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Performance Evaluation of NMD and NTM Nozzle Used for Agricultural Drone Spraying

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Abstract **-** In plant protection system, uniformity of spray liquid application is most important to avoid adverse effects of pesticides on environment and crop injury. A spray patternator was developed to assess the spray liquid application rates for different types of nozzles used in drone spraying. The spray distribution pattern for NMD and NTM nozzle was evaluated under various working pressures and nozzle height using the patternator made by 31 channels, each 6 cm width at the top and 5 cm depth. The factors viz., nozzle type (NMD and NTM Nozzle), nozzle height (200, 300, 400, 500 and 600 mm), working pressure (2, 4, 6, and 8 kg/cm^2), and blower velocity (1.4-1.5 km/h) were selected for the investigation. The experiments were conducted with combinations of different levels of variables. The selected nozzles discharge rate gradually increases with increasing pressure, and the distribution pattern shows that discharge attains a maximum value near the centre of the patternator and as the distance from the centre increases, the spray volume received by the channels decreases. The maximum discharge rate for the NTM nozzle is 1873.0 ml/min, and similarly, for NMD nozzle, the maximum discharge rate 1470.0 ml/min at a working pressure of 8.0 kg/cm^2. In addition, the mean value of swath width increases with an increase in working pressure for both the nozzles. This evaluation supports the use of NMD and NTM nozzle in drone spraying application to improve spray distribution.

Index Terms - crop, drone spraying, patternator, pressure.
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INTRODUCTION

The primary aim of crop protection equipment (sprayers) is the reduction in population of developmental stage of pest which is directly responsible for damage within individual fields and is most efficient when the chemical is applied economically on a scale dictated by the area occupied by the pest and the urgency with which the pest population has to be controlled taking the environment into consideration [1]. Over 99 percent of the applied chemical moves into the eco-system to contaminate the land, water and air [2]. It was reported that 80 per cent of the total pesticide applied to plants may eventually reach the soil, where it can cause major changes in the populations of non-target species such as earthworms [3]. The performance of agricultural spray nozzles is widely based on the droplet size and velocity distributions within the spray area, wind characteristics and the spray volume distribution pattern [4], [5]. Spray testing under realistic pressure conditions is quite challenging. Many obstacles must be overcome in optimizing the test setup and choosing the right processes for nonintrusive measurement procedures [6], [7] and [8]. If optimal operating conditions are not ensured, there is a likely rise of associated field problems like non-uniformity, drift, and evaporation through airborne are, leading to poor efficiency of costly pesticides [9]. The different factors responsible for uniform spray distribution of chemicals across the field are nozzle pressure, height, spray angle, speed of travel, spacing between the nozzles, droplet size, etc. that affects the quality and quantity of spraying. The proper selection of a nozzle type and size is essential for proper pesticide application. The nozzle is a major component in determining the amount of spray applied to an area, the uniformity of application, the coverage obtained on the target surface and the amount of potential drift. Spray deposition on the plant canopy, soil surface or on flying insects takes place by gravitational sedimentation or inertial impact, or a combination of both processes [10], [11]. The effects of nozzle positioning on the spray deposit uniformity and determined the co-efficient of variation in distribution across the spray pattern for different nozzle orientations at fixed nozzle spacing. [12]. The nozzles oriented horizontally and down (vertical downward discharge) had lower spray pattern displacement values than that when oriented vertically down and facing rearward (horizontal discharge) [13]. To standardize the nozzle and its characteristics, a test setup was developed to evaluate nozzles used with sprayers.

