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Effect of nozzle discharge rate and nozzle pressure on uniform deposition of spray

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■ **ABSTRACT :** Cotton is one of the principal commercial crops in India with 9.5 million ha cultivated area which is largest in the world. India is second largest producer of cotton in the world though the yield is only 300 kg/ha as against the world average of 558 kg/ha, due to poor control of insect pest and dry land farming conditions. During pesticide application most of the pesticide is lost through drift. A major reason for such a pesticide loss is insufficient nozzle pressure, nozzle discharge, nozzle height etc. Hence, it is necessary to determine the optimum discharge rate and pressure so as to reduce the pesticide losses from sprayer. Therefore, the hydraulic boom sprayer was tested using the spray scanner and droplet analyzer in the laboratory for cotton crop to study effect of nozzle discharge rates (0.45, 0.70, 0.90 and 1.35 l/min) and nozzle pressures (275.8, 413.7, 551.6 and 689.5 kPa) on spray uniformity. From the study it was found that nozzle discharge rate of 0.9 l/min and nozzle pressure of 689.5 kPa produced more uniform spray with droplet size of 122.53 to 284.80 µm, droplet density of 17 to 29 drops/cm2 and uniformity coefficient of 0.99 to 1.23.

■ **KEY WORDS :** Boom sprayer, Spray scanner, Nozzle discharge rate, Nozzle pressure

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Cotton crop is concentrated in semi arid regions of the country. More than sixty per cent production is contributed by three states alone namely Gujarat, Maharashtra and Andhra Pradesh. Cotton is one of the principal commercial crops in India with 9.5 million ha cultivated area which is largest in the world. India is second largest producer of cotton in the world though the yield is only 300 kg /ha as against the world average of 558 kg/ha due poor control of insect pest and dry land farming conditions. Cotton plays an important role in the national economy providing large employment in the farm marketing and processing sectors. Although, there has been a significant growth in production, productivity and quality of Indian cotton during the last 50 years, it is way below the average world productivity and far below the general quality requirements.

A major reason for such a pesticide loss is insufficient nozzle pressure, nozzle discharge, nozzle height etc. Hence, it is necessary to determine the optimum discharge rate and pressure so as to reduce the pesticide losses from sprayer. Therefore, the hydraulic boom sprayer was tested using the spray scanner and droplet analyzer in the laboratory for cotton crop to study effect of nozzle discharge rates (*viz.,* 0.45, 0.70, 0.90 and 1.35 l/min) and nozzle pressures (*viz.,* 275.8, 413.7, 551.6 and 689.5 kPa) on spray uniformity.

■ METHODOLOGY

A 12 m tractor mounted boom sprayer (Table A) was selected for study and its performance was evaluated in the laboratory. The power for the operation of the boom sprayer was supplied by the power take-off (PTO) shaft of the tractor. The liquid distribution under a spray boom was measured with spray scanner. For spray deposition on cotton crop

Table A : Specifications of the boom sprayer

Technical descriptions	Boom sprayer
Tank capacity	400 lit
Working pressure	689.5 Kpa
Maximum pressure	2758 Kpa
PTO rpm	540
Minimum hp required	35
Gross weight of sprayer	270 kg
Size of sprayer (L × W × H)	1364x1000x1212 mm
Application rate	580 lit/ha
Type and number of nozzles used	Plastic hollow cone, 25

independent variables were nozzle discharge rates 0.45, 0.7, 0.9 and 1.35 l/min and the pressures of nozzle were 275.8, 413.7, 551.6 and 689.5 kpa selected for study. The experiment was replicated three times under laboratory condition on cotton crop.

Experimental set-up :

Different set up were used in the laboratory for evaluating the performance of hydraulic boom sprayer. These were to measure liquid distribution, flow rate of pump, pressure and discharge measurement of nozzles, calibration of the commercial pressure gauge and spray deposition.

Set up for spray scanner :

In the laboratory a 12 m hydraulic boom was positioned on the main frame of the sprayer. The boom sprayer was mounted on 35 hp tractor with the help of three point linkage. The PTO of the tractor was connected to the pedestal pulley with the shaft. Booms of the sprayer were unfolded and open for spray scanner test. A spray scanner was kept on reels exactly beneath the boom length. Position of the scanner was so adjusted that the nozzles of the boom sprayer was at the center of the channels of scanner.

