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Performance evaluation of aero blast sprayer with developed spray lance

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Abstract
Field evaluation of an aero blast sprayer was carried out to determine the distribution pattern of the sprayer based on droplet density and volume of spray deposition using droplet analyser on mango orchard. Preliminary evaluation was conducted at 1500, 1750 and 2000 blower rpm and distance was set at three different levels of distance at minimum (5 m), middle (7 m) and maximum (9 m). It was found that with increasing in blower speed and distance, air velocity and discharge rate decreased. Based upon preliminary evaluation results, the sprayer was evaluated in orchard of mango of 3 kg/cm^2 pressure. The maximum swath width was found to be 5.0 m to 9.9 m. The sprayer was operated at blower speed of 2000 rpm and an distance of 5 m, the maximum air velocity, Discharge (Top, Middle, Bottom) was found to be 7.1 m/s, 774 ml/min (189 ml/min, 358 ml/min, 227 ml/min) for mango orchard, respectively. The volume median diameter (VMD) and number median diameter (NMD) was found to be 136.32 to 234.97 µm, 143.98 to 313.61 µm, 210.87 to 262.11 µm and 31.35 to 45.98, 35.20 to 52.91 and 58.52 to 37.61 for mango tree at 1.5, 2.0 and 2.5 kmph, respectively. The saving of labour and cost of spraying was found to be 50% and 200.84 Rs/h, respectively as compared to tractor operated aero blast sprayer.

Keywords: Air assisted, discharge rate, air velocity, pressure, VMD, NMD, aero blast sprayer

Introduction

Due to high cost of pesticides and herbicides and also machines have non uniform spraying including drifting lead to wastage of liquid. Hence, this caused for incorporating required necessary changes in the existing machines for better spraying. Uniform distribution and deposition of chemical from top to bottom of plant canopy and on the undersides of leaves is of utmost importance for effective pest control. Incorporation of air assistance in spraying system improves the deposition uniformly in the entire tree canopy. Spray deposition on the lower portion of plant leaves, where most of pest's harbor also improves in the air assisted spray application.

With the increasing demand for fruits in the processing industry and consumption in the state, more production is needed. Insects and diseases can hinder the productivity of fruit trees. Therefore, effective spraying is necessary. Currently, most farmers are using self-propelled sprayers and knapsack sprayers in the garden. These sprayers increase the labour requirement, include human difficulties, and have low field capacity, and effective spraying also depends on the skill and spraying method.

To overcome the human factor in spraying and increase field capacity, Aero blast sprayer sprayer may be the best option. The tractor operated aero blast sprayer was found to produce smallest droplet size (254 µ) with better penetration of spray droplets into the canopy, highest field capacity (1.54 ha/h) with lowest man-power requirement (1.95 man-h/ha) (Saha *et al*., 2004) [1]. An air carrier sprayer equipped with an axial flow blower-RK was tested at three levels of pressure (5, 10, 15 bar) and three levels of travel speed (2, 3 and 4 kmph) to determine its distribution pattern for effective spraying in the orange orchard. They reported that for effective spraying tractor travel speed of 2 kmph and system pressure of 15 bars (Tekale *et al*., 2007) [2].

A tractor mounted air-assisted sprayer was developed and evaluated in a field of cotton at three different forward speeds (0.5, 2.5 and 4.0 km/h). At a forward speed of 4.0 km/h, better uniformity coefficient (1.69) and the area covered by droplets on the underside of top, middle and bottom leaves were 1.11, 0.93 and 0.44 % was obtained for the air assisted sprayer (Singh *et al*., 2010) [3]. Sufficient velocity and pressure are needed to cause movement of leaves for under leaf deposition and allow droplets to penetrate in the inner part of the canopy

(Bode *et al.*, 2007; Salyani *et al.*, 2013; Jadav *et al.*, 2019) [4, 5, 6]. Therefore, in this study an air assisted sprayer was selected to evaluate its performance in the field.

Area covered by different types of orchards

Area covered by some of the orchards like almond, apple, guava and mango in different state were given below.

