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Analysis of droplet size 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
Droplet size analysis of orchard sprayer having axial flow blower was carried out to determine the changes in droplet size at different speed and different blade angles. Droplet size 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 minimum value of droplet size at outer canopy and at top position was measured 117.4 µm at blade angle 40˚ and speed of operation 3.5 km/h. Whereas, the maximum value was recorded 207.9 µm at blade angle 25˚ and speed of operation 2.5 km/h. At middle position (Outer canopy) the minimum value of droplet size was recorded 126.0 µm as an effect of blade angle 40˚ and speed 3.5 km/h and maximum value 214.4 µm as an effect of blade angle 25˚ and speed 2.5 km / h. At bottom position (Outer Canopy) the minimum value of droplet size 137.6 µm was obtained as an effect of blade angle 40˚ and speed 3.5 km/h. Whereas, the maximum value was observed 226.0 µm at blade angle 25˚ and speed of operation 2.5 km/h. The minimum value of droplet size at inner canopy and at top position was found to be 109.0 µm at blade angle 40˚ and speed of operation 3.5 km/h whereas the maximum value of droplet size was recorded 198.5 µm at blade angle 25˚ and speed of operation 2.5 km/h. At middle position (Inner canopy)the minimum value of droplet size was measured 116.9 µm as an effect of blade angle 40˚ and speed 3.5 km/h and maximum value 205.3 µm as an effect of blade angle 25˚ and speed 2.5 km / h. At bottom position the minimum value of droplet size 131.1 µm was obtained as a effect of blade angle 40˚ and speed 3.5 km/h. Whereas, the maximum value was observed 219.1 µm at blade angle 25˚ and speed of operation 2.5 km/h.

Keywords: Droplet size, orchard sprayer, axial flow blower, crop canopy

Introduction

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 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 size is an important factor for the pesticides to be applied effectively with minimum contamination to the environment. The droplet size requirement depends upon the pest, the pesticide, its mobility and mode of action. The unit of measure of droplet diameters is the micron (µm) which is equivalent to 0.001 mm. Droplet undisturbed by relative airflow is approximately spherical. The droplet size can be measured either by direct measurement or indirect measurement from strains or impressions. Numerous techniques have been developed to sample and measure droplet size of spray. These methods are simple collection techniques to advanced non-instructive techniques. The most simple and inexpensive technique involved in the measurement of droplet size by capture of droplets spectrum in or some form of medium.

The correct rate of travel is essential for good spray coverage. For a given sprayer and tree size, too slow rate of travel will result in over-spraying which amounts to waste of time, fuel, and possibly spray material. Too high rate of travel will result in insufficient coverage. This study was carried out regarding droplet size analysis at different travel speed and different blade angles of blower impeller.

Material and Methods

Determination of Droplet size

The artificial target was developed for estimation of the droplet size 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 size 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 size 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 droplets size 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 size, µm