MATERIALS AND METHODS

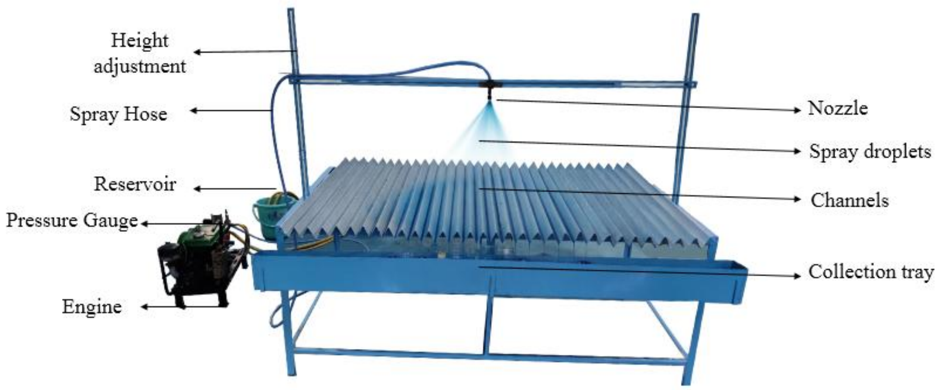

FIGURE 1. SPRAY PATTERNATOR

The quantitative and qualitative evaluation of spray application based on deposit and coverage measurements on artificial targets is relatively simple and fast compared with field experiments [14]. Spray patternator where one or several spray nozzles are mounted above a tilted table with a corrugated surface from which the spray in each channel is collected in graduated cylinders. The volume collected in each cylinder is read and recorded manually or automatically and the data are then entered into a computer for analysis. This process quickly gives accurate characteristics and figures that represent the spray pattern under a spray boom [15]. An experimental patternator setup was developed at Agricultural Engineering College and Research Institute, Kumulur, to study the characteristics and optimization of nozzle operating parameters for various crops in different sprayers.

Spray Patternator

The Patternator, a device used to measure spray distribution, is commonly used to study and correct the spray patterns of agricultural sprayers. Spray patterns and distribution of agricultural sprayers depend on many factors such as: nozzle characteristics and orientation, amount of air assist, travel speed, spray bounce, and micro meteorology during the applications [16], [17] and [18]. The Patternator setup consists of a mainframe, as shown in Figure.1, fabricated with 40×40×5 mm angle iron. The frame was 2100 mm long, 1050 mm wide, with 860 mm in rear and 800 mm in front height to provide the forward slope to the corrugated sheet. Four MS flat pieces of 40 ×5 mm size were fitted at the top side of the frame. Two square rods of 8 mm cross members, each 2100 mm long and 920 mm height, welded to both middle end of the frame.A corrugated GI Aluminium 22 gauge sheet with overall dimensions 1920×1150 mm was used. The patternator was made by 31 number of channels, each 6 cm width at the top and 5 cm depth. The channel was held at the front end of the frame and used to deliver the spray liquid. It was kept inclined (5◦) forward to facilitate water flow to the measuring test tubes. The power generated by the Greaves diesel engine of 3.7 kW capacity. The engine runs at a maximum of 3600 rpm, which is transferred to the piston pump fitted adjacent to the engine through a V-belt drive. A reciprocating type three-cylinder piston pump was provided to deliver the spray liquid at the desired pressure. It is a positive displacement type of pump with varying discharge rates at different pressure ranges. The pump has the following characteristics of normal pressure 0-10 kg/cm^2, maximum pressure 15 kg/ cm^2, 950 revolutions per minute, 3 HP power requirement, and 36 litres per minute suction capacity. The water is drawn from the reservoir tank through the suction hose pipe of the pump, which is fitted with a strainer to avoid dirt and other foreign material entering the pump. The optimum operating pressure should be maintained for water discharge in the form of fine spray through the nozzles. Thus, a control and pressure release valve are fitted between the pump and nozzles to maintain the required pressure. It also directs the excess liquid back to the tank. A pressure gauge is provided on the pump to display the adjusted pressure of the fluid discharged. The complete setup as shown in Figure.1. The channels are aligned perpendicular to the nozzle spray and can be of any convenient length provided that it encompasses the area of the spray. Depth of channels was provided to avoid rebound of spray droplets in to adjacent channels. Top edge of the through dividers should be sharp enough and straight in the horizontal planes. The number of channels may be increased or decreased so that the whole of the spray falls within the patternator. Air supply was maintained a steady output flow using blower. A constant pressure regulator and a pressure gauge are placed as close to the nozzle as possible to maintain uniform pressure. The adjustments were also provided to hold the nozzle at a certain height, and graduated beakers were provided to collect the water from the channels during spraying. The parameters viz. swath width, operating pressure, operating height, and time of spraying were considered to standardize the operating parameters for obtaining better spray volume distribution. The cone nozzle and flat fan nozzle with different operating pressures of 2, 4, 6 and 8 kg/cm^2 were selected for the experiment. The height of nozzle influences the distribution uniformity and width of application area, such that as height increases the width also increases [19]. In order to achieve the uniform coverage or distribution across the swath of the nozzle, the nozzle height must be considered [20], [21]. But the width of spray has to be restricted to the projected width of plant canopy so as to increase the amount of deposition [22], [23]. The nozzles are placed at different heights of 200, 300, 400, 500, 600 mm from the patternator surface. The wind velocity of the laboratory setup was simulated at a range of 1.4 – 1.5 km/h as the drone experience field condition while spraying. The experiment was conducted at each combination of levels of variables, and the observations were recorded.

