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Laboratory performance evaluation of 12 m tractor mounted boom sprayer for cotton crop

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■ ***Abstract*** **:** Cotton farming is a popular agri-business in India. It is one of the principal commercial crops in India. India is second largest producer of cotton in the world. The major reason for pesticide loss is use of inefficient spraying machines, which are unable to maintain specified nozzle pressure, nozzle discharge, nozzle height that affects spray pattern, droplet size, spray uniformity etc. The proposed sprayer was therefore tested using the instrument spray scanner, pump tester, pressure gauge tester, manometer adapter and droplet analyzer in the laboratory for cotton crop. Different tests were conducted such as liquid distribution under spray boom; pump testing, calibration of pressure gauge and droplet deposition on cotton crop. Liquid distribution under spray boom was scattered from average value, maximum pump discharge was 35.94 L/min at 950 rpm, and pressure gauge gave 520.6 kPa pressures for 600 kPa pressure of master gauge. The VMD, UC and DD for nozzle discharge 0.9 l/min and pressure 689.5 kPa was from 130.9-206.39 µm, 1.18-1.31 and 11-27 No/cm^2, respectively.

■ ***Key words*** **:** Boom sprayer, Spray scanner, Pumps tester, 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. Early trend indicates better area coverage in North zone Punjab and Rajasthan. There are reports of reversal of trend of area shift in favour of cotton, in these states but the trend in major states like Gujarat and Maharashtra it is not so (AICCP Annual Report, 2007-2008).

Cotton is one of the principal commercial crops in India. 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.

■ METHODOLOGY

The proposed study was conducted with the technical assistance of ASPEE, Agricultural Research and Development Foundation, Mumbai. A 12 m tractor mounted boom sprayer was selected for study and its performance was evaluated in the laboratory (Table A). The power for the operation of the boom sprayer was supplied by the power take-off (PTO) shaft of the tractor. The instruments namely, spray scanner, pump tester and master pressure gauge were imported from advanced agricultural machinery systems (AAMS), Belgium. The liquid distribution under a spray boom was measured with spray scanner, flow rate of the pump was measured by pump tester, and pressure gauge was calibrated with master pressure gauge tester. For spray, deposition on cotton crop independent variables were nozzle discharge rates 0.45, 0.7, 0.9 and 1.35 lpm, respectively, while the pressures of nozzle were 275.8, 413.7, 551.6 and 689.5 kpa. The experiment was replicated three times under laboratory condition on cotton crop.

Experimental set-up:

Different set ups 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. In laboratory, the nozzles were tested for cone angle and

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	Brass Hollow cone, 25

discharge on patternator at working pressure 689.5 kPa.

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 centre of the channels of scanner. The set up for spray scanner test is shown in Fig. A.

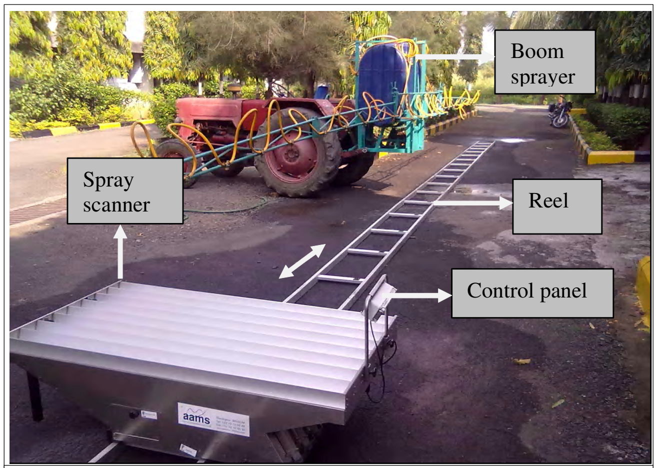

Fig. A : Set up for spray scanner test

Set up for pump testing:

The AAMS pump tester is an instrument to determine the flow rate of the pump on agricultural sprayers. The HTP pump of the boom sprayer was dismounted from the sprayer and coupled with 5 hp motor with the help of two V belts. The suction and delivery hoses of pump tester were connected to suction and delivery of pump. The tank was filled with water and suction and delivery hoses were connected to tank so that water sucked from suction pipe will be received back in tank through delivery hose. The assembly of pump tester, motor and HTP pump is shown in Fig. B.

