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Performance Evaluation of Tractor Mounted Axial Flow Mist Blower Sprayer

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The performance evaluation between existing blower B, C and developed blower A was conducted at Pimpalgaon (Basawant) Dist - Nasik. blower A gave more velocity, discharge at 2260 rpm. Blower efficiency was maximum at 2260 rpm. Corresponding values were 31.62 m/sec, 1.79 m^3/sec and efficiency 22.75 per cent respectively, whereas power required to run the blower was 7.32 kW for which 18 hp tractor can be used to operate it in the field. This blower is suitable for spraying grape and pomegranate crop. The maximum blower efficiency was observed in developed blower 'A' compared to blower 'B' 22.58 per cent and 'C' 17.65 per cent. Laboratory studies revealed that the blower 'A' having low efficiency 22.75% leading to develop the blower with more efficiency. Field performance studies of developed blower 'A' indicated that proper spray deposition and penetration could be obtained at travel speed of 3 kmph and system pressure of 15 bars. The laboratory studies revealed that blower of type A is suitable for grape vineyards and pomegranate orchard. Blower A should be operated at rotational speed of 2260 rpm at system pressure of 15 N/m^2 with tractor forward speed of 3kmph for both crops.

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Keywords: Axial flow; tractor mounted mist blower sprayer; impeller; input power; blower efficiency.

1. INTRODUCTION

"Spraying is one of the most important in plant and crop protection from the point of view of pests and diseases control. There are mainly two methods conventional method of spraying and air carrier spraying" [1]. "The conventional methods of spraying in orchard and tree crop involve low initial cost but having serious drawbacks as large volume of water required per tree, great amount of time and labour is required, more than 50% of the spray fluid is lost by drips, environmental hazards occur due to high application rate, spray cannot penetrate through foliage and backside of the leaves, which generally harbors most of the pest remains unsprayed. The projected growth in the world's population to nine billion by 2050 adds an extra challenge for food security" [1]. "India ranks second in terms of fruit production in the world after China. During 2011-12, India produced 76.42 million tonnes of fruits from an area under cultivation of 6.70 million hectares" [2]. "Punjab is primarily an agrarian state and contributes a major part to country's GDP. A total of 0.71 lakh hectares area was under fruits during the year 2011-12 of which kinnow, orange, malta, citrus, guava, Indian gooseberry, pear, mango, and grapes were the main fruits grown in Punjab. Punjab is third largest state in terms of production of kinnow as it accounts for 12.1% of the total production in the country with a total production under these fruits being 14.20 lakh tonnes for the year" [3]. "With the growing demand for fruits in the processing industry and per capita consumption in the state more production is required. The pest and diseases can be a hindrance to the productivity of the fruit trees. Hence effective spraying is necessary. Most farmers use foot operated sprayer and knapsack sprayers in the orchard. Labour requirement of these sprayers is large and involve human drudgery and has low field capacity and the effective spraying also depends upon the skill and method of spraying" [4]. "To overcome the human factor in spraying and increase field capacity, air assisted orchard sprayer may be the best option. Three different spraying systems namely, tractor operated aero blast sprayer, power knapsack sprayer, and manually operated rocker sprayer were evaluated in a mango orchard. The tractor operated aero blast sprayer was found to produce the 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)" [5].

"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" [6]. "An aero blast sprayer was tested at research farm of UAS Raichur and AAI Allahabad and found that the sprayer had field capacity 1.32 to 2.17 ha/h but found that it had high drift" [7]. "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" [8]. "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" [9,10].

Air carrier sprayers are ideal for spraying in grape and pomegranate orchards because they offer good coverage while using very little water, time, and effort. It employs the blower PTO deliver an air blast of sufficient discharge and velocity. Spray fluid is introduced into this air blast in the form of fine droplets. In air carrier system, centrifugal and axial flow blowers are used. Centrifugal blowers are suitable for small height plants while axial blower is suitable for large height plants. The project was undertaken at ASPEE Research Institute, Mumbai. Therefore, in this study, an air assisted sprayer was selected to evaluate its performance in the field.