Set up for pressure and discharge measurement of nozzles :

The boom sprayer mounted on the tractor was kept in laboratory. A pressure gauge tester was connected to the nozzle with the help of steel pipe. A graduated cylinder was placed under the nozzle and stopwatch was used to measure the discharge. This arrangement was made available for each nozzle mounted on boom sprayer.

Set up for droplet size analysis :

For determination of droplets size of each sprayer, a blue colored dye was mixed with water and the impression of droplets was taken on glossy paper. Three glossy papers were stapled on each position to observe the deposition of the droplets. After making all adjustments, set-up of the equipment was run for 30 minutes before actually starting the experiment. In order to achieve uniform exposure of crop to the spraying the set up was started 3m before the canopy and was collected on the sample cards of glossy paper, sample cards of size 62 mm x 44 mm were used to collect the sample. Royal blue indigo dye was mixed with water to prepare a colored spray solution. The colored spray was allowed to fall onto the sample glossy photographic paper.

After the experiment, the sample cards were carefully removed and then taken for further analysis in the laboratory. Digital image analyzer was used to determine stain diameter and droplet size which analyze these samples after 24 hours of application to ensure that droplets had stopped spreading.

Laboratory performance evaluation of boom sprayer :

Measurement of liquid distribution :

AAMS spray scanner was used to measure the liquid distribution from the spray boom. It was measured for 0.9 l/min discharge and pressure of 689.5 kPa (Anonymous, 2009). Spray scanner was placed on the reel. It automatically moves and measures liquid distribution under spray boom. The liquid distribution under a spray boom reflects the quality of the sprayer and its distribution from all the three section of the spray boom. The distribution was measured with a high precision and was independent of the operator. It has 12 V rechargeable battery. The data was stored in memory box of the spray scanner and is connected with AAMS software already installed in computer for analysis.

Pressure and discharge measurement of nozzles :

Pressure and discharge measurement of the boom sprayer was done under the steady operation in the laboratory. The pressure and discharge was measured from left to right of the boom for each individual nozzle. The pressure was measured with manometer tester. The discharge was measured with the help of graduated cylinder and a stop watch for one minute.

Measurement of droplet deposition :

Laboratory experiments were conducted to study the effect of different experimental variables on spray deposition at different location of leaves and their position.

Instrument used to analyze the droplet spectrum :

Image pro plus most powerful electronic imaging program was used for analysis of glossy paper. The advanced image processing features of the program are provided through the Microsoft Windows, consisted of microscope connected to computer software through Graphical interface card, which enable us to directly visualize the image on computer screen. These images were then processed in a computer which directly gave droplet size and droplet density.

Data analysis :

The data obtained in different experiments were stored in M.S. Excel and statistical analysis was conducted. The image-pro program was used to calculate the VMD and mean diameter of the droplet spectrum collected on the sample card at a specific location. The data were analyzed on computer using factorial CRD statistical software packages.

After analyzing the data, a set of independent variable giving optimum value of droplet density and size were selected.

■ RESULTS AND DISCUSSION

The results of the present study as well as relevant discussions have been presented under following sub heads:

Laboratory performance of the boom sprayer :

Different experiments were conducted in the laboratory to evaluate the performance of the sprayer. They are discussed as follows:

Measurement of liquid distribution under the spray boom :

Fig. 1 shows the spray liquid distribution pattern in per cent under spray boom. The blue lines and dots show the results of individual flow measurement, the black line and dots show the total mean value of the flow over the boom equal to 100 per cent. Green and red line shows the interval of 20 per cent of the total mean value of the flow. It can be observed from the graph that liquid distribution was close to the total mean value and more liquid distribution was observed within ±20 of total mean value. Also the spray scanner was operated up to boom length of 12 m.