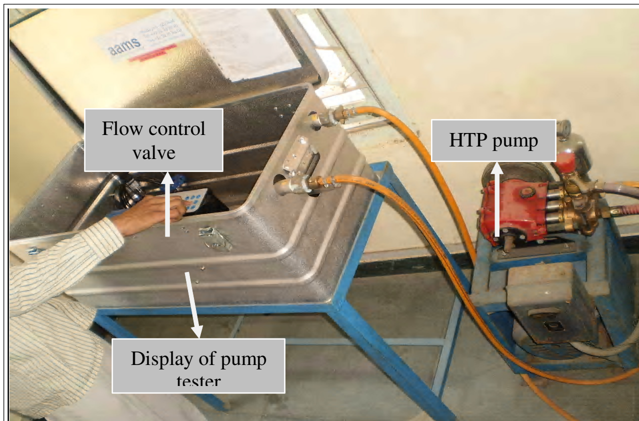

Fig. B : Set up for pump testing

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 pressure gauge testing:

The pressure gauge of the boom sprayer was calibrated with AAMS master pressure gauge. The pressure gauge of the sprayer was dismounted and coupled with the AAMS master gauge. The oil level of the pressure gauge tester was kept sufficient to create pressure.

Set up for droplet size analysis:

For determination of droplets size of each sprayer, a blue coloured 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 coloured spray solution. The coloured 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 analyzed 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 sections 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 were stored in memory box of the spray scanner and connected with AAMS software already installed in computer for analysis.

Measurement of flow rate of pump:

The flow for a certain pressure can be recorded in the monitor for 100 different measurements. These data can be checked on the monitor, printed with the printer, or transferred to a PC with special software. To regulate the pressure, 2 valves were incorporated in the tubing. An electronic pressure sensor was mounted in the circuit to registrate the pressure of the pump. High precision sensors were mounted with an accuracy of 0.5 per cent (flow rate and pressure sensors). The pump tester was built in a rigid box with tubes made of stainless steel. A pressure safety valve was also installed to avoid damage during operation due to high pressure.

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 a graduated cylinder and a stop watch for one minute.

Pressure gauge tester:

AAMS pressure gauge tester was used to check the pressure gauge of the sprayer. Commercial pressure gauge was calibrated with AAMS master pressure gauge tester for known pressures ranging from 100-600 kPa.

Measurement of droplet deposition:

Laboratory experiments were conducted to study the effect of different experimental variables on spray deposition at different locations of leaves and their position. The following independent and dependent variables were selected study:

Independent variables:

Nozzle discharge rates- 0.45, 0.70, 0.90 and 1.35 lpm

Nozzle pressures- 275.8, 423.7, 551.6 and 689.5 kPa.

Dependent variable:

Spray coverage: (Upper and Lower sides of leaves)-Plant position at top, middle and bottom.

Droplets deposition-Volume median diameter (VMD), Uniformity coefficient (UC) and Droplet density (DD).

Plant arrangement:

The cotton plants were raised in the polyethylene bags. During the laboratory experiments, plants were raised in the polythene bags by sowing cotton seeds on the same date and giving controlled amount of fertilizer and other treatments to get uniform growth. Spraying experiments were conducted when the plant attained the age of 85 days.

Plant position:

To facilitate the evaluation of spray penetration into the canopy of the cotton plant, the plant was divided into six different positions depending upon the location of the leaves on the plant, where the effect of independent variable on spray deposition was to be observed. The sections were:

- Top position of the plant and upper leaf surface- Position 1, L1.
- Top position of the plant and lower leaf surface- Position 2, L2.
- Middle position of the plant and upper leaf surface- Position 3, L3.
- Middle position of the plant and lower leaf surface- Position 4, L4.
- Bottom position of the plant and upper leaf surface- Position 5, L5.
- Bottom position of the plant and lower leaf surface- Position 6, L6.

Instrument used to analyze the droplet spectrum:

'Image pro plus' most powerful electronic imaging programme was used for analysis of glossy paper. The advanced image processing features of the programme are provided through the Microsoft Windows, consisted of microscope connected to computer software through Graphical interface card, which enables 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-proprogramme 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

Different experiments were conducted in the laboratory to evaluate the performance of the existing boom sprayer

Measurement of liquid distribution under a spray boom:

Measurement of liquid distribution under spray boom was measured for nozzle discharge of 0.9 l/min and operating pressure of 689.5 kPa in the laboratory. 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 average flow over the boom equal to 100 per cent. Green and yellow line show interval of 20 per cent from average value. It can be observed from the graph that the liquid distribution was scattered from the average value and more distribution was out of interval provided. Also the spray scanner was operated up to boom length of 8 m. This may be due to improper overlap of spray between the nozzle and limitation of spray scanner to record the distribution.