2. MATERIALS AND METHODS

An air-assisted sprayer is of trail type, attached with a tractor drawbar and operated by tractor power take-off (PTO) as shown in Plate2. The sprayer consists of a tank of 200 liter capacity, 10 nozzles, Diaphragm pump, direction control lever, pressure relief valve, and a blower. There is double head cum drip cum nozzle of diameter 1.2 mm on each side of the blower. There is a provision to operate either or both sides of the sprayer nozzles with the direction control lever. A pressure relief valve is provided to operate the sprayer at desired pressure according to the field conditions and blower helps to atomize the particles. The air assisted sprayer employs a blower to produce air stream of sufficient discharge and velocity to carry the spray droplets at the outlet. Specifications of the sprayer are given in (Table 1). "Field-testing was carried out to determine the distribution pattern of the sprayer based on droplet density and volume of spray deposition on grape and pomegranate orchard at determined speed of operation. Before operating the sprayer in the orchard, it was conducted at Pimpalgaon (Basawant) Dist-Nasik. The sprayer was operated at 2030, 2094, 2130, 2160, 2230, 2260, 2350, 2330, 2360, 2450, 2460 and 2490 engine rpm, at three different levels of pressures i.e. minimum, middle and maximum for each nozzle type and corresponding parameters were recorded. Based upon the evaluation of the sprayer at different engine rpm and pressure, it is was evaluated on the basis of swath width and maximum spray height of the fruit tree in the orchard. The field evaluation was carried out at Pimpalgaon (Basawant) Dist- Nasik. The spacing for grape and pomegranate was (1.5x 3) m and (4.0 x 4.0) m. Experiment was conducted for an area of 0.4 ha and 1 ha for grape and pomegranate respectively with an engine rpm of 2260 and pressure of 15 N/m^{2}" [3].

