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Design Modifications of a Horizontal Spray Patternator

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ABSTRACT: The performance evaluation of nozzles used in agricultural sprayer boom is done with spray patternator. The present study was conducted to design and modify a spray patternator, which can be used to evaluate hydraulic spray nozzles. A spray patternator was designed and modified to test two nozzles simultaneously with provision to change the setting height from patternator surface and spacing between the nozzles with varying pressure settings. The 12V DC operated diaphragm pump with self-priming system was used which was capable of building pressure up to 6.8 bar. A recirculation pump was used to return the water from sump to reservoir and a to prevent spray drift during experiment, a drift cover was developed. An automatic pressure control system was developed with a pressure sensor, motor driver and microcontroller.

Keywords: Nozzle, Spray patternator, Spray distribution.

INTRODUCTION

Chemical application is a significant agricultural activity, which prevent the loss of a substantial portion of food and fiber crops, a rise in plant diseases, and the degradation of essential natural habitats (Rice *et al.,* 2007). Liquid chemicals include fertilizers, pesticides and growth regulating hormones (Srivastava *et al.,* 1993). Developing spraying machines involves determining the nozzle characteristics as well as the pump discharge in order to ensure that desired application rate and coverage are not exceeded. The study of nozzle characteristics is of prime importance in order to reduce the excessive chemical spraying and increase in the efficiency of the spraying system. Nozzle characteristics are analyzed from the spray pattern (Choudhary *et al.,* 2023). Spray patternators, also known as spray pattern analysis systems, are devices used to measure and analyze the spray pattern of various types of liquid sprayers. It can able to supply a required amount of the spray pressure and discharge rate. The quantitative analysis of spray patterns is very important for nozzle design, selection and quality control, because the spray angle, the uniformity and the symmetry of the spray patterns are decisive parameters in practical applications (Yang, 2000). The importance of spray patternator lies in their ability to ensure that the spray from a given nozzle is evenly distributed and properly calibrated, which is crucial for achieving optimal performance and efficiency. By analyzing the spray pattern, operators can detect any inconsistencies, such as uneven droplet size, coverage gaps, or excessive overlap, and adjust the equipment accordingly (Choudhary *et al.,* 2023). It is desirable to determine an optimal spacing between the nozzles and a proper height from the target so that the spray distribution is as uniform as possible and the overlap regions do not result in areas of high concentration (Michael *et al.,* 2014). Keeping these factors in mind, the present study modified a spray patternator to be used for evaluating two nozzles simultaneously with provisions to change the spray height and pressure settings and spacing between the nozzles.

MATERIAL AND METHODS

The present study was undertaken to design and modify the existing horizontal spray patternator. The spray patternator designed and developed at Farm Machinery Laboratory of Agricultural and Food Engineering Department, IIT Kharagpur. The major components of the modified spray patternator were drift cover, nozzles with pressure gauge, spray lance, flow control valve, test tubes and collection tray (Fig. 1). The developed water circulation system with major components is depicted in Fig. 2.

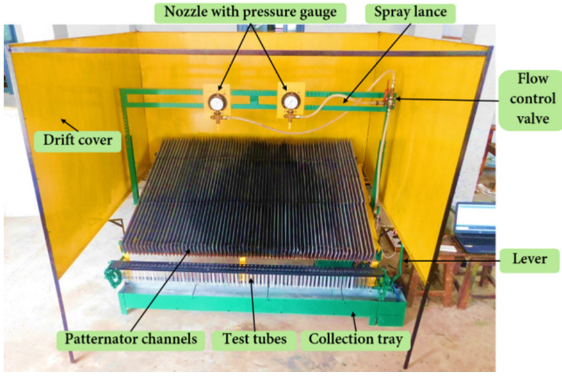

Fig. 1. Major components of the modified horizontal spray patternator.

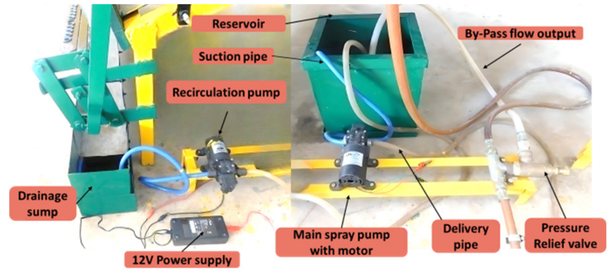

Fig. 2. The developed water circulation system.