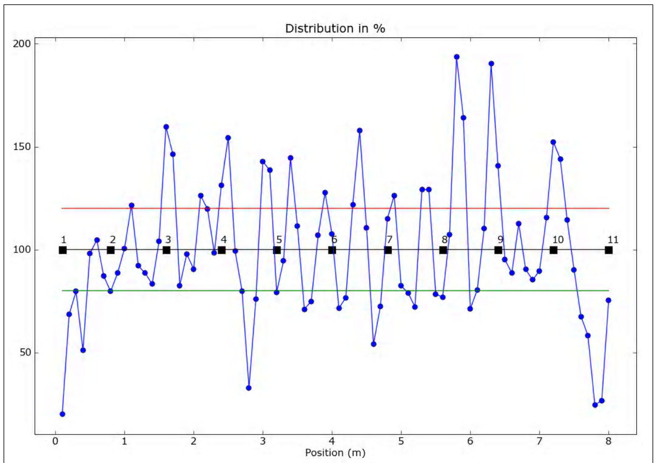

Fig. 1 : Liquid distribution under a spray boom

Measurement of flow rate of the pump:

The pump speeds selected were 800, 850, 900 and 950 rpm for the pump pressures of 275.8, 413.7, 551.6 and 689.5 kPa. At all the selected speeds of pump with increase in pressure, flow rate increases (Hofman, 2004). The minimum and maximum flow rate was found to be 32.40 and 35.94 l/min for 800 and 950 pump rpm, respectively. Fig. 2 shows relationship between HTP pump pressure and flow rate at different pump speeds.

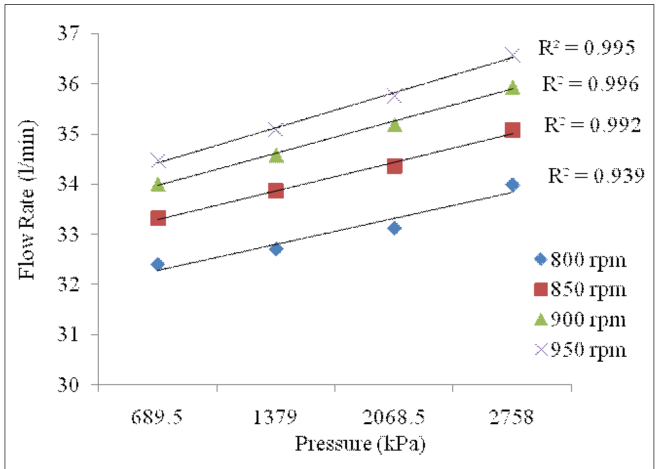

Fig. 2 : Flow rate vs. pressure relationships at different pump speeds

The statistical analysis:

The analysis of variance was done to see the effect of pressure on flow rate at different pump speeds which revealed that pump speed had significant effect on flow rate. A linear relationship was found to have best fit to describe variations in flow rate. The predicted equations with their coefficient of determination values are presented in the Table 1. The general linear equation of second order is as follows:

$$y = mx + c \qquad \text{.........} (1)$$

where,

y = Flow rate (l/min), m= Slope, c= Constant and

x = Pressure (kPa)

This revealed good determination between the predicted and the observed data.

Pressure gauge testing:

The pressure gauge of the sprayer was calibrated with the AAMS master pressure gauge. Fig. 3 shows the calibration of pressure gauge. The maximum and minimum commercial pressure gauge reading was observed as 520.6 and 80.5 kPa for 600 and 100 kPa pressure of AAMS master gauge, respectively. The commercial pressure gauge of the existing boom sprayer showed linear relationship with AAMS master gauge having errors for each pressure.

