Analysis of Droplet Density in relation with combine effect of blade angle and speed of operation of an axial flow blower in air assisted orchard sprayer

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Abstract— **Plant protection activities are most important practices during crop production. Application of maximum pesticide products with the sprayer. The application of fungicides, herbicides, and insecticides is one of the most recurrent and significant tasks in agriculture. Conventional agricultural spraying techniques have made the inconsistency between economic growth and environmental protection in agricultural production. Spraying techniques continuously developed in recent decades. For pesticide application, it is not the only sprayer that is essential, but all the parameters like the type and area of the plant canopy, area of a plant leaf, height of the crop, and volume of plants related to plant protection product applications are very important for obtaining better results. From this point of view, the advancement in agriculture sprayer has been started in last few decades. Droplet density analysis of orchard sprayer having axial flow blower was carried out to determine the changes in droplet density at different speed and different blade angles. Droplet density analysis was carried out at two different positions (Outer and Inner) of crop canopy and at three different heights (Top, Middle, Bottom) of each crop canopy. The combine effect of blower speed and blade angle shows significant difference in the values of droplet density on outer and inner canopy at all positions. When sprayer was operated at 2.5 km/h, the droplet density increased by 22.5 % at blade angle 30˚ as compared to blade angle 25˚. It further increased by 31.4 % and 20 % when the blade angle was increased to 35˚ and 40˚ respectively. At speed of operation 3.0 km/h, recorded increase in droplet density was 22.2 %, 26.0 % and 18.9 % when the blade angle was changed from 25˚ to 30˚, 30˚ to 35˚ and 35˚ to 40˚ respectively. Whereas, at speed of operation 3.5 km/h, increase of 25.5 %, 22.3 % and 12.1 % respectively was recorded for every 5˚ change in blade angle.**

Index Terms— **Droplet Density, agricultural spraying techniques, plants**

I. INTRODUCTION

Pesticide applications are considered significant during the plant protection practices in current agriculture. Efficient use of pesticides can helpful to control plant pests and diseases to increase the crop yields. The use of agrochemicals can effectively enhance the quantity and quality of crops; however, it increases the environmental risks in recent years. Pesticide application utilizes to a significant percentage of the production cost. During chemical plant protection practices, over application of pesticide or inefficient spraying equipment may cause serious issues on human health and the environment. Effective pesticide application is a critical activity during crop production season that requires efficient spraying machinery with proper calibration as well as relevant regulations to reduce off-target spray deposition. Spraying technology aims to effectively and economically application of the precise quantity of the chemical to the set target with minimum threat for the environmental pollution. Conventional agricultural pesticide application practices have developed a contradiction among the yield enhancement, cost effectiveness and environmental protection. Therefore, pesticides have to be applied using suitable spraying systems to avoid adverse effects on environment as well as human health. Thus, in recent decades, spraying methods and technologies have been undergoing continuous evolution. For the orchards and vineyards, a powerful and effective plant-protection method is extensively adopted to attain higher quantity and quality of the production for the orchard and vineyard, it was difficult to apply spray on the whole area of the plant because of the shape and size change from plant to plant. It was very difficult in old times when no proper sprayers design for orchard spraying. To enhance orchard sprayer performance a number of new mechanisms have been introduced such as, an automatic variable-rate (VAR), Electrostatic, air-jet, air assisted and air blast systems.

The air assisted sprayer essentially consisted of blower assembly, power transmission unit, pump, formulation tank, pressure and discharge control assembly. Blower assembly consisted of an impeller mounted on rotor shaft and a casing having an air outlet. Impeller was used to produce required air blast by rotary action of its blades. Casing of the blower included a diffuser and back plate. Diffuser was used to divert the air coming out of the fan radially outward through a circumferential air outlet. Back plate was used to mount the diffuser and inlet blower over it. Discharge arrangement was such that one side of one row, or adjacent side of two rows, could be covered as the machine travels forward between the rows. Power to the blower was given from PTO shaft of the

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tractor. Pump was used to pressurize the spray liquid and deliver it to the nozzles through the hose. The hydraulic type nozzles were fitted at the periphery of the casing. The spray fluid was introduced into the air stream through the nozzles. The spray laden air was then used to replace the already existing air in the tree canopy. This was used to create a cloud like structure all around the tree canopy with spray particles in suspension which after settlement could impede on the target very uniformly. Spray contains a large number of very small spheres of liquid known as droplets. Droplet density is an important factor for the pesticides to be applied effectively with minimum contamination to the environment. . This study was carried out regarding droplet density analysis at different travel speed and different blade angles of blower impeller.