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

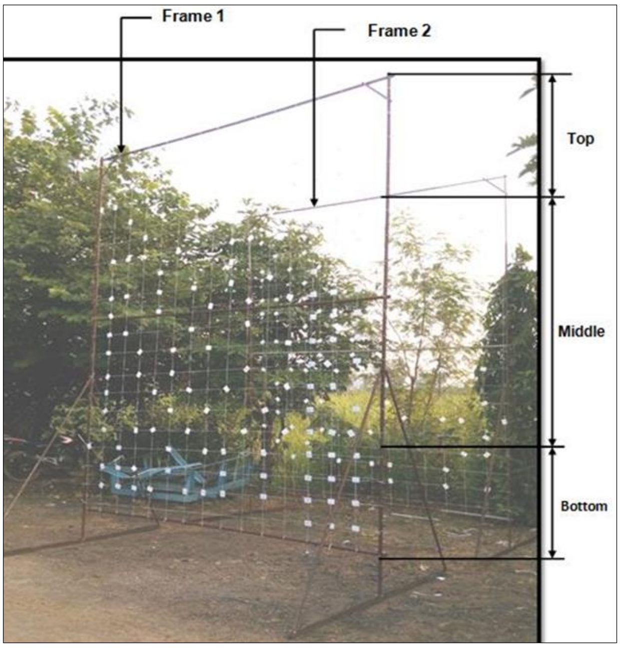

Plate 1: Developed Artificial Tree Target

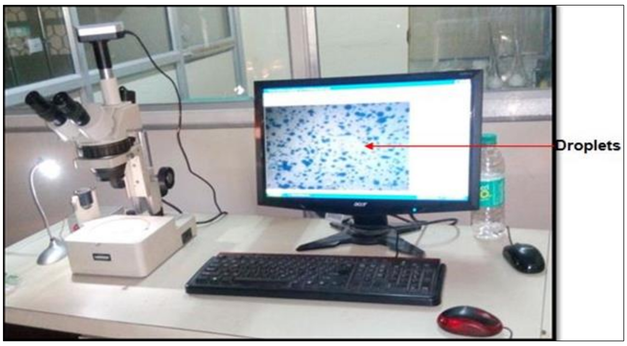

Plate 2: Droplet Size Analysis

Results and Discussion

Droplet size Analysis at outer canopy

Table 1 represents the mean value of droplet size on outer canopy due to combine effect of change in blade angle from 25˚ to 40˚ and speed of operation from 2.5 km/h to 3.5 km/h. The values at top position were recorded as 190.6 µm, 173.5 µm, 154.5 µm and 134.7 µm. The mean value of droplet size obtained as an effect of speed 2.5 km/h, 3.0 km/h, 3.5 km/h at different blade angles 25˚, 30˚, 35˚, & 40˚ were observed as 178.6 µm, 163.8 µm and 147.5 µm respectively and statistical analysis shows significant difference in the mean values of the droplet size. The minimum value of droplet size was measured 117.4 µm at blade angle 40˚ and speed of operation 3.5 km/h. Whereas, the maximum value was recorded 207.9 µm at blade angle 25˚ and speed of operation 2.5 km/h.

Table 1 also shows that the mean value of droplet size 197.4 µm, 181.0 µm, 162.7 µm and 142.7 µm on outer canopy at middle position as an effect of blade angle 25˚, 30˚, 35˚, and 40˚. The mean value of droplet size at speed of operation 2.5 km/h, 3.0 km/h, 3.5 km/h were found to be 186.3 µm, 171.8 µm and 154.8 µm respectively and statistical analysis shows significant difference in the mean values of the droplet size. The minimum value of droplet size was recorded 126.0 µm as an effect of blade angle 40˚ and speed 3.5 km/h and maximum value 214.4 µm as an effect of blade angle 25˚ and speed 2.5 km / h.

At bottom position the mean value of droplet size on outer canopy were recorded as 209.7 µm, 192.1 µm, 177.0 µm and 155.1 µm as an effect of blade angle 25˚, 30˚, 35˚, and 40˚ respectively. Whereas, at speed of operation 2.5 km/h, 3.0 km/h, 3.5 km/h the values measured were 198.0 µm, 184.0 µm and 168.4 µm respectively. Statistical analysis shows that there was a significant difference in the mean values of the droplet size. The minimum value of droplet size 137.6 µm was obtained as an effect of blade angle 40˚ and speed 3.5 km/h. Whereas, the maximum value was observed 226.0 µm at blade angle 25˚ and speed of operation 2.5 km/h.

The fig. 1 shows the decreasing trend for the values of droplet size at all speed of operation with increase in blade angle at top, middle, bottom position. On outer canopy at top position as an effect of speed of operation 2.5 km/h, the droplet size decreased by 10.1%, 8.6% and 12.3% when the blade angle was increased to 30˚, 35˚ and 40˚ respectively.

At speed of operation 3.0 km/h and 3.5 km/h the droplet size decreased by 6.9%, 8.6%, 12.3% and by 9.7%, 12.0%, 15.8% at blade angle 30˚, 35˚ and 40˚ respectively.

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

Sr. No.	Blade angle, degree	Droplet size, µm											
		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	207.9	188.9	175.0	190.6	214.4	196.7	181.0	197.4	226.0	209.2	193.9	209.7
2	30	186.8	175.2	158.4	173.5	194.6	182.4	165.9	181.0	205.1	192.1	179.1	192.1
3	35	170.3	153.8	139.3	154.5	178.2	163.6	146.3	162.7	189.3	178.6	163.0	177.0
4	40	149.6	137.2	117.4	134.7	157.8	144.4	126.0	142.7	171.6	156.2	137.6	155.1
	Mean	178.6	163.8	147.5		186.3	171.8	154.8		198.0	184.07	168.4	
F Test		Sig.				Sig.				Sig.			
SE (m) +		0.5				0.5				0.5			
CD at 5%		1.4				1.4				1.6			

