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Design, Fabrication and Evaluation of Wheel Operated Sprayer

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A B S T R A C T

Now day's scarcity of labour is creating problem during agricultural operation because in agriculture more labour is required. 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, with coefficient of variation (CV %) of 2.50% among the nozzles discharge rate, effective field capacity of 0.075 ha/hr., theoretical field capacity of 0.126 ha/hr. 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.

Introduction

Plant protection equipment plays a significant role in agricultural field to the productivity of a several crops. Agricultural pests, which include organisms such as fungi, bacteria, viruses, insects, mites, nematodes, weeds 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).

The wheel is attached to sprocket and the wheel is attached to gear and that sprocket and gear is joined by chain. That assembly is mounted on frame. By push the cycle that pushing pressure developed by rotated wheels. Then the rotation of wheel joined sprocket will be rotated. As well as gear it will be rotate by the assembly of attaching the chain. The gear is attached to wheel so wheel will be rotated by pushing the operator. in this machine four bar mechanism is applied to convert the rotary motion of chain sprocket into reciprocating action for piston to developed pressure inside of air pump used in spray tank therefore this developed pressure release in the form of water vapor through sprayer boom in this sprayer there are three nozzle used and also provide boom frame for adjust the height and width of nozzle according to requirement of crops

I have proposed a 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.

Materials and Methods

Indian farmers use traditional method, there is large scope for development in agricultural sector. In traditional method weeding process are done by the bull which become costly for farmers having small farming land its time consuming and requires separate setup. The spraying is traditionally done by backpack

spryer with labor which requires more human effort, it cover small area, time consuming and low storage capacity. Therefore to overcome above problems, we have design and develop the flexible equipment which will be beneficial to the medium and small scale farmer for the weeding and spraying operations.

Looking to the problem of manual weeding and backload sprayer the current study is planted to remove the backpack and foot spraying techniques, eliminate the human efforts, to decrease labour cost by advancing the spraying method and constant flow of droplets

Design calculation

Design of frame (Deshpande, 2017)

Length of frame = Centre distance between two sprocket + width of tank + excess

=230+440+570

=1200mm

Height of frame = 30 mm

Width of frame = 240mm
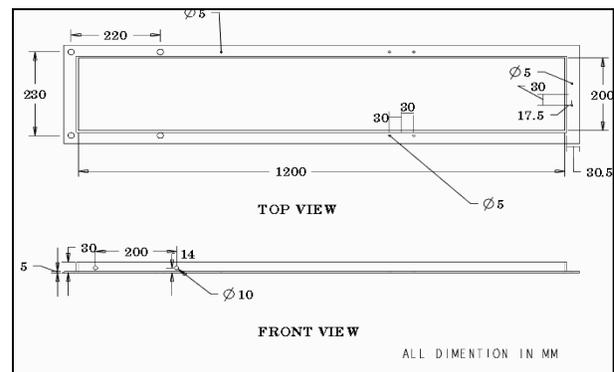
Fig.1 Main frame top view and front view

Selection of wheel (Deshpande, 2017)

Distance between two plant = 1.25
Feet = 38cm
Line covered by one rotation of wheel = 4
38×4=52cm

152=2πr

r=152/2π

r=25cm
Diameter of wheel= 50 cm

Fig.2 cycle wheel

Selection of sprocket (Deshpande, 2017)

$$\frac{1}{3} = \frac{t_p}{t_g}$$

$$\frac{1}{3} = \frac{18}{t_g}$$

$$t_g = 18 \times 3$$

$$t_g = 54$$

$$\frac{t_p}{t_g} = \frac{D_g}{D_p}$$

$$\frac{3}{1} = \frac{D_g}{72.5}$$

Pitch=$\dfrac{number\,of\,teeth\,on\,pinion}{pitch\,circle\,diameter\,of\,pinion}$=$\dfrac{18}{72.5}$ = 0.25mm
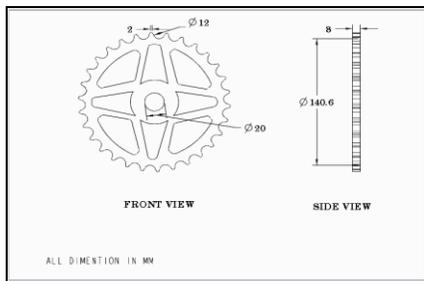