II. Material and Methods

Determination of Droplet size

The artificial target was developed for estimation of the droplet density of the sprayer (Plate 1).The laboratory set up of axial flow blower had different components such as small hp tractor (18.5 hp), artificial target having two frames for fixing glossy paper at different heights, tachometer, anemometer etc. for determining droplet size and droplet density of air assisted sprayer. The average height of the Sapota tree was recorded as 5 m and the average canopy width was recorded 6 m. Hence from this data the dimensions of frame were fixed 5 m x 3 m which was sufficient for recording the required information. Two testing frame was developed having dimensions of 5 m x 3 m. The frames was spaced at a distance of 3 m because, the spraying was done to the half of the crop canopy from one side of blower in the single run of sprayer. Two frames considered as two positions 1) Circumference of plant canopy i.e. outer canopy and 2) Centre of the plant i.e. inner canopy. The glossy papers were fixed on both the frames at three different heights, Top (4-5 m), Middle (2-4 m) and Bottom (1-2 m). The distance between two glossy papers horizontally and vertically kept as 20 cm. Droplet density of spray measured at different heights i.e. top, middle and bottom on both positions. The trials were repeated for different treatments selected for the study. To find out the combine effect of blade angle and speed of operation on droplet density readings were taken at each blade angle and in combination of selected speed of operation. The coloured water was prepared by mixing colour dye in 5 gram per liter of water. The coloured spray solution was filled in the tank. The air carrier sprayer was ready to spray. The sprayer was operated at different blade angles of blower blade. The spray from the sprayer was targeted and allowed to deposit on the glossy papers. These glossy papers were removed from the frame. The glossy papers were grouped in different sets as per their zone on the frame. The traces of coloured spray solution were retained on glossy papers in the form of droplets. The droplet density and other parameter were calculated using droplet analysis software. These glossy papers were analyzed on image analysis system to determine droplet size and droplet. The experiment was carried out at ASPEE, Agricultural Research Foundation, Tansa, Tal-Wada, Dist.- Palghar. Different variables were used for droplet size analysis, described herewith as follows.

Independent variables:

1) Blade angle (25˚, 30˚, 35˚, 40˚)
2) Speed of operation (2.5 km/h, 3 km/h, 3.5km/h))

Dependent variable:

Droplet density (No./square meter)

The laboratory experimental data recorded and it was analyzed by Analysis of variance technique by using CRD.

Power transmission assembly

An 18.5 hp tractor was used as a power source of blower. The power was transferred from the tractor PTO shaft to the pump shaft by primary cardan shaft. The pump transferred the power to the blower assembly by the secondary cardan shaft. The blower was coupled with gear box (The ratio of gear box is 1: 4.5) which increases the rpm of blower.

Instrumentations

Following instruments were used for measuring various parameters during the laboratory testing of the blower.