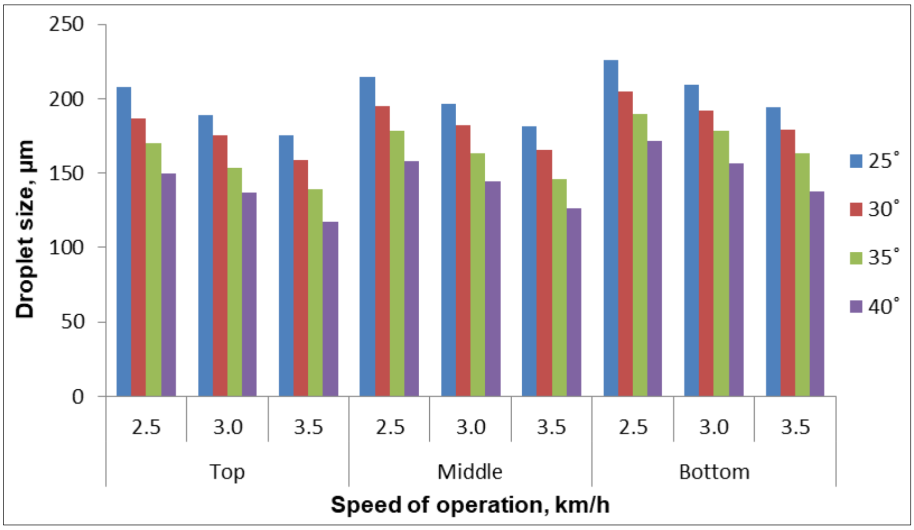

Fig 1: Combine effect of blade angle and speed of operation on droplet size on outer canopy

At middle and bottom position the droplet size decrease almost similar to those values recorded at top position. The decrease in droplet size as an effect of combination of blade angle and speed of operation was in the range of 8% to 15%.

Droplet size Analysis at inner canopy

Table 2 is represents the mean value of droplet size on inner canopy due to an effect of change in blade angle from 25˚ to 40˚ and speed of operation from 2.5 km/h to 3.5 km/h. The mean values recorded at top position 182.7 µm, 164.8 µm, 146.1 µm and 126.9 µm as an effect of blade angle from 25˚ to 40˚. The mean value of droplet size obtained as an effect of speed 2.5 km/h, 3.0 km/h, 3.5 km/h at different blade angles 25˚, 30˚, 35˚, & 40˚ were recorded as 171.0 µm, 155.2 µm and 139.1 µm respectively and statistical analysis shows significant difference in the mean values of the droplet size. The minimum value of droplet size was found to be 109.0 µm at blade angle 40˚ and speed of operation 3.5 km/h whereas the maximum value of droplet size was recorded 198.5 µm at blade angle 25˚ and speed of operation 2.5 km/h.

Table 2 also shows that the mean value of droplet size 190.4 µm, 173.2 µm, 153.4 µm and 133.4 µm on inner canopy at middle position as an effect of blade angle 25˚, 30˚, 35˚, and 40˚. The mean value of droplet size at speed of operation 2.5 km/h, 3.0 km/h, 3.5 km/h were measured as 177.1 µm, 163.3 µm and 147.4 µm respectively and statistical analysis shows significant difference in the mean values of the droplet size. The minimum value of droplet size was measured 116.9 µm as an effect of blade angle 40˚ and speed 3.5 km/h and maximum value 205.3 µm as an effect of blade angle 25˚ and speed 2.5 km / h.

At bottom position the droplet size observed as 201.5 µm, 184.1 µm, 167.6 µm and 147.6 µm on outer canopy at blade angle 25˚, 30˚, 35˚, and 40˚ respectively. Whereas at speed of operation 2.5 km/h, 3 km/h, 3.5 km/h values recorded were 191.0 µm, 174.6 µm and 160.0 µm respectively. Statistical analysis shows that there was a significant difference in the mean values of the droplet size. The minimum value of droplet size 131.1 µm was obtained as an effect of blade angle 40˚ and speed 3.5 km/h. Whereas, the maximum value was observed 219.1 µm at blade angle 25˚ and speed of operation 2.5 km/h. The fig. 2 shows the decreasing trend for the values of droplet size with increase in blade angle at all speed of operation at top, middle, bottom position. On inner canopy at top position with speed of operation 2.5 km/h, the droplet size decreased by 10.0%, 8.9% and 11.7% when the blade angle was increased to 30˚, 35˚ and 40˚ respectively. At speed of operation 3.0 km/h, the droplet size decreased by 7.6%, 14.8% and 11.1% and at speed of operation 3.5 km/h, the value decreased by 11.9%, 10.2% and 17.4% at 30˚, 35˚ and 40˚ respectively.

