Performance Evaluation of Tractor Mounted Axial Flow Mist Blower Sprayer

ABSTRACT

The performance evaluation of existingblowers B, C and developed blower A was conducted at Pimpalgaon (Basawant) Dist - Nasik.The blower Aresulted highervelocity, discharge and efficiency at 2260 rpm and the values were 31.62 m/sec, 1.79 m^3/sec and 22.75 per cent, respectively. The power required to run the blower was 7.32 kW for which 18 hp tractorcould be used to operate in the field. Blower A is suitable for spraying grape and pomegranate crops.The blowerefficiency observed in blowerBwas 22.58 per cent and that of blower C was 17.65 per cent.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 bar. The laboratory studies revealed that blower of type A is suitable for grape vineyard 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 the crops for better field performance.

(Keywords: Axial flow, tractor mounted mist blower sprayer, Impeller, Input power, blower efficiency**)**

INTRODUCTION

"Spraying is the one of the most important operations in plant and crop protection so as to control pests and diseases. There are mainly two methods viz.,conventional method of spraying and air carrier spraying are being adopted generally. The conventional methods of spraying in orchard and tree crop involvelow initial cost but having serious drawbacks as requirement of larger volume of water per treeand also consumption of more time and labour. In addition to that, loss of more than 50% of the spray fluid,which resulted into environmental hazards, difficulty in spray penetration through foliage and backside of the leaves, which generally harbors most of the pest remains unsprayed. The projected growth in world'spopulation is nine billion by 2050 adds an extra challenge for food security" (Anon., 2013). "Globally India ranks second in terms of fruit production after China.During 2011-12, India produced 76.42 million tonnes of fruits from acultivated area of 6.70 million ha"[Anon., 2011-12a]. Punjab is primarily an agrarian state and significantly contributesto country's GDP. A total of 0.71 lakh hectares area was under fruits during 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(14.20 lakhtonnes) and accounts for 12.1% of totalproduction in India (Anon., 2011-12b)."With the growing demand for fruits in processing industries andalso increased per capita consumption in Punjab, more production is required. The pest and diseases can be a hindrance to the productivity of fruit trees. Hence, effective spraying is necessary to reducethe effect of pests and diseases. Presently, most farmers are using foot operated sprayer and knapsack sprayers in orchards. Labour requirement of these sprayers is large and involve human drudgery and have lower field capacity and the effective spraying also depends upon skill and methodof spraying" [Narang et al.2015]."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 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).

"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 patternfor effective spraying in the orange orchard. The authors reported that, for effective spraying, tractor travel speed of 2 kmph and system pressure of 15 bars were found to be optimum" (Tekale et al., 2007)."An aero blast sprayer was tested at research farm of UAS Raichur and AAI Allahabad and found that the sprayer had field capacity of 1.32 to 2.17 ha/h but found to have higher drift"(Anon., 2008). "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) was observedand the area covered by droplets on the underside of top, middle and bottomleaves were 1.11, 0.93 and 0.44 % for the airassisted sprayer" (Singh *et al.*, 2010). "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).

Air carrier sprayer provides good coverage and consuming very less water time and labour, hence it is suitable for spraying in grape and pomegranate orchards. The sprayer which uses air as a carrier for spraying chemicals. It employs the blower PTOand 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 lesser height plants and axial blower is suitable for larger 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.