1. Stopwatch
2. Measuring tape
3. Measuring cylinder
4. Droplet size analyzer

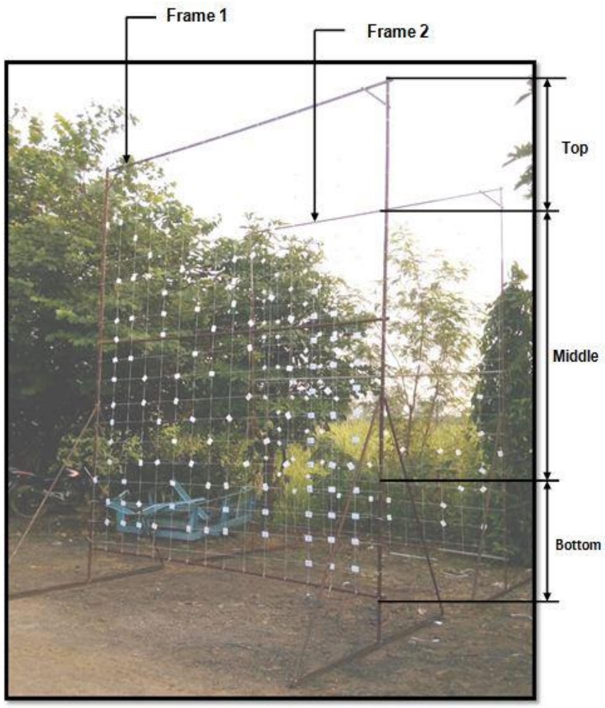

Plate 1 Developed Artificial Tree Target

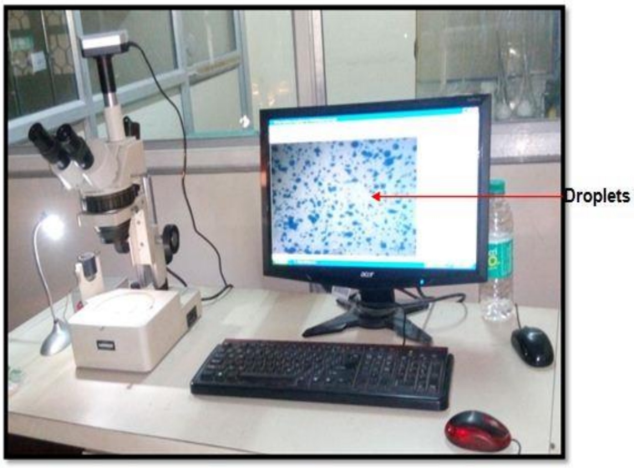

Plate-2 Droplet density analysis

III. Results and Discussions

Droplet density Analysis at outer canopy

Table 1 represents the effect of blade angle and speed of operation on droplet density at top, middle and bottom position. The mean value of droplet density on outer canopy at top position with blade angle 25˚, 30˚, 35˚, and 40˚ were recorded as 37.0, 46.1, 58.5 and 68.0 No./sq.cm respectively. The mean value of droplet density obtained as an effect of speed of operation 2.5 km/h, 3.0 km/h, 3.5 km/h were observed as 41.1, 52.5, and 59.6 No./sq.cm respectively and statistical analysis shows that there was a significant difference in the mean values of the droplet density. The minimum value of droplet density was observed 31.1 No./sq.cm as an effect of blade angle 25˚ and speed of operation 2.5 km/h, whereas the maximum value was recorded 74.5 No./sq.cm as an effect of blade angle 40˚ and speed of operation 3.5 km/h.

Table 1 also shows that the mean value of droplet density on outer canopy at middle position with blade angle 25˚, 30˚, 35˚, and 40˚ and values recorded were as 32.1, 42.0, 53.8 and 63.5 No./sq.cm respectively. The mean value of droplet density obtained as an effect of speed 2.5 km/h, 3.0 km/h, 3.5 km/h were also observed as 40.6, 47.7 and 53.3 respectively. The statistical analysis of data shows that there was a significant difference in the mean values of the droplet density at 5 % level of significance. The minimum value of droplet density was recorded 26.5 No./sq.cm as an effect of blade angle 25˚ and speed of operation 2.5 km/h and maximum value was observed 70.3 No./sq.cm as an effect of blade angle 40˚ and speed of operation 3.5 km/h.

The mean value of droplet density on outer canopy at bottom position with blade angle 25˚, 30˚, 35˚, and 40˚ were measured as 27.6, 36.7, 49.6 and 59.5 No./sq.cm respectively. The mean value of droplet density obtained as an effect of speed of operation 2.5 km/h, 3.0 km/h, 3.5 km/h were recorded as 36.5, 43.1 and 50.4 No./sq.cm respectively. The statistical analysis of data shows that there was a significant difference in the mean values of the droplet density.