Main Spray Pump. The quantity of pesticide application rate varies from crop to crop. Currently, different types of liquid spray equipment are available in the market. The discharge rate and spray angle are mainly depending upon the type of spray nozzle and operating pressure. The pressure fluctuation in the nozzle should be within the range of ±2.5%. In the existing patternator, the pressure fluctuation was ±10%. A new water pump was used which is a positive displacement type with self-priming the characteristic (Fig. 2). The available piston pump was replaced with a self-priming diaphragm pump in order to get constant pressure during operation. The discharge rate of pump is a function speed of the motor which was controlled through a DC voltage supply. Thus, by changing the input voltage, the discharge rate and pressure was varied as per requirement.

Estimation of capacity of main spray pump

Number of nozzles on the test set up = 2

Maximum discharge rate of each nozzle = 1200 ml/min

Total discharge rate required for nozzles = 1200 × 2 = 2400 ml/min

Assuming 5%, leakage loss in pipe line = (2400 ×5)/100 = 120 ml/min

Total discharge rate required = 2400 + 120 = 2520 ml/min

Volumetric efficiency of pump = 90 %

Capacity of pump = 2520 /0.90 = 2800 ml/min

Maximum working pressure = 6 bar

Nozzle control valves. Independent control of the two nozzles was not possible due to the use of single valve for flow control. In modified design, a T- joint is used to supply water individually to each nozzle and two flow control valves are provided with one in each pipeline to control the flow of water separately. A plate with holes was attached with each nozzle to increase or decrease the height of nozzle from patternator surface and to change the spacing between the nozzles. Nozzle testing at various positions of the boom using individual control of nozzles.

Recirculation pump. In existing system, there was no provision for recirculation of water from sump to reservoir. A self-priming pump was used for recirculation of water from sump to reservoir (Fig. 2). The pump then removes the air and circulate water. The pump was selected according to the requirement of flow and availability. The pump was driven by DC supply.

Development of provision to prevent spray drift. Spray drift is the movement of a pesticide through the air, during or after application, to a site other than the intended target. Drift is considered to be the most challenging problem facing applicators and pesticide manufacturers. In existing system, there was no provision to prevent effect of drift on spray coming from nozzles. Spray distribution of nozzles was affected by drift. A drift prevent cover was developed to minimize the drift effect on spray distribution of nozzles. The drift cover is made of GI sheet of 1 mm thickness. Vertical and horizontal angle bars (25mm × 3 mm) are used to support the sheet of cover.

Pressure relief valve. The pressure relief valve was used to protect a hydraulic system when the pressure is reached higher than the working pressure of system. In this system, the pressure relief valve is used to control the pressure from 0-10 kg/cm^2. The pressure in pressure relief valve is set by using the adjustment screw (Fig. 2).

Automatic pump control system. Automatic pump control system includes a microcontroller, motor driver and pressure sensor. Pressure sensor sense the pressure mechanically and gives an output signal to the microcontroller. On the basis of output of pressure sensor, input voltage was decided which is given by using a motor diver to the motor pump assembly. When the input voltage of the pump motor assembly is changed the discharge of pump changes and nozzle pressure also changes.

Reservoir, sump and collecting tray. The reservoir, sump and collecting tray were designed and fabricated earlier and was available in Farm Machinery Laboratory. The flow requirement was 2.8lpm to conduct the test of two spray nozzles at a time. Reservoir capacity is 15 l. Uniform wetting of patternator was achieved before the test. The dimensions of reservoir were 25×25×25 cm. The length of collecting tray is 190 cm and width is 15 cm. Slope of the collecting tray was 2% to allow water to flow towards the sump.

RESULT AND DISCUSSION

Pressure of main spray pump vs input supply voltage. An automatic pump control system was developed. The relationship between main spray pump input voltage and the pressure is plotted in Fig. 3. It can be seen that there is a linear relationship between the pressure and voltage. The microcontroller has to adjust the input voltage in order to obtain a set pressure.

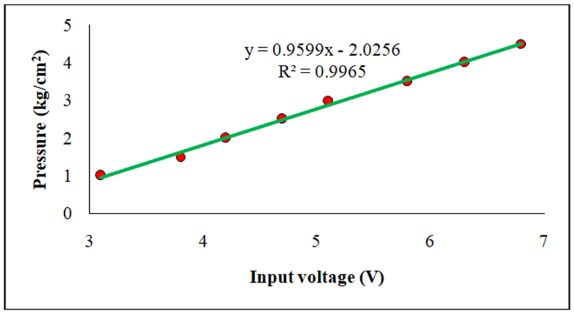

Fig. 3. Main spray pump vs input supply voltage relationship.