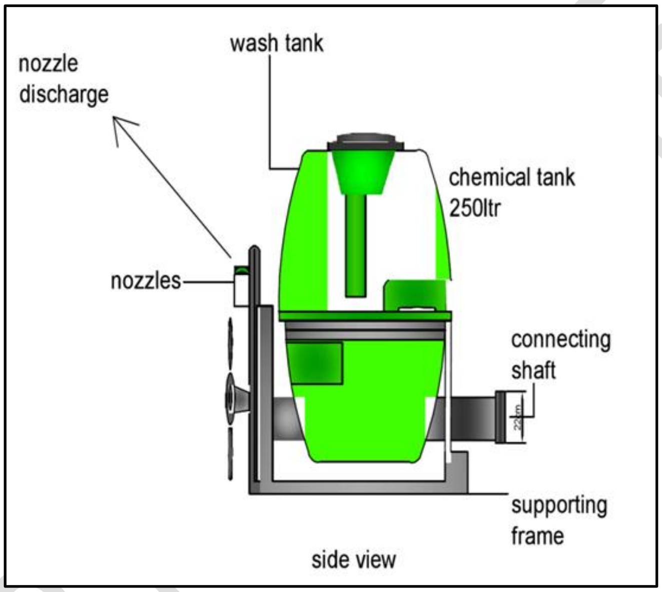

Plate 1. Components of air assisted sprayer

Plate 2.A view of developed axial flower blower

MATERIAL AND METHODS

An air assisted sprayer is of trail type, attached with tractor drawbar and operated by tractor power take off (PTO) as shown in Plate2. The sprayer consists of a tank of 200 litre capacity, 10 nozzles, diaphragm pump, direction control lever, pressure relief valve and a blower. They are provided with 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 fieldconditions 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 Table1. Field-testing was carried out to determine the distribution pattern of sprayer based on droplet density and volume of spray deposition on Grape and Pomegranate orchard at thedetermined speed of operation. Before operating the sprayer in the orchard, a studywas 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 levels of pressures i.e. minimum, middle and maximum for each nozzle type and corresponding parameters were recorded. The sprayer was evaluated on the basis of swath width and maximum spray height of the fruit tree in the orchard at different engine rpm and pressure[Narang et al.2015].

During fieldevaluation at Pimpalgaon (Basawant) Dist- Nasik, the spacing for grape and pomegranate was maintained at 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, respectivelywith an engine rpm of 2260 and pressure of 15 N/m^2.

Three replications were taken in the field for each orchard at varying pressure and rpm. Parameters like swath width, height of spray, discharge, speed and fuel consumption were recorded in an 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, middleand lower canopy. The number of droplets was noted under each classified range of intervals of 50 microns up to 500 microns. Using the number of droplets and diameter of droplet in the particular size range, graphswere plotted between actual diameter and cumulative percentage of volume. “The droplet size at which cumulative percentage of volume contributed to reach 50 percent was taken as Volume Median Diameter (VMD) of the sprayed particles. From the graph of cumulative percentage, number of droplets and actual dropletsize, the droplet size at which cumulative percentage number of droplets reached 50 percent was taken as the Number Median Diameter (NMD) of sprayed particles. Uniformity coefficient (UC) was calculated by dividing VMD by NMD. Droplet density was obtained by dividing number of droplets per unit square cm" (Singh *et al.*, 2010).

Constructional details of tractor mounted axial flow mist blower

The performance of tractor mounted air carrier sprayer was evaluated in the grape and pomegranate fields.

Sprayer consists of the 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 assisted axial flow mist blower are givenin Table 1.The sprayer'soverall view is illustrated in Plate no.1.The detailed components of air assisted sprayer are given in Plate 2 andspecification of a developed air assisted orchard sprayer is given in Table2.

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 existingand 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

(Grapevineyard)

RESULT 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 experiments.Performance of developed blower at different speed of operation (RPM) is presented in Table3.

The field evaluation was carried out for grape and pomegranate orchard. During evaluation, theaverage temperature was found to be 22.5 C with a wind velocity of 1.0km/h. The average height of grape and pomegranate orchard wasrecorded between 2.3 and 2.5 m. The canopy of the tree wasaround 7.0 mand the branches were hanging, so nozzlesalong the periphery blower of both sides were opened. Basedupon the preliminary evaluation of sprayer, the sprayer was operatedat an engine rpm of 2260 and pressure of 15 N/m^2,so thatspray may reach the maximum height of grape and pomegranate orchardof about 2.5 m. The forward speed of tractor was maintained at 3km/h.

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

The performance comparison of blower 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, 1.71m3/s and 22.58 per cent, respectively. Whereas, the power required to run the blower is 15.65 kW, which requires 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 17.65 per cent, respectively. This blower was suitable for tractors above 35hp. This blower was recommended by the manufacturer for orchard crop.

