Original Research Article   https://doi.org/10.20546/ijcmas.2020.901.171

Laboratory Performance of Developed Centrifugal Blower of Aero Blast Sprayer for High Density Plantation Mango Orchard

B. B. Badgire[*], S. M. Mathur, R. K. Rathod and G. S. Tiwari

*Department of Farm machinery and power Engineering, CTAE, MPUAT,
Udaipur-313001, Rajasthan, India*

*Corresponding author

A B S T R A C T

Effective pest control requires precise and uniform application of pesticide on the target area. Air assistance in spraying system improves the deposition uniformly in the entire tree canopy. Requirement of air volume is influenced by leaf area, leaf density and canopy volume of tree. High power air assisted sprayers are used for blanket spray application in developed countries. In India manual or HTP sprayers are used for spraying horticultural crops which results in uneven spraying, incurring more cost and inefficient pest control. To overcome these limitations a suitable centrifugal blower is developed for aero blast sprayer in HDP mango orchard. To assess air volume requirement for spraying on HDP matured mango orchard, tree parameters canopy volume, mean leaf area, leaf density and total leaf area of tree were estimated. Air volume requirement for HDP mango orchard spraying was calculated. The centrifugal blower with forward curved blade was developed to deliver the air of 2.5 m^3/s required for effective spraying in HDP mango orchard. The developed centrifugal blower was tested in the laboratory at 1800, 2000, 2200, and 2400 rpm. The desired air discharge of 2.66 m^3/s was found at 2200 rpm whereas theoretical requirement was 2.50 m^3/s for efficient spraying operation in HDP mango orchard. The maximum blower efficiency of 93.26 per cent and the sufficient spray throw was found at 2200 rpm blower speed.

Introduction

In India, horticulture has gained commercial tone in recent years and is an important component of Indian agriculture, having very significant share in the economy of the country. India has the advantage of diverse agro-climatic conditions that enables it to produce a wide range of horticultural crops round the year. The horticulture crops also provide better alternative for diversification of Indian agriculture in view of higher return. The projected growth in the world's population to nine billion by 2050 adds an extra challenge for food security (Anon., 2013). With the ever growing population and having limited land, water and labor resources and increase in the difference between food demand and supply, agricultural production has to be increased. Precise application of agriculture input like seed, fertilizer, water and pesticide is need of the day to increase the

yield and productivity in field crops and horticultural crops.

The continuing decline in the availability of cultivable land, rising energy and land cost together with the mounting demand for horticultural produce, have given thrust to the concept of high density planting (HDP) of horticultural crops (Reddy, 2004).

Centrifugal blower discharges air at high velocity and low volume, which affects atomization, carry, penetration and coverage (Pompe & Holterman, 1992). It also discharges air at high velocity with low volume which increases carry distance of spray & penetration through canopy to reach tree canopy and hit the target effectively. The high velocity air stream produce better atomization and effective leaf coverage from both sides due to more air turbulence. To achieve effective spraying, air assisted sprayer is needed to operate correctly. The blower output must be in accordance with weather and crop characteristics.

The performance evaluation of developed centrifugal blower in lab will help to finalize operating parameter for effective application of pesticide in high density mango orchard with minimum losses and environmental pollution.

Materials and Methods

Tree parameters measurement

Fox *et al.,* (2008) revealed that for best possible results, sprayer air velocity, volume and drop spectra should match to tree size, shape and density of canopy. In air carrier sprayer, spray liquid is conveyed to the target by air. The volume of air required is equal to the volume of the tree for effective coverage. The original air present in the canopy volume should be replaced by spray laden air generated by air assisted sprayer.