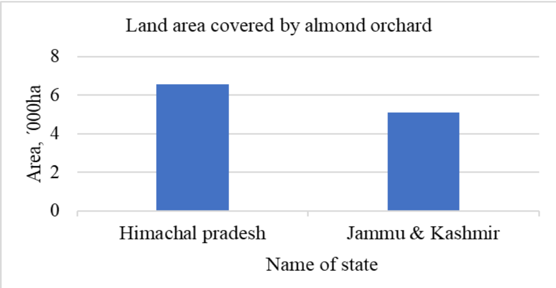

Fig 1.1: Area covered by almond orchard

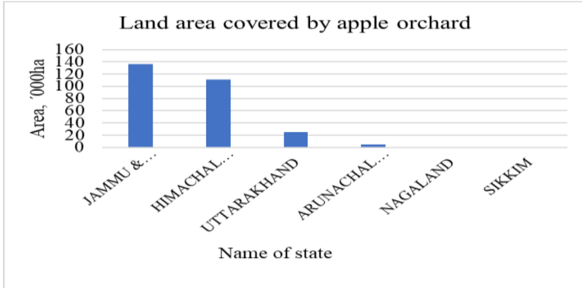

Fig 1.2: Area covered by apple orchard

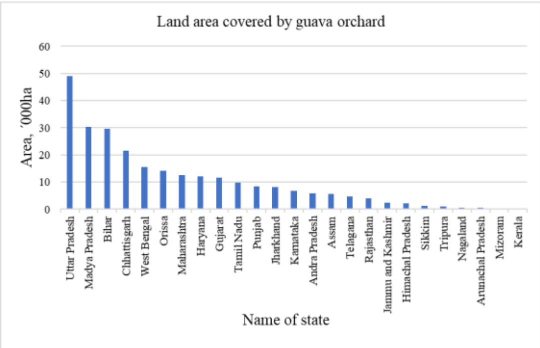

Fig 1.3: Area covered by guava orchard

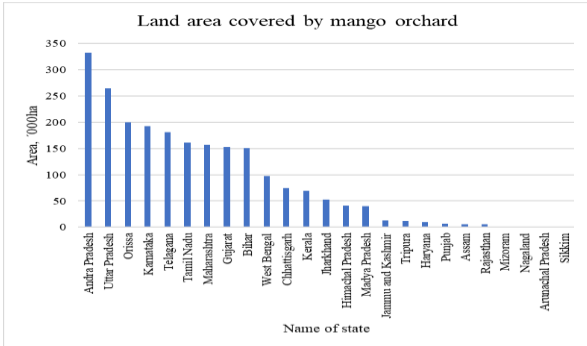

Fig 1.4: Area covered by mango orchard

Material and Methods

On the basis of the function requirement a Aero blast sprayer with developed spray lance was developed to spraying in the orchard. Aero blast sprayer with developed spray lance consisted Frame, Flexible pipe, DC motors, pedestal, worm gears. The power source for developed spray lance was battery.

In working principal, aero blast sprayer PTO power transmitted to the gearbox of the sprayer and then it transferred to a blower. Blower operation produces high velocity air which transferred to the lance of a sprayer. Power was taken from PTO through belt to rotate diaphragm pump for sucking pesticide/herbicide from chemical tank and pass to nozzle of the lance which is connected by a delivery pipe. DC motors were attached to the lance with the spur gear which rotates lance horizontally and vertically as per uses. The delivery lance system aero blast sprayer mounted on the lance frame (Fig 1.5). Lance frame was supported on a thrust bearing mounted on the main frame of the sprayer.

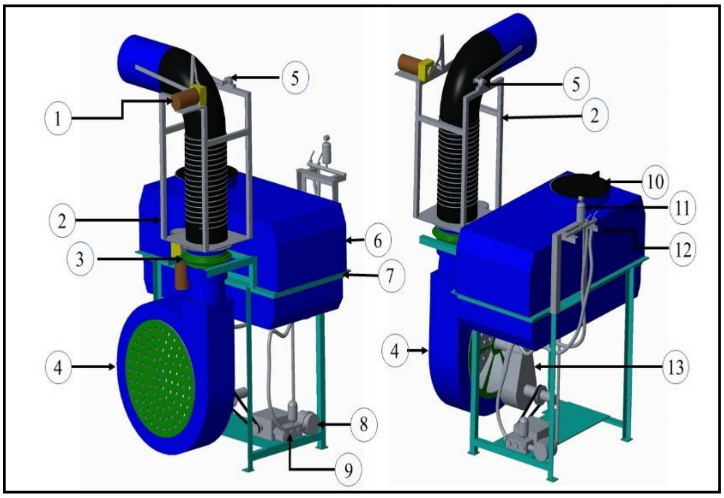

Fig 1.5: Aero blast sprayer with developed spray lance

Table 1.1 Name of parts in aero blast sprayer with developed spray lance

Sr. No.	Parts name
1	DC motor
2	Lance frame
3	Thrust bearing
4	Blower
5	Pedestal
6	Chemical tank
7	Main frame
8	Filter
9	Diaphragm pump
10	Filler hole
11	Pressure vessel
12	Control panel
13	Gear box

Machine parameters

Machine parameters such as effective working width, speed of operation, blower speed, pressure, VMD and NMD were measured/calculated as follows:

Swath width

The working width covered by the sprayer during operation.