Discharge and pressure measurement of nozzles:

For lab testing, the boom sprayer was operated at 689.5 kPa operating pressure (Nalavade, 2008). The pressure and

Table 1 : Predicted equations and coefficient of determination values for flow rate

Pump parameter	Pump rpm	Regression coefficients		Coefficient of co-relation (R^2)	Computed F
		m	c		
Flow rate (l/min)	800	0.703	33.71	0.995	235.377**
	850	0.643	33.32	0.996	434.724**
	900	0.573	32.72	0.992	5.159×10^4**
	950	0.519	31.75	0.939	2.58×10^4**

** indicates significance of value at P=0.01

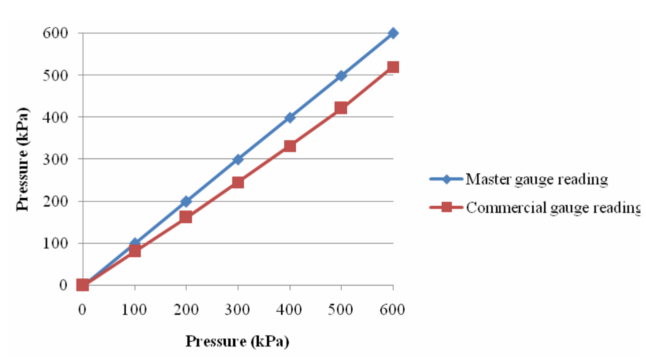

Fig. 3 : Calibration of commercial pressure gauge with AAMS master gauge for existing boom sprayer

discharge of nozzles were taken from left to right for each individual nozzle.

Fig. 4 shows nozzle discharges of existing boom sprayer for 689.5 kPa operating pressure. The nozzle discharge varied from 0.53 to 0.77 l/min. maximum discharge was observed in the nozzle 12 to 15 ranging from 0.72 to 0.77 l/min. Fig. 5 shows nozzle pressures of existing boom sprayer for 689.5 kPa operating pressure. The nozzle pressure varied from 137.9 to 206.85 kPa. Maximum pressure was observed in the nozzle 12 to 16 ranging from 241.32 to 248.22 kPa.

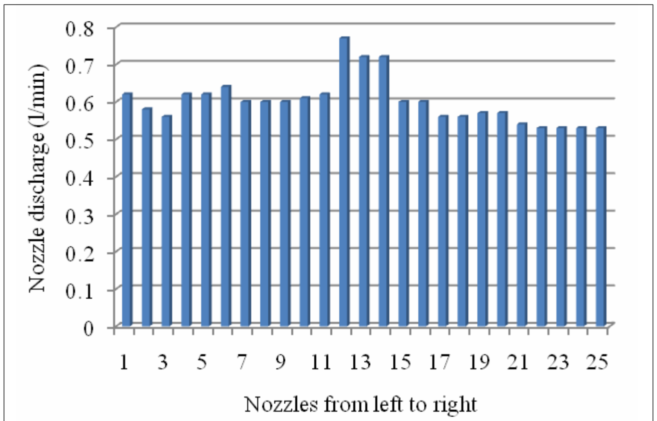

Fig. 4 : Nozzle discharge of existing boom sprayer for 689.5 kPa operating pressure

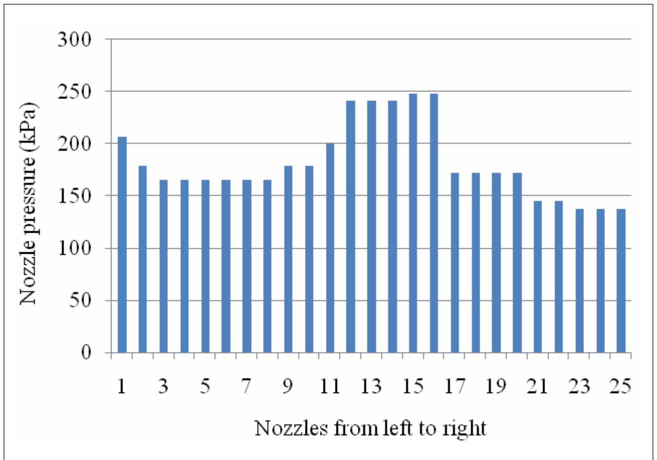

Fig. 5 : Nozzle pressures of existing boom sprayer for 689.5 kPa operating pressure

Effect on droplet size (VMD):

The VMD of boom sprayer varied from 130.9 µm to 294.41 µm at nozzle discharge rates of 0.45, 0.7, 0.9 and 1.35 l/min and nozzle pressure of 275.8, 413.7, 551.6 and 689.5 kPa, respectively. Smallest droplet size was observed at nozzle discharge of 0.9 l/min and pressure 689.5 kPa. The droplet size for top upper and top lower plant position were found 209.36 and 199.5, bottom upper and bottom lower were found as 178.67 and 160.5, respectively whereas for bottom upper and lower it were 145.3 and 130.9 (Fig. 6).