Mango trees have different shape and size. The information regarding canopy size, canopy height, leaf area, leaf density and canopy volume is required to estimate the air volume and spray volume application on mango tree. The data was collected for *kesar* mango variety with 9 years of age for 25 matured trees , from high density mango orchard research farm of American Spring & Pressing Works Private Limited popularly known as 'ASPEE' Agricultural Research and Development Foundation, Malad (W), Mumbai-400064 located at Tanasa Ta. Wada Dist. Palghar near Thane (Maharashtra). The observation of overall canopy height above ground level, height to the point of maximum canopy diameter, height from ground to canopy skirt, canopy diameter parallel to the row were recorded (Fig.1). These tree parameters were measured with clinometer height gauge and a measuring tape.

Estimation of Air volume required for spraying HDP mango orchard

The theoretical air volume (m^3/s) required for HDP mango orchard was calculated as follows (Joseph, 1990).

$$\text{Air volume } (m^3/s) = \frac{\text{Speed } \left(\frac{km}{h}\right) \times \text{Spray width (m)} \times \text{Tree height (m)} \times 1000}{6.5 \times 3600}$$

Following assumptions were made:

a) 18 hp Tractor having operating speed of 2.5 km/h for spraying operation.
b) Operating spray width one side only, this is half of the mean canopy diameter of the mango tree and measured as 2.052m
c) Factor of safety for dense canopy is 6.5. (Joseph, 1990).

Considering these assumptions, the air volume is as follows:

$$\text{Air volume } (m^3/s) = \frac{2.5\left(\frac{km}{h}\right) \times 2.052\ (m) \times 4.66\ (m) \times 1000}{6.5 \times 3600}$$

$= 1.021 = 1.0$

Air volume $(m^3/s) = 1.00\ m^3/s$

Therefore air volume of $1.0\ m^3/s$ required to spray one side of row of mango tree. To spray internal two sides of row of mango trees double air volume is required.

Air volume required for two internal sides of row $= 2 \times 1 = 2m^3/s$

Considering the blower efficiency 80% (Wilson *et al*., 1962) for effective spraying, the air volume required is as follows

The air volume required $= 2/0.8$
$= 2.5\ m^3/s$

Therefore, the theoretical air volume required for efficient spraying in HDP mango orchard was $2.5\ m^3/s$.

Centrifugal blower

The centrifugal blower is power driven machine moving continuous mass of air. It consists of an impeller confined to rotate in spiral involute casing. A centrifugal blower with forward curved blade impeller was selected and developed for the required air velocity and volume to be used in aero blast sprayer for HDP mango trees. Centrifugal blower consists of impeller and casing as shown in (Fig.2,3,4 and 5).

The developed centrifugal blower was fabricated and details are as given in Table A,

Experimental set-up for laboratory testing of centrifugal blower

All the experiments were conducted following American Air Moving and Control Association (AMCA) standard. A complete set up for testing the performance of the centrifugal blower has shown in (Fig. 6). It was essentially consisted of a blower assembly, a wind tunnel assembly, power transmission assembly and various measurement instruments.

Experimental plan for performance evaluation of centrifugal blower in the laboratory

Type of variable	Variable	Number of level	Level value	Statistical design
Independent	Speed, rpm	04	1800, 2000, 2200, 2400	
Dependent	Air velocity, m/s Air discharge, m^3/s Air pressure, N/m^2 Spray throw Blower efficiency, % Power requirement			CRD with three replications

The following procedure was implemented for evaluation of performance of centrifugal blower in the laboratory. The laboratory experiments were conducted as per AMCA standard.

1. Impeller was fitted in blower casing and the blower casing outlet was connected to wind tunnel assembly. The impeller was rotated in the clockwise or forward direction.
2. The proper combination of belt and 2 groove pulley selected to required blower speed as 1800 rpm.
3. Pitot tube was fixed with the help of screw provided at one point of the twenty traverse points and connected to the manometer.
4. Initially before starting the electric motor, the initial reading was recorded such as

temperature and RH at the test location of the laboratory.