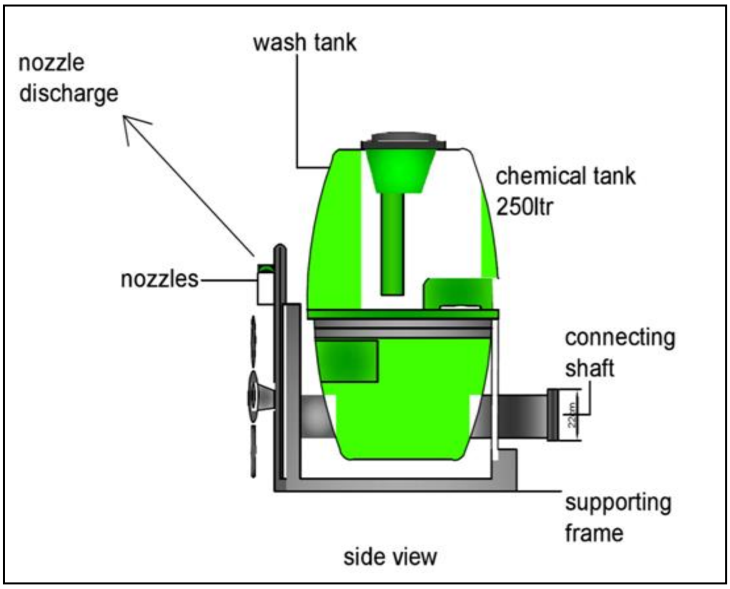

Plate 1. Components of air assisted sprayer

Plate 2. A view of developed axial flower blower

“Three replications were taken in the field for each orchard at different level pressure and at different rpm. Parameters like swath width, height of spray, discharge, speed, and fuel consumption were recorded for a particular orchard. VMD, NMD, uniformity coefficient, droplet density was also calculated. For spray deposition, three rows were randomly selected in the orchard and water sensitive paper strips of size (7.5 x 2.5) cm were placed on the selected trees and divided into three portions viz. top, middle, and lower canopy. The number of droplets were noted under each classified range of intervals of 50 microns up to 500 microns. Using the number of droplets and diameter of the droplet in the particular size range graphs was plotted between actual diameter and cumulative percentage of volume” (Singh et al., 2010). “The droplet size at which cumulative percentage of volume contributed reached 50 percent was taken as the Volume Median Diameter (VMD) of the sprayed particles. From the graph of cumulative percentage number of droplets and actual droplet size, the droplet size at which cumulative percentage number of droplets reached 50 percent was taken as the Number Median Diameter (NMD) of the sprayed particles. Uniformity coefficient (UC) was calculated by dividing VMD by NMD. Droplet density was obtained by dividing no. of droplets per unit square cm” [7].

Constructional details of tractor mounted axial flow mist blower: The performance of tractor mounted air carrier sprayer was evaluated in the grape and pomegranate field.

The sprayer consists of following components:

1. Axial blower
2. Frame for mounting blower
3. Distributor
4. Nozzles
5. Pesticide tank
6. Strainers
7. Power transmission units
8. Hydraulic pump

The detailed specifications of existing air assisted sprayer and developed air assistate axial flow mist blower is given in Table 1. Its overall view is shown in Plate no.1. The detailed components of air assisted sprayer are given in Plate 2 and specification of a developed air assisted orchard sprayer are given in Table 2.

Table 1. Specification of a developed air assisted orchard sprayer

Particulars	Description
Tank capacity, l	1000
Power source	Tractor PTO
No. of nozzles	10
Types of nozzles	Double head cum drip cum nozzle of diameter 1.2 mm
Pump type	Diaphragm

Table 2. Comparison of existing and developed axial flow mist blower A, B & C

Sr. No.	Specification axial flow mist blower	A (Developed)	B (Existing)	C (Existing)
1	Blade profile	Axial	Axial	Axial
2	Number of blades	9	9	9
3	Diameter of tip, mm	600	590	600
4	Hub diameter, mm	280	240	310
5	Boss ratio	0.47	0.40	0.47
6	Chord length, mm	174.4	100	110
7	Material of blade	Nylon	Nylon	Nylon
8	Material of hub	Aluminum	Aluminum	Aluminum
9	Casing diameter, mm	700	660	660
10	Spacing between two blades at hub (mm)	30	40	55
11	Spacing between two blades at tip(mm)	210	192.5	200
12	Total weight of impeller, kg	6.20	5.27	5.70
13	Gear box ratio	1.5	1:4.5	1:4.5

Plate 3. Field evaluation of axial flow blower with air assisted orchard sprayer (Pomegranate orchard)

Plate 4. Field evaluation of axial flow blower with air assisted orchard sprayer (Grape vineyard)

3. RESULTS AND DISCUSSION

Field performance of sprayer: Field trials were carried out for the evaluation of volume deposition and droplet distribution for tractor mounted air assisted spraying system. Split plot design with nine treatments each with three replications were made to conduct the field trails. Performance of developed blower at different speed of operation (RPM) as in Table. 3.

The field evaluation was carried out for the grape and pomegranate orchard. During the evaluation, the average temperature was 22.5 C and wind velocity of 1.0 km/h. The average height of grape and pomegranate orchard was recorded between 2.3-2.5 m. The canopy of the tree was around 7.0 meter and the branches were hanging, so nozzles along the periphery blower of both sides were opened. Based upon preliminary evaluation of the sprayer, it was operated at an engine rpm of 2260 and pressure of 15 N/m^2 so that spray may reach the maximum height of grape and pomegranate orchard 2.5 m. The forward speed of tractor was 3 km/h.

The performance comparison of blowers A, B, and C was done on the basis of power requirement, air discharge, air velocity and efficiency.

The blower B gave more velocity, discharge of air and efficiency at 2490 rpm. Corresponding values were 33.54 m/sec, 1.71m^3/s and efficiency 22.58 per cent respectively. Whereas the power required to run the blower is 15.65 kW this required above 30 hp Tractor to operate in the field. This blower was designed for Spot crop by the manufacturer.