Table 1 Combine effect of blade angle and speed of operation on droplet density on outer canopy

Sr. No.	Blade angle, degree	Droplet density, No./sq.cm											
		Top				Middle				Bottom			
		Speed of operation, km/h											
		2.5	3.0	3.5	Mean	2.5	3.0	3.5	Mean	2.5	3.0	3.5	Mean
1	25	31.1	36.5	43.3	37.0	26.5	31.5	38.5	32.1	22.3	27.0	33.5	27.6
2	30	38.5	46.0	54.0	46.1	34.5	41.1	50.5	42.0	29.5	35.5	45.3	36.7
3	35	50.5	58.5	66.6	58.5	46.0	53.5	62.0	53.8	42.8	49.1	57.0	49.6
4	40	60.3	69.1	74.5	68.0	55.5	64.8	70.3	63.5	51.6	61.0	66.0	59.5
	Mean	45.1	52.5	59.6		40.6	47.7	55.3		36.5	43.1	50.4	
F Test		Sig.				Sig.				Sig.			
SE (m) ±		0.5				0.4				0.4			

CD at 5%	1.4	1.4	1.3

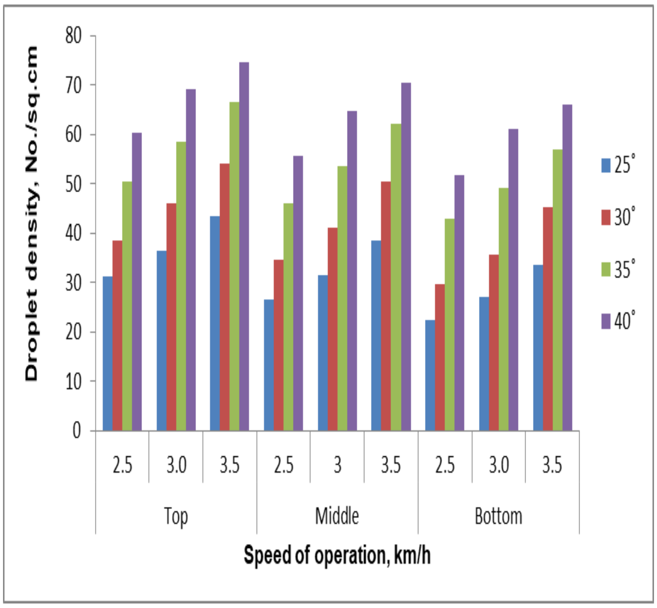

Fig.1 Combine effect of blade angle and speed of operation on droplet density on outer canopy

The fig. 1 shows the increasing trend for the values of droplet density with increase in speed of operation as well as blade angle on top, middle, bottom position. On outer canopy at top position when sprayer was operated at 2.5 km/h, the droplet density increased by 22.5 % at blade angle 30˚ as compared to blade angle 25˚. It further increased by 31.4 % and 20 % when the blade angle was increased to 35˚ and 40˚ respectively. At speed of operation 3.0 km/h, recorded increase in droplet density was 22.2 %, 26.0 % and 18.9 % when the blade angle was changed from 25˚ to 30˚, 30˚ to 35˚ and 35˚ to 40˚ respectively. Whereas, at speed of operation 3.5 km/h, increase of 25.5 %, 22.3 % and 12.1 % respectively was recorded for every 5˚ change in blade angle.

At middle and bottom position when sprayer was operated at speed of operation 2.5 km/h the increase in droplet density was observed in range of 35.2 % to 19.5 % and 44.8 % to 21.4 % with shift in blade angle by every 5˚ ranges from 25˚ to 40˚ respectively. When the speed of operation was increased to 3.0 km/h the increase in droplet density was observed in the range of 32.2 % to 20.7 % and 40.0 % to 24.4 % at middle and bottom position respectively. However, when speed of operation was increased to 3.5 km/h, the increase in droplet density was recorded in the range of 31.5 % to 12.9 % and 36.3 % to 15.7 % at middle and bottom position respectively.