5. Electric motor was started and current was stabilized and reading were taken.
6. The dynamic head was measured at test section by connecting both end of pitot tube to the manometer. The static head at test section was measured by connecting static head section of Pitot tube to the manometer. Another dynamic head end was kept open to the atmosphere.
7. Current and voltage consumed by the electric motor was measured by ammeter and voltmeter and was recorded.
8. The procedure was repeated from step 3 to 7 for all traverse point of wind tunnel.
9. The procedure was repeated from 3 to 8 for other three speeds of blower.
   10. Three replications were conducted for all above experiments.

Results and Discussion

During the study, air volume requirement for pesticide application on high density plantation mango tree was assessed. Based on the requirement a centrifugal blower for aero blast (air assisted) sprayer was designed and developed for 18 hp tractor. The developed blower was tested in the laboratory to know the effect of speed (rpm) of operation.

Physiological parameters of HDP mango trees

Various tree parameters and canopy volume of 25 mango trees of Cv. Kesar variety in HDP mango orchard are presented in table 1. The age of mango trees was 9 years. The canopy volume based on prolate spheroid formula and tree parameters were analyzed by statistical software. The minimum and maximum canopy volume was found to be 14.13 m^3 and 30.67 m^3 respectively. The mean canopy volume was 19.58 m^3. The mean

diameter parallel to the row, mean overall canopy height above ground level, mean height at maximum canopy diameter and mean height from ground to canopy skirt were found to be 4.10 m, 4.66 m, 2.67 m and 1.17 m respectively.

Performance evaluation of centrifugal blower in laboratory

Centrifugal blower was tested in the laboratory at four levels of speed adopting AMCA standard and procedure. The data collected were analyzed statistically and presented through table 5.4 to table 5.15. The performance curves are also presented through fig 5.1 to fig.5 .10. During the laboratory test temperature and relative humidity were measured and were found in the range 32^0C- 35^0C and 36 - 40 per cent respectively, three replications of the readings were taken.

Effect of blower speed on air velocity and air discharge of the blower

The developed centrifugal blower was run in the laboratory at four levels (1800, 2000, 2200, 2400 rpm) and data were collected for air velocity and air discharge and given in table 3.

The data were analyzed statistically and ANOVA (table 2) shows that blower speed had significant effect on air velocity and air discharge of the centrifugal blower at 1 and 5 per cent level of significance respectively. The relationship between air discharge with blower speed is shown in fig. 1. The curve shows that the air discharge increases with the increase in blower speed. Similar results were reported by Adachi *et al.,* (2001) and Dhande (2014) for testing of centrifugal blower in the laboratory.

Table.A

Impeller	
Type	: forward curved blade
Inlet diameter	: 340 mm
Outlet diameter	: 410 mm
Width of impeller	: 230 mm
Material	: Stainless steel
Blade	
Inlet blade angle	: 14^0
Outlet blade angle	: 160^0
Width of blade	: 35 mm
Length of blade	: 115 mm (one side) x 2
Number of blades	: 40 (single side) x 2
Material	: Stainless steel
Casing	
Maximum diameter	: 725 mm
Minimum diameter	: 635 mm
Width of casing	: 270 mm
Outlet size	: 210 mm Ø
Casing inlet size	: 460mm Ø and 280 mm Ø
Material	: Fiber Reinforced plastic (FRP)

Table.1 Physiological parameters of high density plantation mango orchard of variety Cv Kesar and canopy volume

