capacity of 20 litters, a full tank can cover an area of 0.07ha, which needs a refilling of 14 times to cover one hectare with an application rate of 281 lit/ha, an average discharge rate 13.04ml/sand effective field capacity of 0.83 ha/hr., it also has a good uniformity of coverage with an average percentage overlap of 32.53%.

The sprayer forward speed and spray application are synchronized, so that once the sprayer attained the optimal uniform discharge along all the nozzles it will maintain its uniformity till the next tank filling. Moreover the sprayer applies the pesticide at about 3m away from the operator, which minimized the chances of exposure of chemical to the operator and alleviates carrying the chemical tank at the back of the operator's shoulder.

REFERENCE

[1]. Ajit K., et.al. *Engineering Principles of Agricultural machines,* 2nd ed., American Society of Agricultural and Biological Engineers: 2950 Niles Road, St. Joseph, MI 49085-9659 USA, 2012.

[2]. Cooke, B.M. *Disease assessment and yield loss in the Epidemiology of Plant Diseases*, (Ed. D. G. Jones), Dordrecht, Kluwer Publishers the Netherlands, 1998, pp. 42–72.

[3]. FAO. *Agriculture Pesticides Sprayers*, Vol.2: FAO technical standards: sprayer specifications and test procedures, 1994, 7-8.

[4]. Garman C.F. and Navasero N. C. *Mechanization of Small Upland Rice Farms an Overview of Upland Rice Research*, Los Banos, Philippines, 1984, IRRI: 379-382.

[5]. Gomez K. A and Gomez A.A. *Statistical procedure for Agricultural Research*,2nded., John Wiley and Sons, Inc., New York, 1984.

[6]. Hastings, J. J and Quick G. R, editors., *Development of a set of Minimum Standard Specifications for Lever Operated knapsack sprayer*, Malaysia.1988, IRRI, 98.

[7]. Khan A., et al. "*Application technology for agro-chemicals in Pakistan*", In. Salokhe,V. M., ed. Proceedings of the international

workshop on safe and efficient application of agro-chemicals and bio-products in south and Southeast Asia, Bangkok, Thailand,1997, 79-101.

[8]. Liu GQ, Zhang G, Li J, et al. "*Source and distribution characteristic of atmospheric organochlorine pesticides in the Pearl River estuary and adjacent South China Sea*", Environmental Science, 2008, 29(12): 3320-3325

[9]. Mamat, J. M and OmarD. Country report: *Status of small Sprayers Usage's, Features and Standard in Malaysia*, Malaysia.1992, IRRI, 146.

[10]. Matthews G.et al. *Small sprayer standards, safety and future direction for Asia*, IRRI: Los Banos (Philippines), 2008, IRRI: 3

[11]. Matthews, G.A. *Pesticide Application Methods. Longman Scientific and Technical*, New York, 2nd Edition, 1992, 405pp.

[12]. M. G Wolman and Fournier F. G. A.*Plant Protection and Land Transformation*. John Wiley and Sons, Inc., New York, 1987.

[13]. SharmaD.N and Mukesh S. *Farm machinery design principles and problems*. SUNIKUMARJANI for JANIBROTHERS, New Delhi, 2010.

[14]. Takeshima Hiroyuki and Salau Sheu. *Agricultural Mechanization and the Smallholder farmers in Nigeria, International Food Policy Research Institute and Nigeria Strategy Support program*; Policy Note ,2010, No. 22 pp. 2.