Nozzle

Nozzle design determines how the physical properties of the spray liquid interact with the characteristics of the spray formed. Spray drift reduction and improved canopy penetration could be achieved with proper nozzle selection and operation parameters for the control of pests [24].

FIGURE 2 NMD AND NTM NOZZLE (0.5 mm Orifice Diameter)

Uniformity coefficient of the spray

The uniformity of spray of the nozzles was evaluated through a patternator. The nozzles were tested at different height and pressure combinations simultaneously. The discharge obtained from different channels of the patternator was measured for both the nozzles. The uniformity coefficient of the spray was calculated by using the formula

$$\text{Uniformity coefficient} = 1 - \sum_{i=o}^{n} \bar{x} - x_1 \qquad (1)$$

Where, x = average volume of spray collected in all beakers, ml; x_1 = volume collected in each beaker, ml; n = No. of beakers

Spray angle

The height of the nozzles from the ground has to be adjusted with respect to the height of plant canopy to get maximum coverage of spray [25], [26]. Since adjusting the height of nozzles during field operation is quite impossible, the nozzle has to be fixed at desired height before entering into the field. According to Indian Standard, IS: 8548 – 1977, the spray angle for each nozzle was calculated based on working width and nozzle height. The spray angle of the nozzle was calculated using the formula

$$W = 2h\tan\frac{\theta}{2} \qquad (2)$$

Where, W = width of spray, mm; h =height of the spray, mm; θ = spray angle in degrees

Discharge rate

Flow of spray fluid and droplet formation is a complex phenomenon characterized by the physical properties and flow rate of fluid [27], [28]. The discharge rate was measured by collecting the discharge fluid (v) for a unit time at one minute (t) in a measuring jar and it was calculated as litre/minute.

$$Q = \frac{V}{t} \text{ (litre/minute)} \qquad (3)$$

FIGURE 3 SPRAY DISTRIBUTION - NMD AND NTM NOZZLE

RESULTS AND DISCUSSION

Effect of spray volumetric distribution on NMD and NTM nozzle with different height and working pressure

The volumetric distributions of the nozzles obtained from the patternator test were presented through trend lines (Figure.4 to Figure. 7) and the effect of height and pressure on the volumetric distribution was studied as shown in Figure.3. Each trend line represents the average discharge collected from the channels of the patternator at a particular height and pressure. The different trend lines in the Figure 4 to 7 account for the change of distribution pattern with height (200 to 600 mm) for NMD and NTM nozzles. Most of the curves attained maximum value near the centre and gradually declined towards the ends. The trends for 600 mm height showed a maximum collection from each channel obtained at all working pressures in NMD nozzle. Similarly, the trends for 400 mm height showed a maximum collection from each channel obtained at all working pressures. It was found from Figures 4 to 7, with an increase in the nozzle height, the curves became more flat and wide, as the height increases, the number of channels collecting the spray increases while the peak discharge value in the channels decreases. This shows that nozzle height influences the swath width. The distribution pattern shows that, discharge attains a maximum value near the centre and as the distance from the centre increases, the spray volume received by the channels decreases.