Forward speed (m/s)

Forward speed of tractor was determined by ratio of 100 m plot length and time required to cover field.

$$\text{Speed (km/h)} = \frac{Distance\ (m)}{Time\ required\ to\ cover\ the\ distance\ (s)} \times 3.6$$

Blower speed
Blower speed can be quickly determined using an electronic tachometer. The tachometer was pointed at the rotating blades and within a few seconds, a reading of "blades per minute" is given.

Fig 1.6: Tachometer

Spraying capacity
Test stand for spray deposition and air trajectories experimented in the laboratory.

Droplet size
A digital scale droplet analyser was used to determine droplet size and droplet density.

Fig 1.7: Digital scale droplet analyser to analyse droplet size

Anemometer
A digital vane-type anemometer (LT Lutron AM-4201) was used to measure the velocity of air coming out from the blower. Anemometer has liquid crystal display (LCD). It has capacity to measure up to 25 m/s air velocity.

Fig 1.8: Anemometer

Droplet size (VMD)
The Volume Median Diameter (VMD) refers to the midpoint droplet size (median), where half of the volume of spray was in smaller droplets, and half of the volume was in larger droplets than the median.

Number median diameter (NMD)
The Number Median Diameter (NMD) was the droplet diameter where the number of droplets above the NMD was equal to the number of droplets below the NMD. The NMD was usually smaller than the VMD because most pesticide sprays usually contain a large number of very small droplets.

Results and Discussion
The result of aero blast sprayer with developed spray lance was obtain during field tests. The results obtained have been analysed and discussed under the following headings:

- Air velocity (m/s)
- VMD (µm)
- NMD (µm)
- UC
- Discharge (ml/min)

Air velocity
The air velocity was measured at 5 m, 7 m and 9 m from the air outlet of the blower. The average air velocities (Table 1.2) were obtained at blower speed of 1500, 1700 and 2000, respectively. These air velocities were selected to study their effect on spray angle, spray width and spray height for types of nozzles under laboratory conditions.

Table 1.2: Air velocity from aero blast sprayer for various targeted distances at different blower speeds

Sr. No.	Blower speed (rpm)	Air velocity (m/s) Distance (m)		
		5 m	7 m	9 m
1	1500	5.4	4.1	2.6
2	1750	6.8	5.3	4.2
3	2000	7.1	6.19	5.11

In fig 1.9 showed that when blower speed was increased then air velocity was increased. When distance was increased then air velocity was decreased. It was affected by spraying capacity of sprayer.

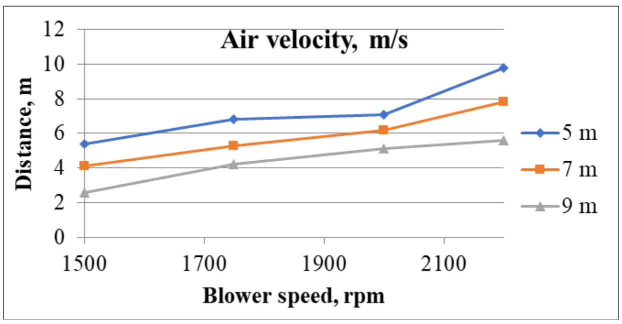

Fig 1.9: Mean air velocity from aero blast sprayer at various target distance

Spray droplet spectrum on leaves in case of the hollow cone nozzle
Effects of VMD, NMD and UC at forward speed 1.5 km/h

VMD, NMD and UC were calculated from obtain values by droplet analyzer. Obtain values were analyzed and shown in Table 1.3.

Table 1.3: Effects of VMD, NMD and UC for leaves on the sprayer under field conditions at forward speed 1.5 km/h

Portion of tree	Parameter	
Top	VMD (µm)	234.97
	NMD (µm)	45.98
	UC	5.17
Middle	VMD (µm)	231.37
	NMD (µm)	40.81
	UC	5.60
Bottom	VMD (µm)	136.32
	NMD (µm)	31.35
	UC	4.29

Effects of VMD, NMD and UC for leaves on the sprayer under field conditions at forward speed 1.5 km/h and 2000 rpm blower speed. The volumetric mean diameter on top, middle and bottom side of leaves varied from 136.32 to 234.97. The numerical mean diameter on top, middle and bottom side of leaves varied from 31.35 to 45.98. The uniformity coefficient on top, middle and bottom side of leaves varied from 4.29 to 5.60. The value of uniformity coefficient was found to be nearer to unity which indicated more uniformity of spraying.