Fig.3 Gear

Selection of chain length (R.S. Khurmi, 2005)

Chain type roller ISO chain no.05B
pitch = 0.25mm
Length of chain, = KP
No. of chain =

$$K= \frac{t_1+t_2}{2} + \frac{2x}{p} + \left(\frac{t_2-t_1}{2\pi}\right)^2 \times \frac{p}{x}$$

$$K= \frac{54+18}{2} +2\times 479/.25+ \left(\frac{54-18}{2\pi}\right)^2 \times \frac{.25}{479}$$

K= 36+3824+0.00299
K= 3860mm
L=K×P
L= 3860×0.25
L= 965mm
L= 96.50cm
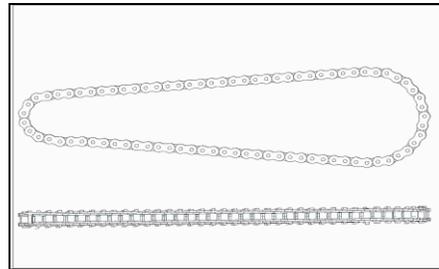
Fig.4 chain

Design of slider crank mechanism

Crank mechanism. A linear motion, back and forth, is transferred to a circular motion or vice versa. A rod is connected to a rotational crank, by moving the rod a circular motion is created. Alternatively, turning the rotational crank creates a linear motion.
Crank, AB = 15.1 cm
Connecting Rod, BC1 = 10.8 cm
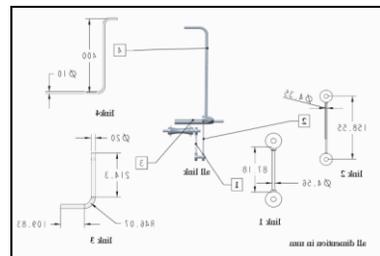
Fig.5 Crank assembly

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Determination of dimensions in the slider cranks mechanism

According to Grashof's law for a four bar mechanism, the sum of the shortest and longest link lengths should not be greater than the sum of the remaining two link lengths if there is to be Continuous relative
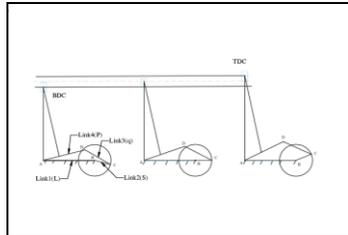

Fig.6 Free body diagram of the slider- crank at TDS and BDC position.

Selection of bearing

The roller contact consist of four part inner and outer faces a rolling element like ball, roller or needle and cage with hold the rolling element together and space them evenly around periphery

Fig.7 Bearing

Selection of knapsack sprayer

In manufacturing the sprayer a standard 16 litter knapsack sprayer were dismantled and the tank with piston pump integration is used

Fig.8 Knapsack sprayer

Selection of shaft

A drive shaft, driveshaft, driving shaft, propeller shaft (prop shaft), or cardan shaft is a mechanical component for transmitting torque and rotation, usually used to connect other components of a drive train that cannot be connected directly because of distance or need to allow for relative movement between them.
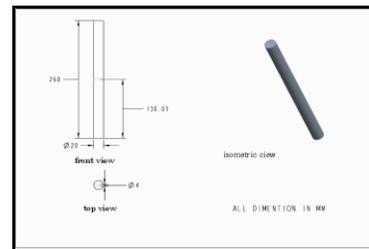
**Fig.9** Front, top and isometric view of shaft.