Table 2 Combine effect of blade angle and speed of operation on droplet density on inner canopy

Sr. No.	Blade angle, degree	Droplet density, No./sq.cm											
		Top				Middle				Bottom			
		Speed of operation, km/h											
		2.5	**3.0**	**3.5**	**Mean**	**2.5**	**3.0**	**3.5**	**Mean**	**2.5**	**3.0**	**3.5**	**Mean**
1	**25**	36.0	41.8	49.3	42.3	31.0	37.0	43.0	37.0	27.3	30.6	38.3	32.1
2	**30**	44.0	49.8	59.5	51.1	38.8	46.1	55.5	46.8	33.3	40.8	48.0	40.7
3	**35**	57.7	64.3	72.6	64.7	51.0	57.3	66.5	58.2	46.3	52.8	63.6	54.2
4	**40**	65.1	74.3	79.1	72.8	62.8	68.1	76.3	69.1	56.6	64.6	72.5	64.6
	Mean	50.5	57.5	65.1		45.9	52.1	60.3		40.9	47.2	55.6	
F Test		**Sig.**				**Sig.**				**Sig.**			
SE (m) ±		0.5				0.5				0.5			
CD at 5%		1.6				1.5				1.4			

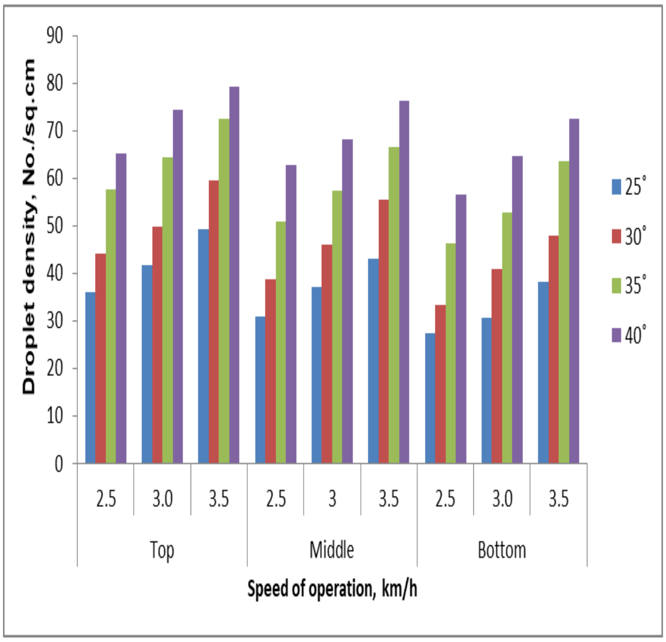

Fig.2 Combine effect of blade angle and speed of operation on droplet density on inner canopy

The fig. 2 shows the increasing trend for the values of droplet density with increase in speed of operation as well as blade angle on top, middle, bottom position. On outer canopy at top position when sprayer was operated at speed 2.5 km/h, the droplet density increased by 22.2 % at blade angle 30˚ as compared to blade angle 25˚. It further increased by 29.5 and 14.0 % when the blade angle was increased to 35˚ and 40˚ respectively. At speed of operation 3.0 km/h, recorded increase in droplet density was 19.5 %, 30.6 % and 15.6 % for blade angle 30˚, 35˚ and 40˚ respectively. Whereas, at speed of operation 3.5 km/h, increase of 20.4 %, 22.0 % and 9.7 % was recorded for same change in blade angle respectively.

At middle and bottom position when sprayer was operated at speed of operation 2.5 km/h the increase in droplet density was observed in range of 34.2 % to 21.5 % and 39.3 % to 21.7 % with shift in blade angle by every 5˚ from 25˚ to 40˚ respectively. At speed of operation 3.0 km/h the increase in droplet density was observed in the range of 24.3 % to 19.2 % and 33.3 % to 23.0 % at middle and bottom position respectively. Whereas at speed of operation 3.5 km/h, the increase in droplet density was recorded in the range of 27.9 % to 15.1 % and 31.2 % to 14.2 % at middle and bottom position respectively.

Conclusion

The combine effect of blade angle and speed of operation shows significant difference in the values of droplet density.

The combine effect of blade angle and speed of operation shows the increasing trend for the values of droplet density at all speed of operation with increase in blade angle at top, middle and bottom position.

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