On middle position the droplet size decreased by 10.2%, 8.1% and 12.4% when the blade angle was increased from 25˚ to 30˚, 30˚ to 35˚ and 35˚ to 40˚ respectively at speed of operation 2.5 km/h. At speed of operation 3.0 km/h and 3.5 km/h the droplet size decreased by 8.3%, 13.1%, 11.8% and 8.6%, 13.2%, 15.9% at 30˚, 35˚ and 40˚ respectively.

On bottom position with speed 2.5 km/h, the droplet size decreased by 9.1% when the blade angle was increased from 25˚ to 30˚. It further decreased by 9.04% and 9.9% when the blade angle was increased from 30˚ to 35˚ and 35˚ to 40˚. At speed 3.0 km/h, the decrease in value was observed as 9.5%, 6.1% and 12.4% when the blade angle was increased to 30˚, 35˚ and 40˚respectively. While at speed 3.5 km/h, the droplet size decreased by 8.06%, 11.6% and 13.2% when the blade angle was increased to 30˚, 35˚ and 40˚ respectively.

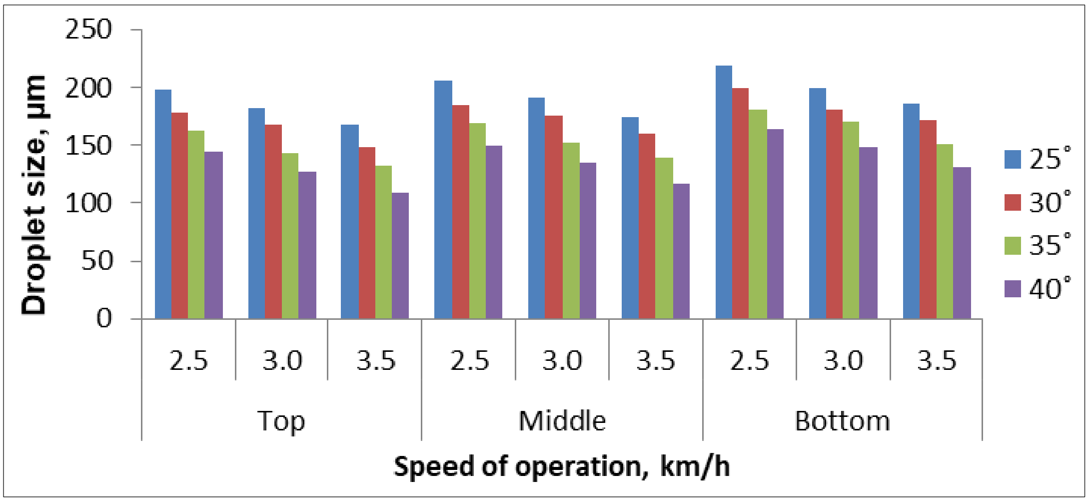

Fig 2: Combine effect of blade angle and speed of operation on droplet size on inner canopy

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

Sr. No.	Blade angle, degree	Droplet size, µm											
		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	198.5	182.1	167.4	182.7	205.3	191.3	174.6	190.4	219.1	199.5	186.1	201.5
2	30	178.5	168.1	147.7	164.8	184.9	175.3	159.3	173.2	199.8	180.9	171.5	184.1
3	35	162.9	143.0	132.5	146.1	169.1	152.2	138.8	153.4	181.4	169.9	151.4	167.6
4	40	143.9	127.8	109.0	126.9	148.9	134.5	116.9	133.4	163.8	148.0	131.1	147.6
	Mean	171.0	155.2	139.1		177.1	163.3	147.4		191.0	174.6	160.0	
F Test		Sig.				Sig.				Sig.			
SE (m) +		0.6				0.5				0.6			
CD at 5%		1.8				1.6				1.9			

Conclusions

1. The combine effect of blade angle and speed of operation shows significant difference in the values of droplet size.
2. The combine effect of blade angle and speed of operation shows the decreasing trend for the values of droplet size at all speed of operation with increase in blade angle at top, middle, bottom position.

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