Selection of nozzle

The spray angle does not hold for long spray distances. As illustrated in the figure below, the spray angle tends to collapse or diverge as you move away from the orifice. Theoretical coverage of spray patterns at various distances from the nozzle orifice is listed below.
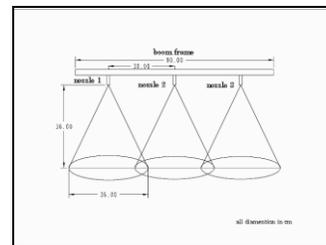

Fig.10 Sprayer pattern
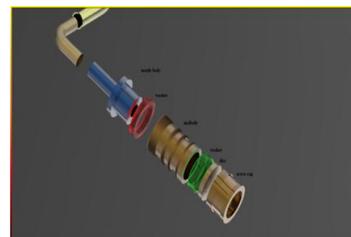
Fig.11 Dismantle part of nozzle
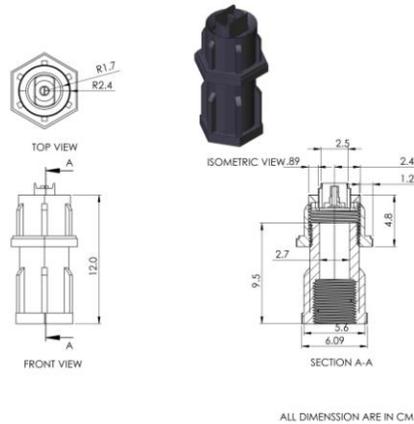
Fig.12 Dismantle part of nozzle

Sprayer boom's pipe

The boom is made of steel square pipe whose length is 90 cm, outside length is 30 mm and inside diameter is 28 mm. That means, distances between nozzles to nozzle is maintained by 30 cm. It has three pieces, each of them 15 cm long, which are connected with nozzle holders. Both sides of each pipe are a taper with a ring.

Fig.13 Sprayer boom's pipe

Design and development of the frame for holding the sprayer boom

A frame is made of MS bar. It is 100 cm long. This frame is fixed at the front of the implement main frame A holder is made on the bar rod is adjustable to distanced of nozzle to cover the crop as a required
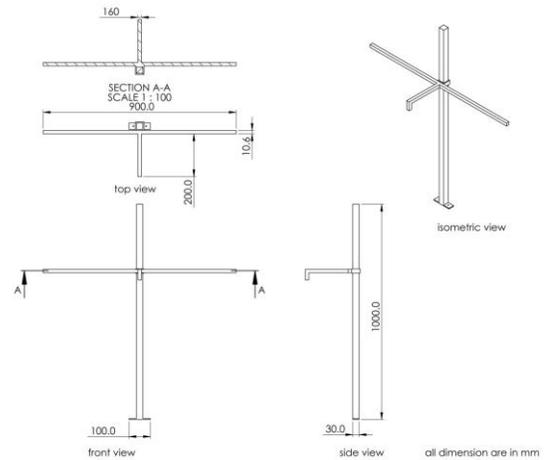
Fig.14 Line diagram of frame for holding the sprayer boom

Design and development of a frame for fixing the tank

A frame is made of MS flat bar (2 cm x 0.3 cm) for fixing the tank with the main frame at the rear side. It is made to make a provision to set tank at the frame .The tank will be attached at the rear of the main frame to support the front and back of the tank during Spraying row vegetable crops,
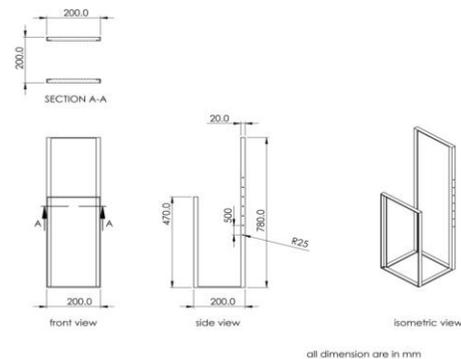
Fig.15 Line diagram frame to fixing the tank