The blower C gave more velocity, discharge of air and efficiency at 2450 rpm. Corresponding values were 31.63 m/sec, 1.70 and efficiency 17.65 per cent respectively. This blower was suitable for tractors above 35 hp. This blower was recommended by the manufacturer for orchard crop.

The blower A gave more velocity, discharge at 2260 rpm. Blower efficiency was maximum at 2260 rpm. Corresponding values were 31.62 m/sec, 1.79 m^3/sec and efficiency 22.75 per cent respectively whereas power required to run the blower was 7.32 kW for which 18 hp tractor can be used to operate it in the field. This blower is suitable for spraying grape and pomegranate crop, where a limitation of size is governing factor.

The relationship between the speed of rotation and efficiency of blower is shown in Fig. 1. Data showed that maximum blower efficiency was found at 2260 rpm i.e. 22.75 per cent after this the efficiency decreased.

Table 3. Performance of developed blower at different speed of operation (RPM)

Sr. No.	Performance parameters	Speed of operation (RPM)			
B					
		2130	**2230**	**2360**	**2490**
1	Mean air velocity, m/s	28.51	30.03	32.16	33.54
2	Air discharge m^3/s	1.46	1.53	1.64	1.71
3	Total pressure N/m^2	666.25	734.98	853.18	915.65
4	Input power to motor kW	7.40	7.38	7.95	7.97
5	Blower efficiency per cent	15.10	17.52	20.22	22.58
6	Power coefficient	1.09	1.11	1.13	1.30
C					
		2030	**2160**	**2350**	**2450**
1	Mean air velocity, m/s	25.40	23.12	24.36	31.63
2	Air discharge m^3/s	1.34	1.52	1.60	1.70
3	Total pressure N/m^2	616.97	717.5	763.91	809.71
4	Input power to motor kW	7.53	8.33	8.41	8.63
5	Blower efficiency per cent	11.40	0.09	12.16	17.65
6	Power coefficient	1.14	1.17	0.91	0.92
A					
		2094	**2260**	**2380**	**2460**
1	Mean air velocity, m/s	25.82	31.62	30.87	27.18
2	Air discharge m^3/s	1.37	1.54	1.63	1.79
3	Total pressure N/m^2	615.97	713.5	759.92	804.71
4	Input power to motor kW	7.53	8.33	8.41	8.63
5	Blower efficiency per cent	13.40	22.75	19.12	17.65
6	Power coefficient	1.10	1.12	0.98	1.05
7	Input power to blower kW	6.29	7.32	7.67	7.88

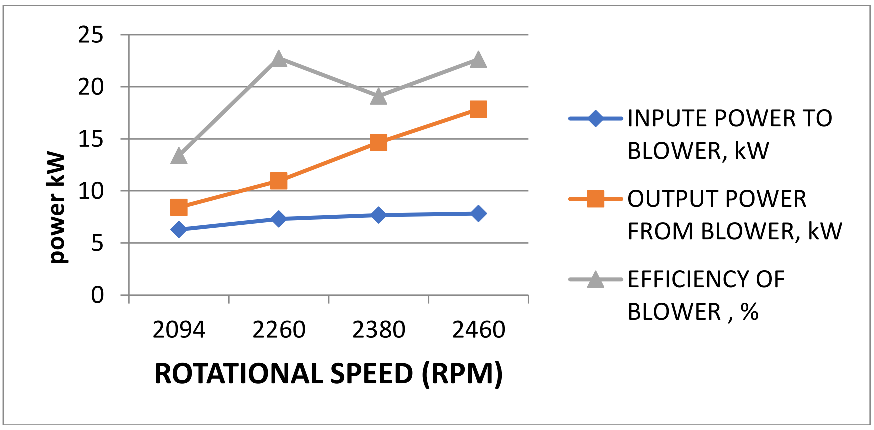

Fig. 1. Effect of rotational speed on power and efficiency for developed blower 'A'

This blower was operated in the field at 2260 rpm, where air velocity, air discharge and efficiency of the blower were found to be 31.62 m/s, 1.54 and 22.75 per cent respectively and input power was 7.32 kW. So at this speed developed blower A was operated by 18 hp tractor.