Sample no.	D_1(m)	H_t(m)	H_c(m)	H_s(m)	PS_{cv}(m^3)
1	3.60	4.46	2.60	1.00	14.22
2	4.10	4.90	2.71	0.95	30.67
3	3.57	4.57	2.65	1.10	14.36
4	4.70	5.10	2.80	1.20	28.20
5	3.65	4.56	2.45	1.15	16.02
6	4.25	4.71	2.70	1.25	20.46
7	4.10	4.31	2.65	1.10	16.16
8	3.80	4.15	2.41	1.10	14.47
9	3.90	4.20	2.50	1.20	14.84
10	4.30	4.81	2.81	1.31	20.86
11	4.50	5.10	2.90	1.40	24.83
12	4.15	4.71	2.75	1.20	19.22
13	3.90	4.62	2.62	1.15	17.40
14	3.85	4.81	2.51	1.10	19.26
15	4.21	4.90	2.65	1.25	22.28
16	4.60	4.90	2.70	1.15	25.92
17	3.65	4.41	2.60	1.10	14.13
18	3.85	4.61	2.71	1.00	16.46
19	4.20	4.82	2.80	1.20	20.26
20	3.95	4.30	2.75	1.15	14.26
21	4.36	4.61	2.80	1.28	19.54
22	4.10	4.55	2.61	1.10	18.58
23	4.40	4.71	2.65	1.20	22.33
24	4.51	4.75	2.71	1.25	21.77
25	4.40	4.92	2.80	1.30	22.99
Minimum	3.57	4.15	2.41	0.95	14.13
maximum	4.70	5.10	2.90	1.40	30.67
mean	4.10	4.66	2.67	1.17	19.58
S.D.	0.32	0.26	0.12	0.10	4.57
C.V.	0.08	0.06	0.04	0.09	0.23

S.D.   =   Standard deviation
C.V.   =   Coefficient of variation
PS_{cv} =   Canopy volume,m^3
D_1 =   Canopy diameter parallel to the row(m)
H_t =   Overall canopy height above ground level, m
H_c =   Height at maximum canopy diameter, m
H_s =   Height from ground to canopy skirt,

Table.2 CRD ANOVA of performance of Centrifugal Blower for different Parameters

SN	Parameters	Treatment	Error	P
	df	[3]	[8]	
1	Mean air velocity, m/s	398.52127**	0.27495	0.000
2	Air discharge, m^3/s	0.2466*	0.03515	0.013
3	Dynamic pressure, N/m^2	111858.54**	0.434125	0.000
4	Static pressure, N/m^2	264.64927**	0.086175	0.000
5	Total pressure, N/m^2	101983.99**	0.2539583	0.000
6	Input power to blower, kW	1.5049**	0.0872833	0.001
7	Output power of blower, kW	2.401675**	0.002325	0.000
8	Efficiency of blower, %	45.370475**	0.00125	0.000
9	Spray throw, m	13.6875**	0.0325	0.000

* Significant at 5 per cent and ** Significant at 1 per cent

Table.3 Performance of Centrifugal Blower at different blower speeds

Sr. No.	Parameters	Blower speed in rpm (N)			
		1800	2000	2200	2400
1	Mean air velocity, m/s	84.34	88.31	104.51	107.45
2	Air discharge, m^3/s	2.16	2.25	2.66	2.73
3	Dynamic pressure, N/m^2	1244.90	1350.84	1534.28	1679.96
4	Static pressure, N/m^2	78.48	68.67	58.86	58.86
5	Total pressure, N/m^2	1323.37	1419.51	1593.14	1738.82
6	Input to blower, kW	3.35	3.71	4.54	5.54
7	Output of blower, kW	2.84	3.19	4.24	4.76
8	Efficiency of blower, %	84.84	86.03	93.26	85.78
9	Horizontal spray throw, m	11.00	12.50	14.00	16.00

Fig.1 Measurement of canopy height and other tree parameters in HDP mango orchard