Discharge rate and spray angle. A hollow cone nozzle with 1 mm orifice diameter was evaluated to measurement of discharge rate and spray angle at pressure from 215.75 to 333.43 kPa. The discharge rate of a nozzle measured in mili-liter per minute. It was measured by using a 500-ml capacity cylindrical jar over a given interval of 1 minute. For measurement of spray angle, a simple two leg protractor was used. It was observed that the discharge rate and spray angle increase as increase in pressure by changing the input voltage of the pump (Fig. 4 and 5). This was observed because the operating pressure was directly proportional to the square root of the discharge rate (Kepner *et al.,* 2005). As the operating pressure increased the velocity of flow was also increased, hence discharge rate was found to be increased with increased pressure (Shashi *et al.,* 2005). Similar results were reported by Iqbal *et al.* (2005); Kathirvel *et al.* (2002).

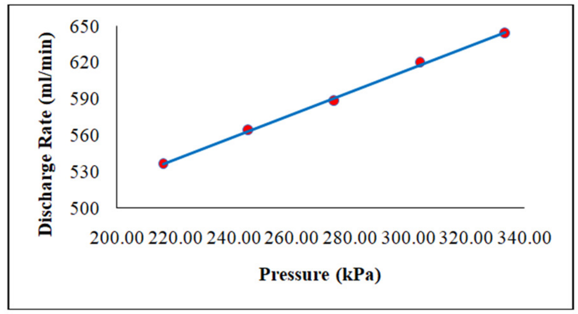

Fig. 4. Pressure-discharge rate relationship for hollow cone nozzle.

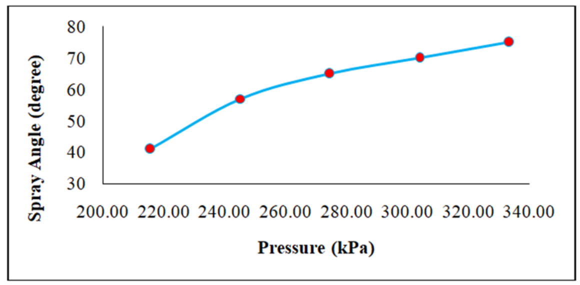

Fig. 5. Pressure-spray angle relationship for hollow cone nozzle.

Spray distribution with and without drift cover. For measurement of spray distribution, the hollow cone nozzle with 1 mm orifice diameter evaluated with or without drift cover. The collection period of spray volume was 15 sec, boom height was 50 cm and pressure were varied from 215.75 to 333.43 kPa. The test was carried out as per the IS 10064: 1982.The spray distribution pattern of hollow cone nozzle with orifice size 1 mm with and without drift cover is depicted in Fig. 6 (a and b). It was observed that nozzle with drift cover gives more uniform spray distribution than without drift cover.

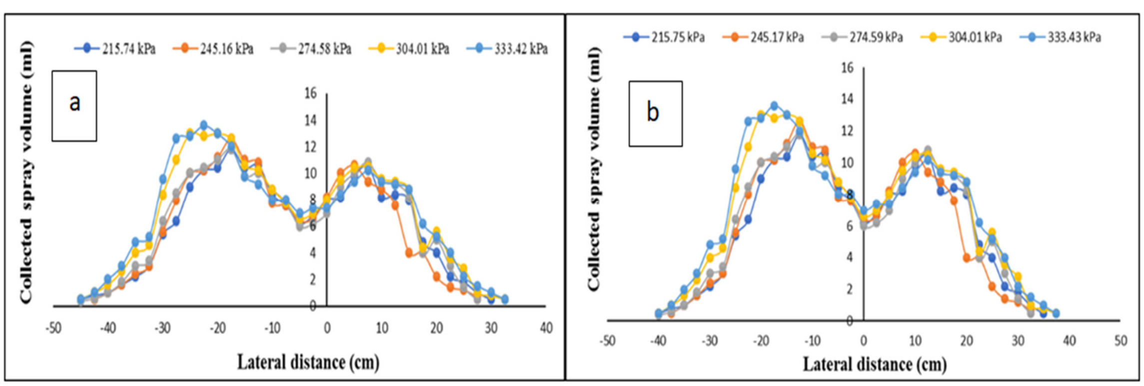

Fig. 6. Spray distribution pattern of hollow cone nozzle with 1 mm orifice and with (a) drift cover (b) or without.

CONCLUSIONS

The result indicated that there is linear relationship between input voltage and pressure and the working pressure of nozzle is constant. The result indicated that the pressure of nozzle affects the operational parameters such as discharge rate, spray angle and spray distribution. As pressure increases the discharge rate, spray angle and spray swath of liquid spray also increase. Overall, the benefits of modifying an existing horizontal spray patternator can be significant, and can contribute to improved productivity, profitability, and overall performance in a variety of industries that rely on liquid spraying applications. Overall, spray patternators play a vital role in ensuring the performance and reliability of various liquid spraying applications. They enable operators to fine-tune their equipment for optimal efficiency, while also reducing waste and improving overall productivity.

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Conflict of Interest. None.

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