Effect of working pressure and nozzle on discharge rate

The discharge rate of the two nozzles at different working pressure is shown graphically in Figure 8. It was observed that the mean value of discharge rate increase with an increase in working pressure for both the nozzles. For the NTM nozzle, the discharge rate increased from 1042 ml/min to 1873 ml/min with an increase in working pressure from 2.0 kg/cm^2 to 8.0 kg/cm^2. For the NMD nozzle, the discharge rate increases from 834.8 ml/min to 1470.0 ml/min with an increase in working pressure from 2.0 kg/cm^2 to 8.0 kg/cm^2. The selected nozzles discharge rate gradually increases with increasing pressure, which was in close agreement with the results reported by [29] and [30].

Effect of working pressure and nozzle height on swath width

Swath width of spray pattern generated by NMD and NTM nozzle at different working pressures and from different nozzle heights are shown graphically in Figure.9 and Figure.10. It was observed that the mean value of swath width increases with an increase in working pressure for both the nozzles. For NMD nozzle, the swath width varies from 360 mm to 1140 mm, with an increase in nozzle mounting height of 200 mm to 600 mm above the patternator in working pressure from 2.0 kg/cm^2 to 8 kg/cm^2. For NTM nozzle, the swath width varies from 300 mm to 900 mm with an increase in nozzle mounting height of 200 mm to 600 mm above the patternator in working pressure from 2.0 kg/cm^2 to 8 kg/cm^2.