Fig.2 Schematic diagram of developed impeller of centrifugal blower

ELEVATION   SIDE VIEW

ALL DIMENSIONS ARE IN MM
NO OF BLADE = 40
BLADE THICKNESS = 16 SWG = 1.62 MM
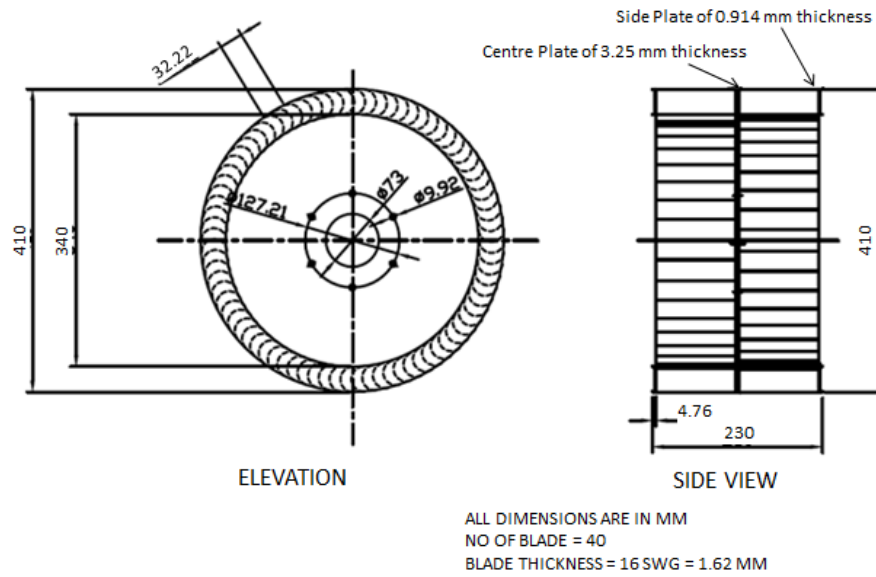
Fig.3 Developed impeller

1544
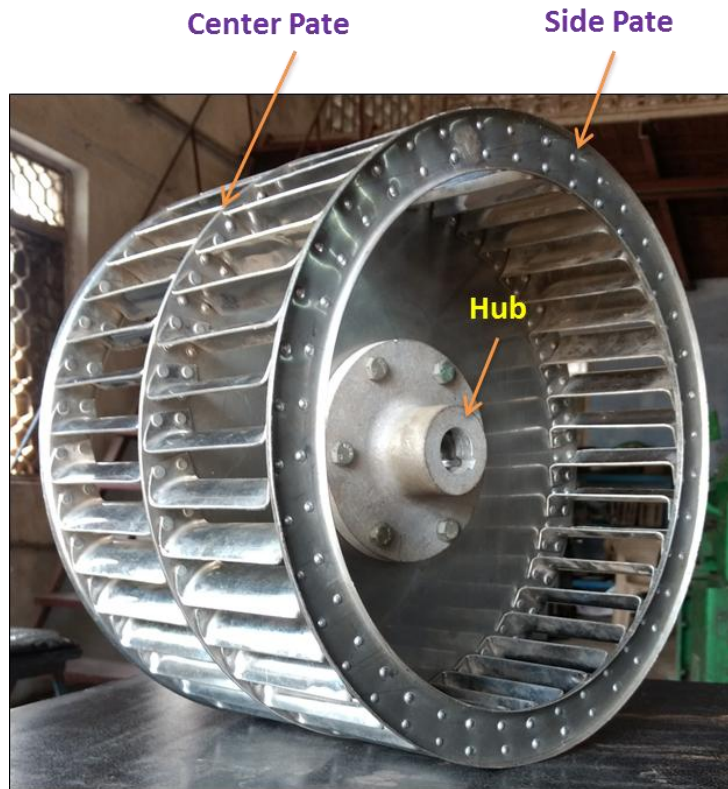
Fig.4 The schematic diagram of blower casing