Effects of VMD, NMD and UC at forward speed 2.0 km/h
VMD, NMD and UC were calculated from output value of droplet analyzer. Obtain values were analyzed and shown in Table 1.4. Effects of VMD, NMD and UC for leaves on the sprayer under field conditions at forward speed 2.0 km/h and 2000 rpm blower speed. The volumetric mean diameter on top, middle and bottom side of leaves varied from 143.98 to 313.61. The numerical mean diameter on top, middle and bottom side of leaves varied from 35.20 to 52.91. The uniformity coefficient on top, middle and bottom side of leaves varied from 3.94 to 6.77. The value of uniformity coefficient was found to be nearer to unity which indicated more uniformity of spraying.

Table 1.4: Effects of VMD, NMD and UC for leaves on the sprayer under field conditions at forward speed 2.0 km/h

Portion of tree	Parameter	
Top	VMD (µm)	313.61
	NMD (µm)	52.91
	UC	6.77
Middle	VMD (µm)	189.50
	NMD (µm)	40.98
	UC	4.63
Bottom	VMD (µm)	143.98
	NMD (µm)	35.20
	UC	3.94

Effects of VMD, NMD and UC at forward speed 2.5 km/h
VMD, NMD and UC were calculated from gain output of droplet analyzer. Obtain values were analyzed and shown in Table 1.5.

Table 1.5: Effects of VMD, NMD and UC for leaves at forward speed 2.5 km/h

Portion of tree	Parameter	
Top	VMD (µm)	262.11
	NMD (µm)	37.61
	UC	7.30
Middle	VMD (µm)	230.33
	NMD (µm)	53.83
	UC	4.86
Bottom	VMD (µm)	210.87
	NMD (µm)	58.52
	UC	3.71

Effects of VMD, NMD and UC for leaves on the sprayer under field conditions at forward speed 2.5 km/h and 2000 rpm blower speed. The volumetric mean diameter on top, middle and bottom side of leaves varied from 210.87 to 290.35. The numerical mean diameter on top, middle and bottom side of leaves varied from 37.61 to 58.52. The uniformity coefficient on top, middle and bottom side of leaves varied from 3.71 to 7.30. The value of uniformity coefficient was found to be nearer to unity which indicated more uniformity of spraying.

Discharge at various portions of tree at different distances
The discharge of droplet was taken at top, middle and bottom position of the tree. The discharge at top, middle and bottom of tree was decreased with increase in distance. Total discharge of sprayer was 774 ml/min, 344 ml/min and 231.5 ml/min at 5 m, 7 m and 9 m distance, respectively from tree as shown in Table 1.6.

Table 1.6: Discharge at Top, Middle, Bottom of tree at different distances

Sr. No.	Portion of tree	Discharge (ml/min)		
		5 m	7 m	9 m
1	Top	189	43	36
2	Middle	358	184	128
3	Bottom	227	117	67.5
Total		774	344	231.5

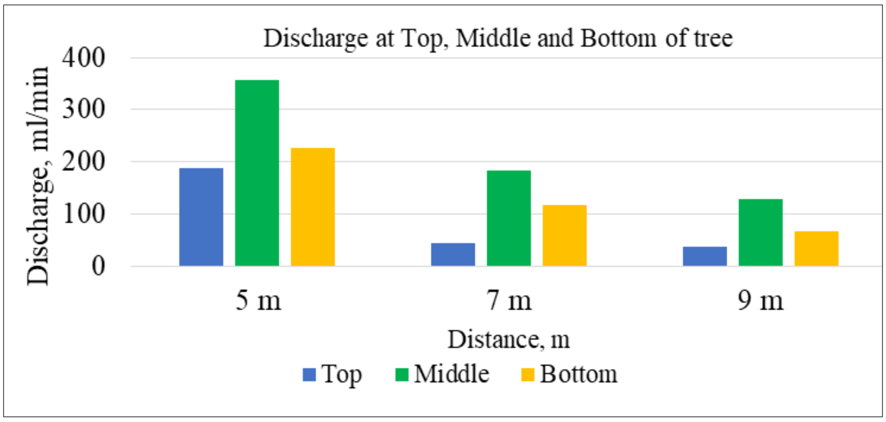

Fig 2: Discharge at top, middle and bottom of tree at different distances

In Fig. 2 showed the discharge at top, middle, bottom of tree at 5 m, 7 m and 9 m distance. Highest discharge of sprayer was at middle portion of tree and it was 358 ml/min, 184 ml/min and 128 ml/min at 5 m, 7 m and 9 m distances, respectively. Lowest discharge of sprayer was at top portion of tree and it was 189 ml/min, 43 ml/min and 36 ml/min at 5 m, 7 m and 9 m distances, respectively.

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