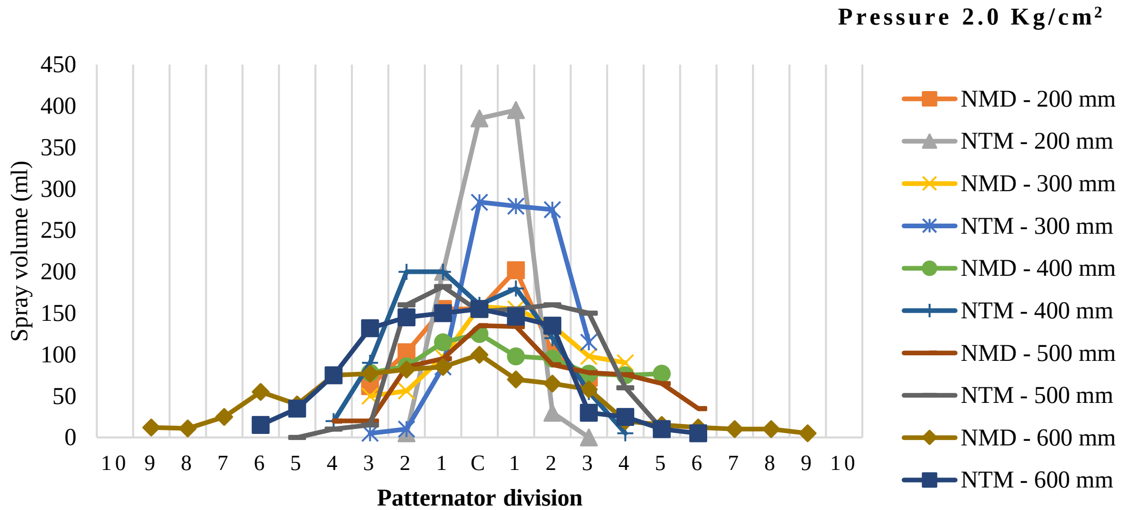

FIGURE 4 SPRAY VOLUMETRIC DISTRIBUTION ON NMD AND NTM NOZZLE WITH DIFFERENT HEIGHTS AT 2.0 kg/cm^2 WORKING PRESSURE

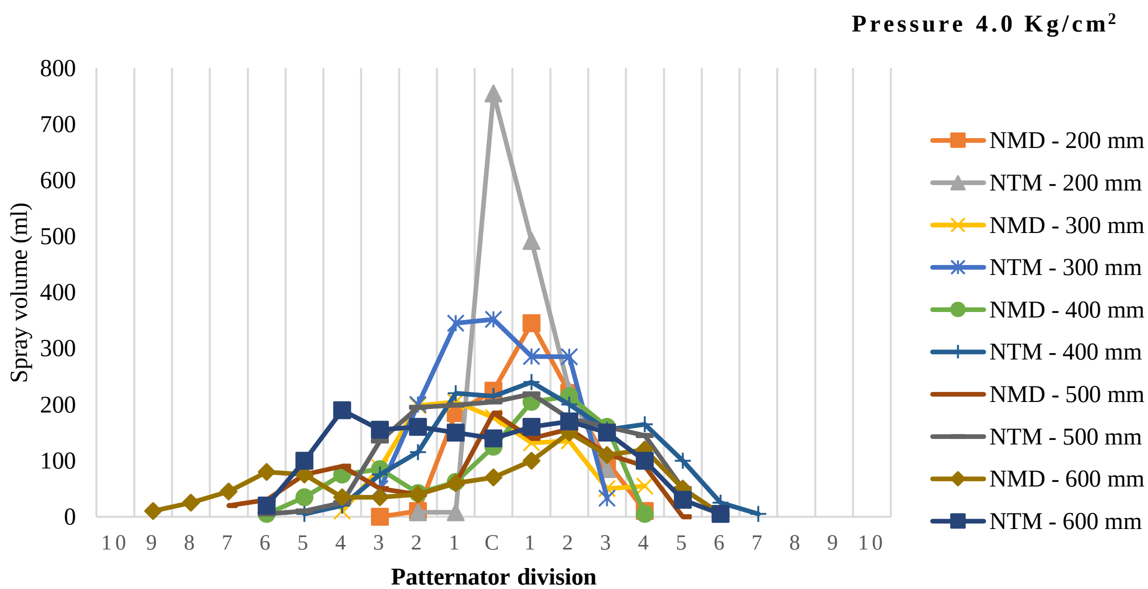

FIGURE 5 SPRAY VOLUMETRIC DISTRIBUTION ON NMD AND NTM NOZZLE WITH DIFFERENT HEIGHTS AT 4.0 kg/cm^2 WORKING PRESSURE

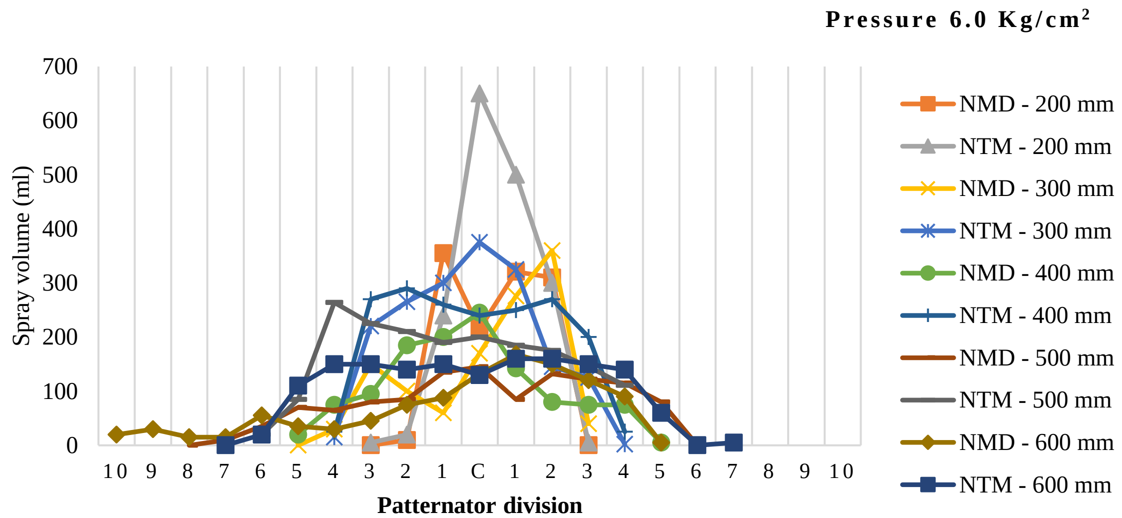

FIGURE 6 SPRAY VOLUMETRIC DISTRIBUTION ON NMD AND NTM NOZZLE WITH DIFFERENT HEIGHTS AT 6.0 kg/cm^2 WORKING PRESSURE