| S N O	DISCRIPTION	PART NO	QU A.
01	SPRAYAR TANK FRAME	01	01
02	PISTON	02	01
03	4 BAR LINK	03	01
04	SPRAYAR TANK	04	01
05	SUPPORT WHEEL	05	02
06	CRANK	06	01
07	PINION SHAFT	07	01
08	PINION GEAR	08	01
09	GEAR SHAFT	09	01
10	GRAUND WHEEL	10	01
11	BEARING	11	01
12	MAIN FRAME	12	01
13	TYRE	13	01
14	BOOM FRAME	14	01
15	NOZZLE	15	03
16	DELIVERY PIPE	16	01
17	CAP	17	01
18	CHAIN	18	01
19	GEAR	19	01
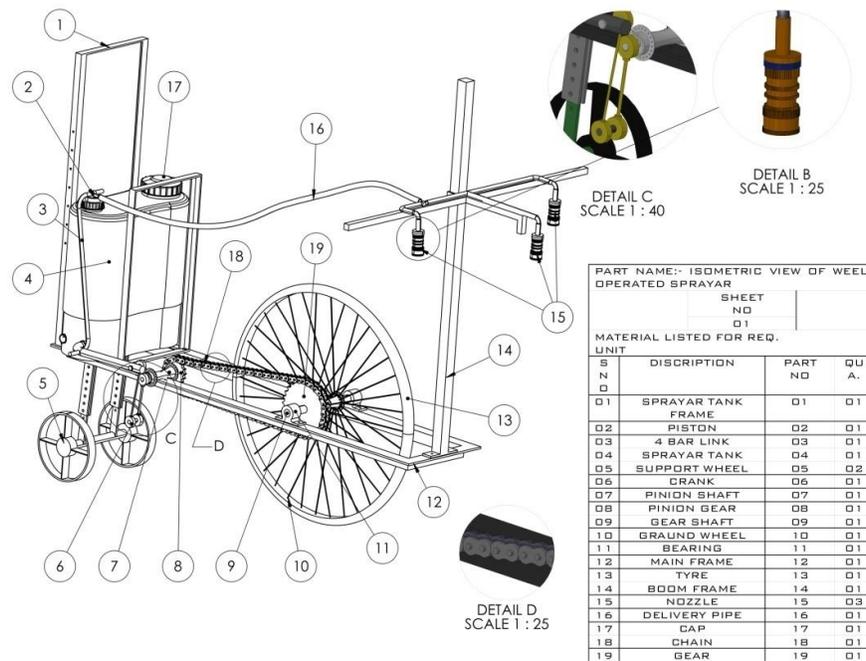
Fig.16 Entire assembly of mono wheel operated sprayer cum weeder

Pressure = 1 to 3 bar (14.5-43.5 psi)
Area covered by each nozzle approximate 1.5

Field performance of mono wheel operated sprayer cum weeder

The developed wheel operated sprayer was evaluated in BRSM CAET &RS Mungeli Farm, chickpea crop in the line sown of variety vaibhav-JG-30 month of November during crop season 2017-18 , row to row spacing of 30 cm and plant to plant spacing randomly. The soil in the experiment site was clay soil, area of 100 m^2 and.

The field tests were conducted at 15 days of crop age with height of plants ranging from 5-10 cm. The different performances of sprayer test like speed of travel, field capacity, power requirement and performance index was calculated.

Performance test

The following observations were taken during the field test.

Speed of operation

Speed of operation of wheel operated sprayer cum weeder was measured the time required to cover 8m distance. By recording speed was calculated by using following formula. (RNAM procedure)

$$\text{Speed (kmph)} = \frac{3.6 \times \text{Distance traveled (m)}}{\text{time(s)}} \text{... (2)}$$

Power requirement

Calculation of power is needed to determine the efficient use of man power. A man can produce power equal to 0.05 to 0.1 hp operated for day long work. It was the power requirement to the implement by the man with average pushing force and speed. It was

calculated by using the following formula (Michael and Ojha, 1966).

$$\text{Power (hp)} = \frac{\text{draft(kg)} \times \text{speed} \frac{m}{s}}{75} \dots\dots (3)$$

Theoretical field capacity

Theoretical field capacity (Dubey, 2001)

$$(\text{ha h}^{-1}) = \frac{S \times W}{10} \quad \dots (4)$$

Where,
S = Speed of operation, kmph
W = Theoretical width covered and is equal to number of furrow openers multiplied by distance between two consecutive furrow openers