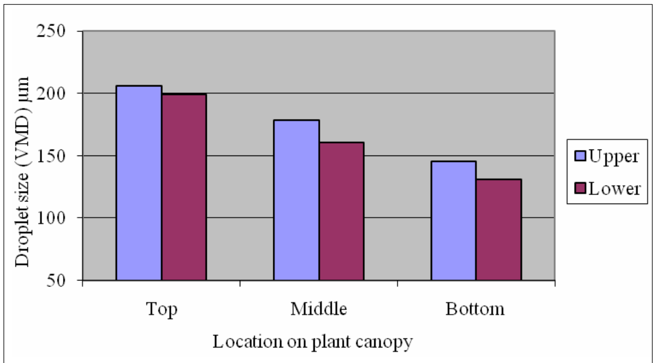

Fig. 6 : Spray deposition on plant canopy at nozzle discharge rate 0.9 l/min and pressure 689.5 kPa

Effect on uniformity coefficient (UC):

The uniformity coefficient of sprayer was found in the range of 1.18-1.31. The uniformity coefficient for top upper and top lower plant position were 1.34 and 1.29, middle upper and middle lower were 1.25 and 1.23, whereas for bottom upper and lower plant position it was 1.19 and 1.18 (Fig. 7)

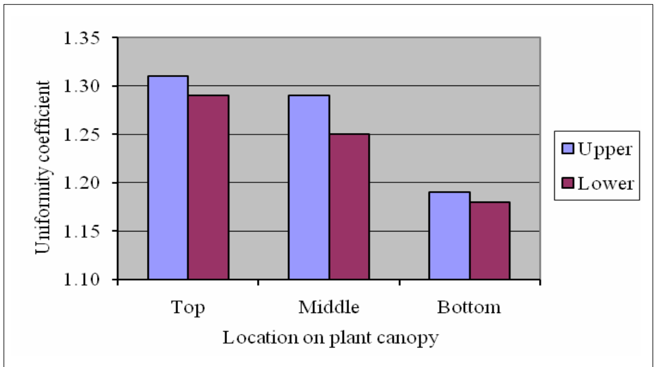

Fig. 7 : Uniformity deposition at nozzle discharge rate 0.9 l/min and pressure 689.5 kPa

Effect on droplet density (DD):

The droplet density of boom sprayer varied from 11-27 No/cm^2. The droplet densities for top upper and lower position were 27 and 19 No/cm^2, middle upper and lower position were 17 and 14 No/cm^2, whereas for bottom upper and lower plant position it was 12 and 11 No/cm^2 (Fig. 8). Bouse (1994) and Zhang *et al.* (1994) have also made some observations on measuring nozzle spray uniformity and nozzle type. Herbst and Wold and Padmanathan and Kathirvel (2007) have also contributed some informations on broom sprayers.

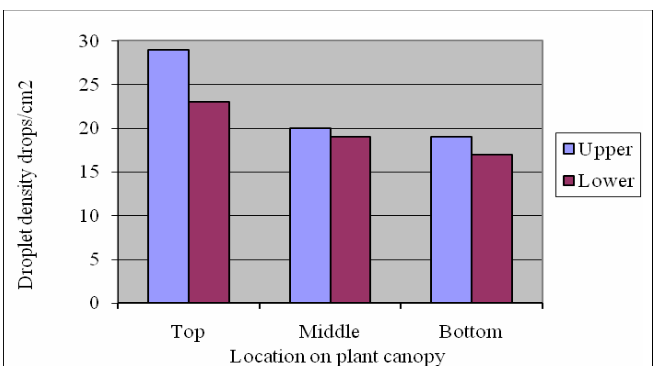

Fig. 8 : Droplet density at nozzle discharge rate 0.9 l /min and pressure 689.5 kPa

Conclusion:

– The liquid distribution under a spray boom was scattered from average distribution and more flow was found out of interval provided.

– Pump gave discharge of 36.50 lit/min for 950 rpm.

– Pressure gauge showed variation in pressure when calibrated with AAMS master pressure gauge.

– Mean nozzle discharge and pressure of nozzles was found 0.600 l/min and 182.1 kPa, respectively.

– The VMD, UC and DD for nozzle discharge 0.9 l/min and pressure 689.5 kPa ranged from 130.9-206.39 μm, 1.18-1.31 and 11-27 No/cm^2, respectively.

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