The blower A gave more velocity and discharge at 2260 rpm with values of 31.62 m/sec and1.79 m^3/sec. Blower efficiency was maximum (22.75 per cent) at 2260 rpm. The power required to run the blower was 7.32 kW for which 18 hp tractorwas used to operate it in the field. This blower is suitable for spraying grape and pomegranate crop, where the limitation of size is the governing factor

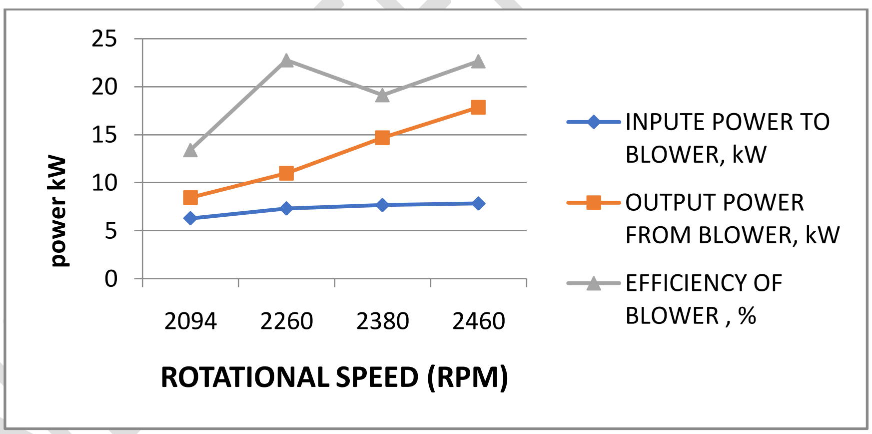

Fig 1. Effect of rotational speed on power and efficiency for developed blower 'A'

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 and further decreased with increase of rpm.

So 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 18hp tractor.

1. **Droplet size and uniformity coefficient**

The average volume median diameter (VMD) for grape crop was found to be 324µm and average Number median diameter (NMD) was 126µm. Average uniformity coefficient was fund to be 2.70. For average volume median diameter (VMD) for pomegranate crop was found to be 325 µm and average number median diameter (NMD) was 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,ats the increase of pressure,the number of droplets also increasedas shown in Fig. 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(Table 4). 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.

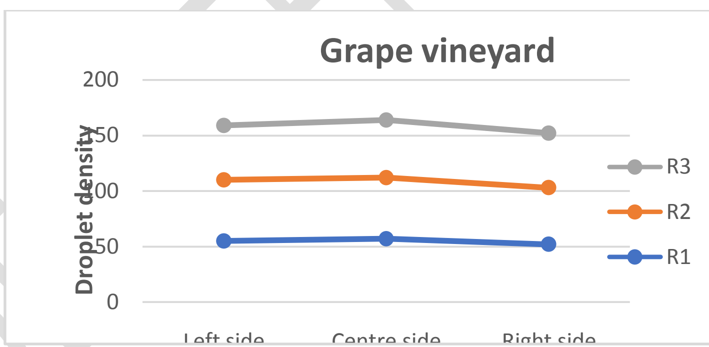

Fig 2.Number of droplets per square centimeter for grape vineyard

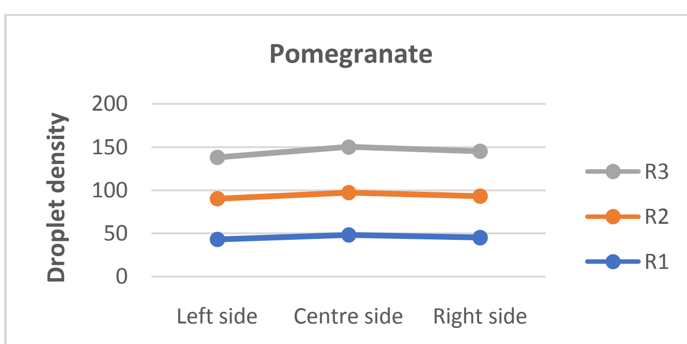

Fig 3.Number of droplets per square centimeter for pomegranate

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

CONCLUSION

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 observed and analyzed, the following conclusions are drawn.

1. Static pressure and dynamic pressure increase linearly with increase in rotational speed.
2. Maximum blower efficiency was observed in the developed blower A as 22.75 per cent as compared to blower 'B' of 22.58 per cent and 'C' of 17.65 per cent.
3. Blowers '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. Maximum air discharge was observed in blower 'A' (1.79 m^3/s) compared withthe discharge of blower 'B' (1.71m^3/s) and blower 'C' (1.70m^3/s).
5. The blower 'B', 'C' and 'A' needed tractors of size 30hp, 35hp and 18hp, 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 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. 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 spraydeposition 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 (464ucc) on backside surface than frontside (240 ucc) of leaf for grape crop and (388ucc) on backside surface than front side(194ucc) leaf of pomegranate orchard.
4. When system pressure increases from 10 barsto 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.

The 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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