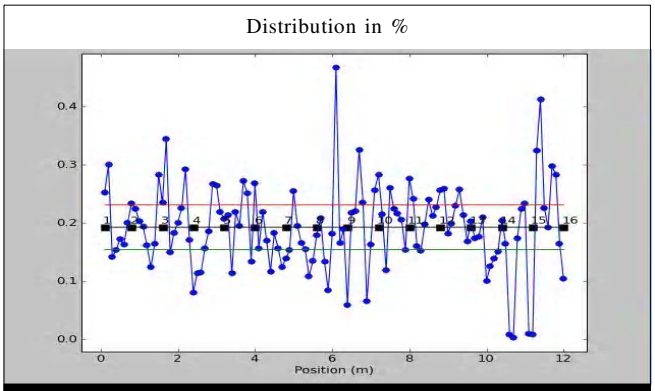

Fig. 1: Liquid distribution under the spray boom for the boom sprayer

Discharge and pressure measurement of nozzles :

For lab testing, the boom sprayer was operated at 689.5 kPa operating pressure. The pressure and discharge reading of nozzles were taken from left to right for each individual nozzle. The results are presented in Fig. 2 and Fig. 3.

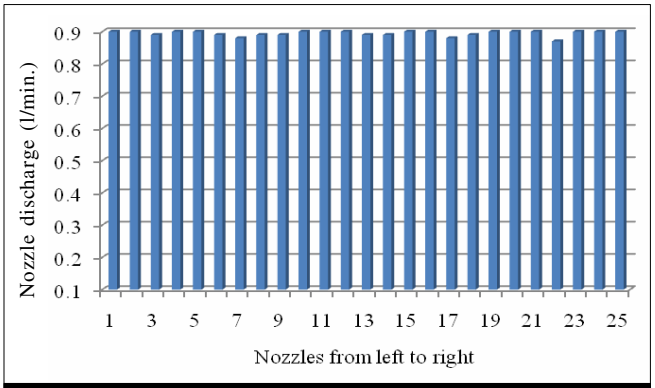

Fig. 2: Nozzle discharge of boom sprayer for 689.5 kPa operating pressure

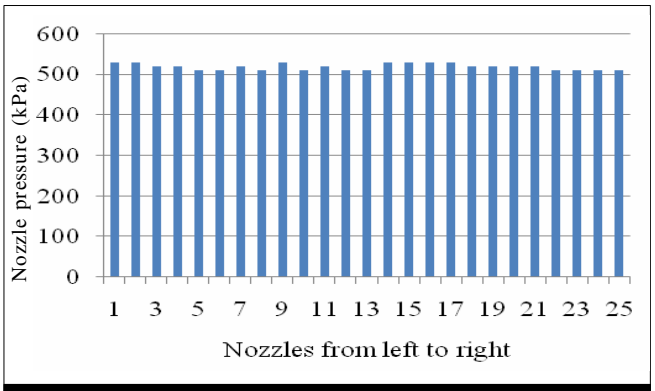

Fig. 3: Nozzle pressures of boom sprayer for 689.5 kPa operating pressure

The nozzle discharge varied from 0.87 to 0.90 l/min. When measured from left to right of boom. The nozzle pressure varied from 510 to 530 kPa. Therefore, the performance of the boom sprayer was near to perfection.

Effect of nozzle discharge rates and pressures on droplet size (VMD), droplet density (DD) and uniformity co-efficient (UC) of boom sprayer :

Effect on droplet size (VMD) :

The VMD of boom sprayer varied from 122.53 µm to 284.80 µm at nozzle discharge rates of 0.45, 0.70, 0.90 and 1.35 l/min and nozzle pressure of 275.8, 413.7, 551.6 and 689.5 kPa. The smallest droplet size was at the nozzle pressure of 689.5 kPa and nozzle discharge of 0.90 l/min and the largest size was at a nozzle pressure of 275.8 kPa and discharge rate of 0.45 l/min. The droplet sizes (VMD) were very close to the effective range of 150 µm to 250 µm (Mathews, 1979). The droplet size for top upper and top lower plant position were found as 181.55 µm and 174.47 µm, bottom upper and bottom lower were found as 172.80 and 169.71, whereas for bottom upper and bottom lower it were 165.68 µm and 155.44 µm. Fig. 4 shows the droplet size for three different locations. Optimum droplet size (*i.e.* between 150 to 250 µm)