Effective field capacity

Effective field capacity (Dubey, 2001)

$$(\text{ha h}^{-1}) = \frac{A}{T_1 - T_2} \quad \dots (5)$$

Where,
A = actual area covered, ha
T_1 = Total time require for operation, h
T_2 = non-productive time, h

Field efficiency

It was calculated by using the following formula. (Dubey, 2001)

Field efficiency
$$= \frac{\text{Effective field capacity}}{\text{theoretical field capacity}} \times 100 \quad \dots (6)$$

Nozzle discharge rate

Nozzle discharge test was done to evaluate the amount of liquid discharge from each nozzle and to check the variation between the discharge rates of each nozzle within 5 m intervals in each 5 m interval the time taken and discharge data was collected and recorded for each nozzle by tying a plastic bag on each

nozzle. After each 5 m interval the sprayer were stopped,

Spray overlap

The overlap is defined as the width covered by two adjacent nozzles divided by the width covered by a single nozzle, expressed in present. It mainly affects spray pattern of the sprayer it depends on the boom height and nozzle spacing below fig. Shown some parameter were taken during testing,
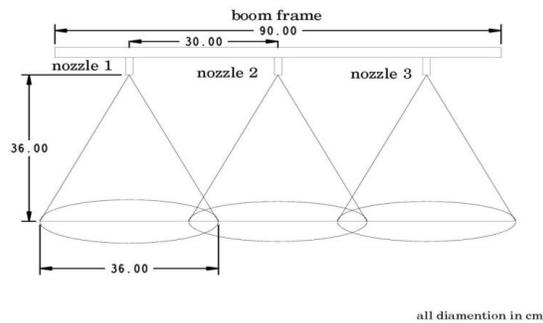
Fig.17 Sprayer overlap

Results and Discussion

The wheel operated sprayer is easy to operate due to cycle wheel as its ground wheel and The developed wheel operated sprayer used for line sown upland crops and vegetable crops, as row spacing can be adjusted. As far as physiological aspect is concern it is light in weight *i.e.* 30 kg and its handle height and angle of operation can be adjusted as per operator requirement.

Discharge of sprayer

During the discharge rate test in 15m with 5m interval of individual nozzle, the average nozzles discharge varies from 8.83 to 8.45 ml s^{-1}, 11.63 to11.38 ml s^{-1} and 12.43 to 12.15ml s^{-1}, with the average discharge of 8.63 ml s^{-1}, 11.54 ml s^{-1} and 12.33 ml s^{-1}at the 1st, 2nd and 3rd 5m intervals respectively at a bar pressure of 1.8 bars. The coefficient of variation for the average of nozzle discharges was 0.01089 per

cent, in 1st 5m, 2nd 5m and 3rd 5m respectively, which showed that the variation in discharges of the nozzle was below acceptable variation of 10per cent as per the recommendation (Gomez and Gomez, 1984).

Table.A Particular

S.No	Particular	
1	Name of implement	wheel operated sprayer
2	Type of sprayer	Manually operated wheel operated
3	Manufacturing's Address	BRSM CAET &RS Mungeli, CG.
4	Crop for Which suitable.	Chickpea, mustard, wheat, safflower.
5	Overall dimension in mm. Length: Width: Height:	 1677 900 1394
6	Weight in kg.	30kg
7	Dimension of sprayer tank in, mm: Length: Width: Height:	 182 369 431
8	Weight of applicator with and without clean water of full tank Capacity without a Discharge line With water, kg. Without water, kg.	 19 3
9	Detail of handle Construction: Height of handle from ground level, cm Details of adjustment:	 Adjustment 0-66.8 to 0-96.8 Adjustment through nut and bolt
10	Details of shank/ tool holder, cm Material: Dimension: Section- Length- Mounting details:	 Mild steel Rectangle 15 Angular hole, nut and bolt
11	Tank capacity: l	16
12	Dimension of pump plunger, piston, or diaphragm, cm	30*4
13	Diameter of cylinder, mm	40
14	Length of stroke, mm	58
15	Mesh of strainer on pump inlet	1
16	Type of nozzle as standard accessory	Fan type
17	Ground clearance	36.4(ground surface to main frame)
18	Details of transporting system	Mono wheel as well as ground wheel
19	Safety aspects	No required