ALL DIMENSIONS ARE IN MM
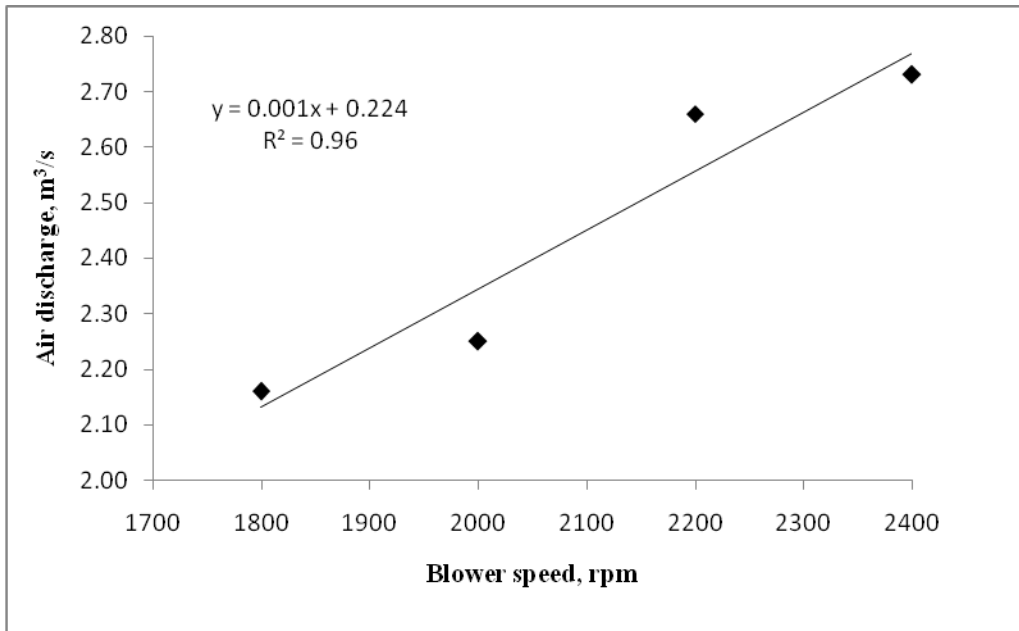
ELEVATION

SIDE VIEW
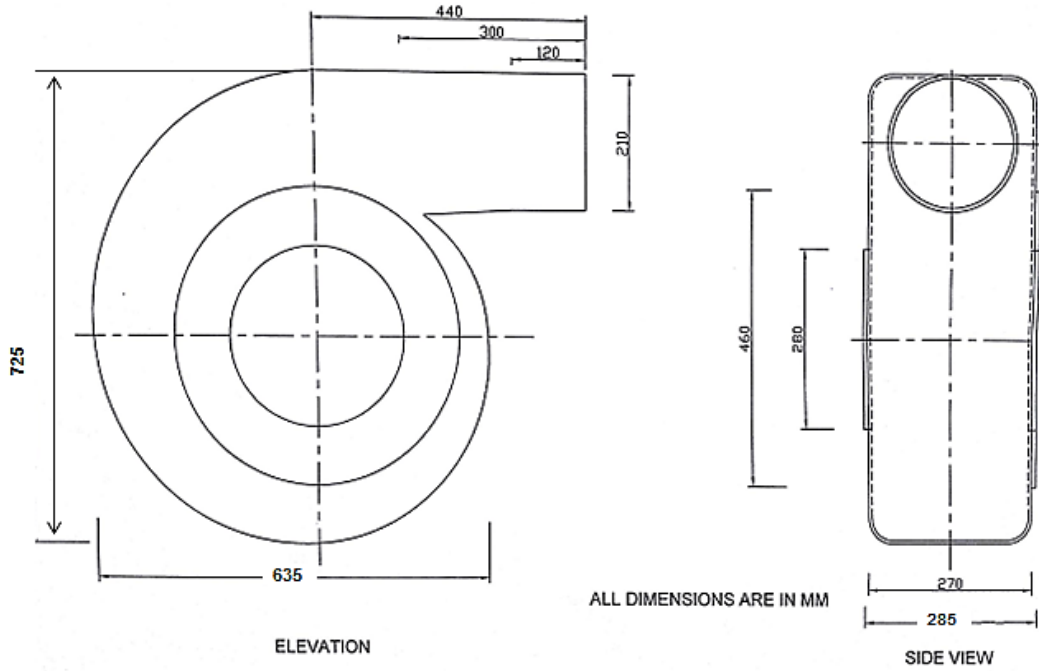
Fig.5 The developed blower casing