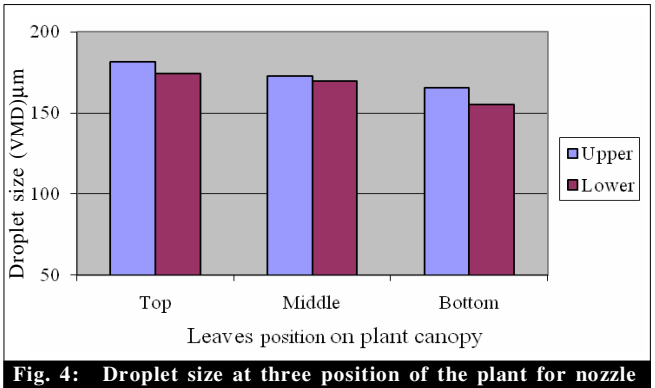

Fig. 4: Droplet size at three position of the plant for nozzle discharge rate of 0.90 l/min and pressure 689.5 kPa for boom sprayer

was obtained for nozzle discharge rate of 0.90 l/min and nozzle pressure of 689.5 kPa.

Effect on uniformity co-efficient (UC) :

The uniformity co-efficient of sprayer was found in the range 0.73 to 2.10. The uniformity co-efficient for top upper and top lower plant position were 1.23 and 1.23, middle upper and middle lower were 1.20 and 1.13, whereas for bottom upper and bottom lower plant position they were 1.12 and 0.99. Fig 5 shows the uniformity co-efficient of boom sprayer for 0.90 l/min nozzle discharge and 689.5 kPa operating pressure.

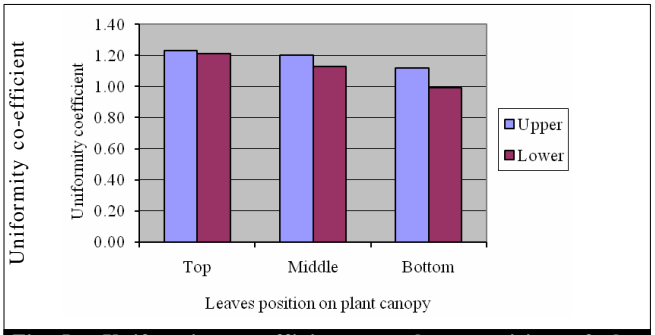

Fig. 5: Uniformity co-efficienct at three position of the plant for nozzle discharge rate of 0.90 l/min and pressure 689.5 kPa for boom sprayer

Effect on droplet density (*DD*) :

The droplet density of boom sprayer varied from 13-29 drops/cm^2. The droplet densities for top upper and top lower position were 29 and 23 drops/cm^2, middle upper and middle lower position were 20 and 19 drops/cm^2, whereas for bottom upper and bottom lower plant position it were 19 and 17 drops/cm^2. Fig 6 shows droplet density for various plant positions.

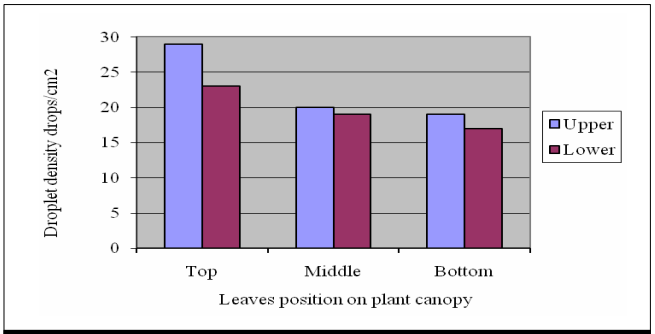

Fig. 6: Droplet density (DD) at three position of the plant for nozzle discharge rate of 0.9 l/min and pressure 689.5 kPa for boom sprayer

Conclusion :

- The liquid distribution under the boom sprayer was within the ±20 per cent of total mean value.
- Pump gave discharge of 49.80 lit/min for 950 rpm.
- The discharge and pressure of the boom sprayer was nearly uniform in all nozzles.
- Droplet size (VMD) of the boom sprayer ranged from 155.44 to 181.55 µm
- Droplet density (DD) of the boom sprayer ranged from 17 to 29 drops/cm^2
- The uniformity coefficient of the boom sprayer ranged from 0.99 to 1.23.
- The nozzle pressure of 689.5 kPa and nozzle discharge rate of 0.90 l/min was found more significant for uniform spraying.

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