Table.1 Discharge rate of individual nozzle in the 1st 5m

No of trail	Discharge, ml s^{-1}			Mean discharge in ml s^{-1}	CV,
	Nozzle no				%
	N1	N2	N3		
1	8.45	8.63	8.83	8.63	
2	11.38	11.63	11.61	11.54	
3	12.15	12.41	12.43	12.33	
Average	10.66	10.89	10.95	10.83	0.01089

N1, N2, N3 are three flat fan nozzles fitted on the boom at 30cm spacing

Table.2 Spray overlaps between nozzles

DAS point	Overlap in cm		Mean average Overlap	CV
	N1-N2	N2-N3		per cent
At 5 m	10.3	10.5	10.4	
At 10m	10.4	10.2	10.3	
At 15m	10.6	10.4	10.5	
Average Overlap	10.43	10.36	10.4	
Average Overlap per cent	15.8	15.6	15.7	0.02

N1- N2 and N2-N3 are the adjacent three flat fan nozzles fitted on the boom at 30 cm spacing

Table.3 Discharge rate of individual nozzle in the field test

Rep.	Discharge, ml s^{-1}			Mean discharge in ml s-1	CV per cent
	Nozzle no				
	N1	N2	N3		
1	10.75	10.45	10.35	10.51	
2	10.65	10.15	10.85	10.55	
3	10.15	10.75	10.85	10.58	
average	10.51	10.45	10.68	10.55	0.08

N1, N2 andN3 are three flat fan nozzles fitted on the boom at 30 cm spacing

Table.4 Speed of travel of mono wheel sprayer cum weeder

Sr. No	Distance covered (m)	Time (min.)	Speed (m/min.)	Average speed (m/min.)
1	10	0.36	27.8	28.2
2	10	0.50	33.4	
3	10	0.43	23.3	

Table.5 Field capacity of wheel operated sprayer

S.No.	Area, m^2	Time, min.	Actual field capacity, ha/h	Theoretical field capacity, ha/h	Field efficiency, %
1	100	8	0.075	0.126	59.52
2	100	8.5	0.070	0.126	55.56
3	100	9	0.067	0.126	53.17

Spray overlap

During the spray overlap test in the average per cent overlap between the nozzles varies from 15.6 per cent to 15.7 at boom height of 30cm and nozzle spacing of 30 cm. which showed that the variation in overlap of the nozzle was within the range of 15 − 50 per cent. The coefficient of variation (CV per cent) of percentage overlap between the nozzles were 0.02per cent which shows very small variability of overlap between consecutive adjacent nozzles. These mean that the uniformity and coverage of the spray was good.

Discharge rate of sprayer in field

The field size, test duration, spray pressure, swath, discharge, speed of operation, field capacity and other relevant information were taken. The average discharge rate varies from 10.51to10.68ml s^{-1} with the average discharge of 10.55ml s^{-1} it was observed that at an operating pressure of 1.8 bars at the forward speed of 1.4 km h^{-1}.

Speed of travel of wheel operated sprayer

The test was conducted by selecting a distance of 10 m and time for travel this distance was noted. Readings of travel speed were recorded and average speed of travel was calculated and presented in Table 4:

Field capacity of wheel operated sprayer

The average travelling speed was found to be 28.2 m/min. The field capacity was measured by selecting plots of size 10x 10 m and observations were recorded while operating the sprayer in these plots (Table 5).

Conclusion

Based on result above the sprayer has managed to maintain an average nozzle pressure of 1.8 bars during both the field and laboratory test at an average speed of 1.4km/hr. The average nozzles discharge rate variation along travel distance reduced and attained an optimum discharge rate the nozzles 30 m distance.

The prayer is manufactured with tank capacity of 16 litters, a full tank can cover an area of 0.075 ha, which needs a refilling of 14 times to cover one hectare with an application rate of 638.09 l/ha, an average discharge rate 10.55ml/sec. effective field capacity of 0.075

ha/hr., it also has a good uniformity of coverage with an average percentage overlap of 15.7%.

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.

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