1. Droplet size and uniformity coefficient

The average volume median diameter (VMD) for grape crop was found to be 324 µm and average Number median diameter (NMD) 126 µm respectively. Average uniformity coefficient was fund to be 2.70. For average volume median diameter (VMD) for the pomegranate crop was found to be 325 µm and the average number median diameter (NMD) 120 µm respectively. Average uniformity coefficient was found to be 2.50 for pomegranate. It was observed that larger droplets.

2. Droplet density

The data indicated that as the pressure increased the number of droplets also increased as shown in Figs. 2 & 3. The droplet density was found to be more than 40 no/cm^2 at all system pressures for both grape and pomegranate crops as mentioned in Table 4. The volume of spray deposition was more on centre side than at left and right side of spraying. It is due to wind velocity disturbance while spraying.

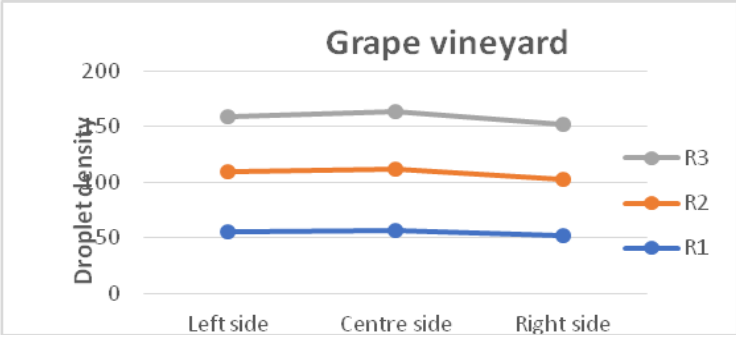

Fig. 2. Number of droplets per square centimeter for grape vineyard

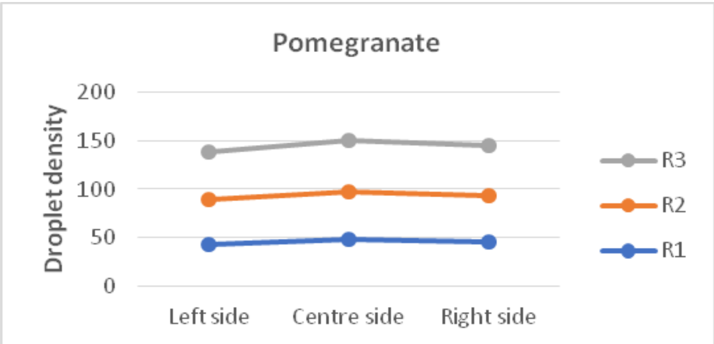

Fig. 3. Number of droplets per square centimeter for pomegranate

Table 4. Droplet density for Grape vineyard and pomegranate orchard (number of droplets per square centimeter)

Orchard	Replication	Position		
Grape vineyard		Left	Centre	Right
	R1	55	57	52
	R2	55	55	51
	R3	49	52	49
Pomegranate	R1	43	48	45
	R2	47	49	48
	R3	48	53	52

4. CONCLUSION

Laboratory performance of existing & developed axial flow mist blower: Three axial flow mist blowers namely 'B', 'C', and developed blower 'A' were tested separately. in the laboratory at different speeds, such as blower 'B' from 2130 rpm to 2490 rpm, blower 'C' from 2030 to 2450 rpm, developed blower 'A' from 2094 rpm to 2460 rpm respectively. From the data collected, the following conclusions are drawn:

1. It indicates that static pressure and dynamic pressure increase linearly with an increase in rotational speed.
2. The maximum blower efficiency was observed in developed blower 'A' 22.75 per cent as compared to blower 'B' 22.58 per cent and 'C' 17.65 per cent.
3. The blower 'B' 'C' and 'A' were operated best in the field at 2490 rpm,2450 rpm and 2260 rpm speed of impeller respectively, and needed 15.65 kW,17.81kW and10.98 kW power respectively.
4. The maximum air discharge was observed in blower 'A' (1.79 m^3/s) as compared to the discharge of blower 'B' (1.71 m^3/s) and blower 'C' (1.70 m^3/s).
5. The blower 'B', 'C', and 'A' needed tractors of size 30 hp, 35 hp and 18 hp respectively.
6. The maximum air velocity was observed in blower 'B' (33.54 m/s) as compared to blower 'C' (31.63 m/s) and blower 'A' (31.62 m/s).

Field performance of axial flow mist blower 'A': Axial flow mist blower A was tested in the grape and pomegranate crop to study the effect of travel speed and pressure on the performance of the blower. There were overall nine treatments which includes three system pressure P_1=10 bar, P_2 =15bar and P_3 =20 bar and three travel speed N_1=2 kmph. N_2=3 kmph. N_3=3.5 kmph. An experimental layout of split plot design was selected for experimentation. The results are given below:

1. The field test of blower indicates that the travel speeds have significant effect on the spray deposition on the left side of spraying.
2. The best results of spraying were obtained when sprayer was operated at travel speed of 3 kmph and system pressure of 15 bar for both crops.
3. The spray volume deposition was obtained more (464 ucc) on backside surface than front side (240 ucc) of leaf for grape crop and (388 ucc) on backside surface than front side (194 ucc) leaf of pomegranate orchard.
4. When system pressure increase from 10 bars to 20 bars. The volume of spray deposition increases whereas when travel speed increases from 2 kmph to 3.5 kmph the volume of spray deposition decreases.

Blower A should be operated at rotational speed of 2260 rpm at system pressure of 15 N/m^2 with tractor forward speed of 3 kmph for both crops.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Anonymous. Indian Horticulture Database 2013. NHB, New Delhi. Paper No. AA 91-005; 2013.
2. Anonymous. A study of marketing of mangoes in India; 2011-12a. Cited from http://www.oiirj.org/oiirj/nov2013-special-issue/28. pdf.
3. Anonymous. Report of the Joint Inspection Team for their visit to Punjab to review National Horticulture Mission Progress; 2011-12b. Cited from http://nhm.nic.in/JIT_Reports/JIT-Punjab-Oct-2012.pdf
4. Narang MK, Mishra A, Thakur SS, Dogra B, Chandel R. Performance evaluation of air assisted orchard sprayer. Agricultural Research Journal. 2015;52(4):87-91.
5. Saha K P, Varshney A C and Narang S. Performance evaluation of different spraying systems in mango orchard. Journal of Agricultural Engineering. 2004; 41(2):20-24.
6. Tekale DD, Kawade SC, Sawant BP. Performance evaluation of air carrier sprayer for orange orchard. Karnataka J Agric Sci. 2007;20(2):330-32.
7. Anonymous. Research highlights. All India Coordinated Research Project on Farm Implements and Machinery, CIAE Bhopal. 2008;51-52.
8. Singh S, Singh S, Dixit AK, Khurana R. Development and field evaluation of tractor-mounted air-assisted sprayer for cotton. AMA. 2010;41(3): 33-40.
9. Bode M, Heide M, Von Bergmann K, Ferriani P, Heinze S, Bihlmayer G,

Kubetzka A, Pietzsch O, Blügel S, Wiesendanger R. Chiral magnetic order at surfaces driven by inversion asymmetry. Nature. 2007 May 10;447 (7141):190-3.

10. Salyani M, Miller DR, Farooq M, Sweeb RD. Effects of sprayer operating parameters on airborne drift from kinnow air-carrier sprayers. Agric Eng Int, CIGR Journal. 2013;15:27-36.

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