Fig.6 Complete set up for testing the performance of the centrifugal blower

Fig.1 Effect of blower speed on air discharge output of blower

Effect of blower speed on blower efficiency and horizontal spray throw

The performance parameters of developed blower like blower efficiency and horizontal spray throw was calculated at all four levels of blower speeds and are given in table 3. The data were analyzed statistically and reported in table 2. ANOVA (table 2) shows that the blower speed had a significant effect on blower efficiency and horizontal spray throw at 1 per cent level of significance. The results obtained (table 2) shows that maximum blower efficiency of 93.26 per cent was found at 2200 rpm and minimum of 84.48 per cent was at 1800 rpm. The blower speed increased

from 1800 rpm to 2200 rpm, the efficiency of blower increased and thereafter decreased with increase of blower speed and it was 85.78 per cent at 2400 rpm. This effect observed may be due to decrease in the static pressure at the casing tongue as air discharge increased. Also the results obtained reveals that the spray throw varied from 11.00 m at 1800 rpm to 16.00 m at 2400 rpm. and spray throw increases with increase in speed of blower. Similar results were obtained by Vibhakar (2012) and Dhande (2014).

Effect of blower speed on input power and total pressure of the blower

The developed centrifugal blower was operated at four speeds (1800, 2000, 2200, 2400 rpm) and data were collected for input power and total pressure and given in table 3. The data were analyzed statistically. Table 2 shows that blower speed has significant effect on the input power and total air pressure had a significant effect at 1 per cent level of significance. The input power and total air pressure of blower are increased with increase in blower speed.

The table 3 shows that that the desired air discharge of 2.66 m^3/s was found at 2200 rpm whereas theoretical requirement was 2.50 m^3/s for efficient spraying operation in HDP mango orchard. Furthermore the table also shows that the maximum blower efficiency of 93.26 per cent and the sufficient horizontal spray throw was found at 2200 rpm blower speed.

On the basis of research carried out and result obtained the following conclusion were drawn.

1. Air volume requirement of aero blast sprayer for HDP mango orchard was found 2.5 m^3/s.
2. The best performance of design and developed centrifugal blower was found at 2200 rpm with air velocity 104.51m/s, air discharge 2.66 m^3/s, blower input power 4.54 kW and blower efficiency 93.26%.

References

Adachi, T., Sugota, N. and Yamada, Y. 2001. Study on the Performance of a Sirocco Fan (Optimum Design of Blade Shape). *International Journal of Rotating Machinery* 7 : 405-414.

Anonymous. 2013. Indian Horticulture Database 2013. *NHB, New Delhi.* Paper No. AA 91-005.

Dhande, K. G. 2014. Design and development of centrifugal blower and rotary atomizer of air-assisted sprayer for Mango orchard. Unpublished Ph.D Thesis. MPUAT Udaipur (India)

Fox, R.D., Derksen, R.C., Zhu, H., Brazee, R.D. and Svensson, S.A. 2008. A history of Air blast sprayer: Development and future prospects. *Trans. of the ASABE* 51 : 405-410.

Joseph, M. B. 1990. Calibration of mist blower. *Applied Technology Course, Hardi Publications,* Leida Spain: 1-4.

Pompe, J. C. A. M. and Holterman, H. J. 1992. Technical aspects of pesticide application Wageningen Agriculture University.

Reddy, B.M.C. 2004. High density planting in horticultural crops. First Indian Horticulture Congress, 6th-9th November, New Delhi p. 36.

Vibhakar, N.N., Masutage and Channiwala, S.A. 2012. Three dimensional CFD Analysis of backward curved radial tipped Centrifugal Fan designed as per unified methodology with varying number of blades. *Int.J. of emerging trends in engg. and development.* 2(1):246-256.

Wilson and Irons. 1962. The swath pattern of

tomato disease control with air blast sprayers. The Ohio Agricultural Experiments Research Station. Circular No.77.