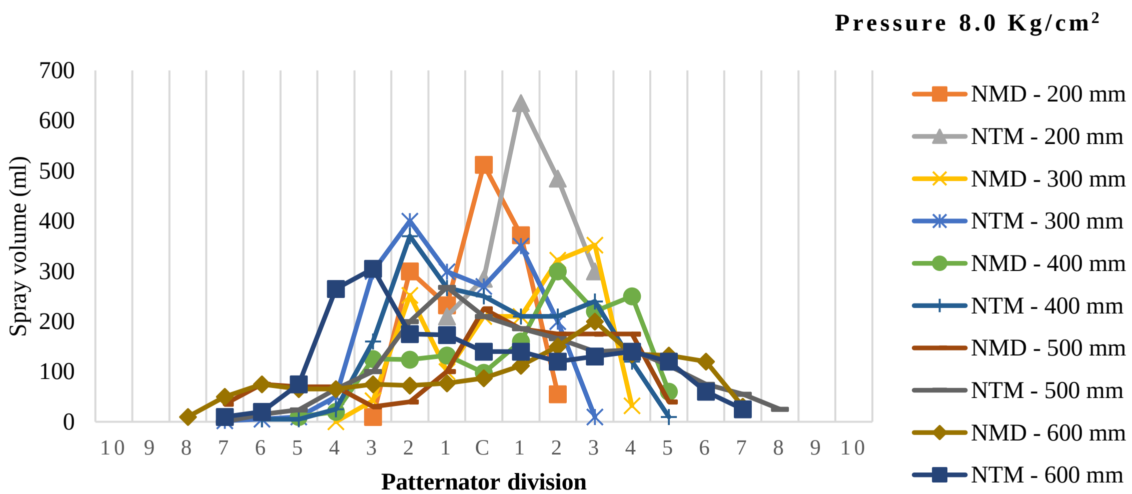

FIGURE 7 SPRAY VOLUMETRIC DISTRIBUTION ON NMD AND NTM NOZZLE WITH DIFFERENT HEIGHTS AT 8.0 kg/cm^2 WORKING PRESSURE

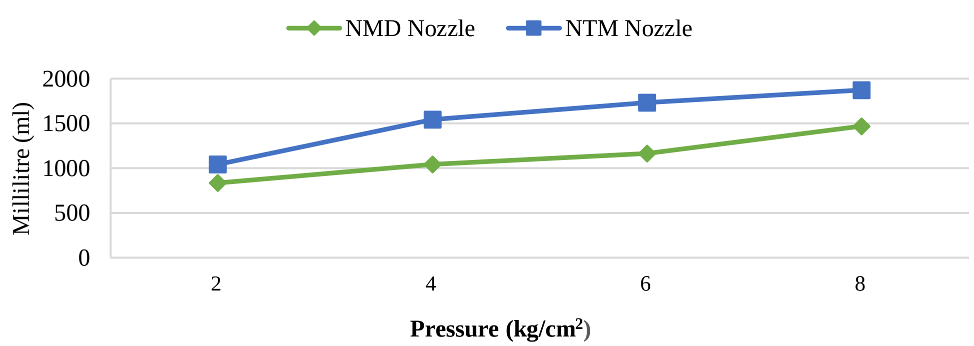

FIGURE 8 EFFECT OF WORKING PRESSURE AND NOZZLE ON DISCHARGE RATE

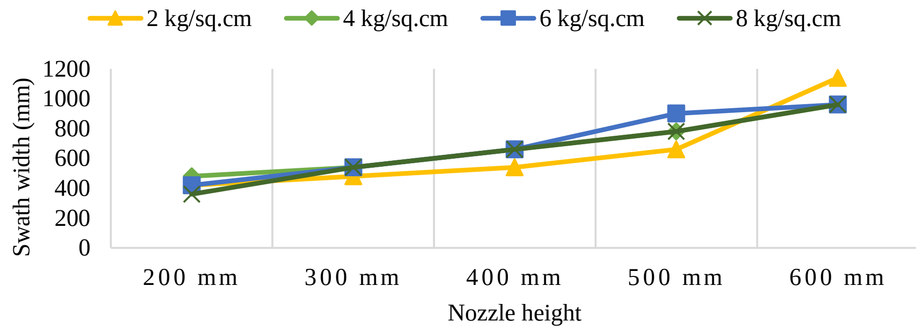

FIGURE 9 EFFECT OF PRESSURE ON SWATH WIDTH OF NMD NOZZLE WITH DIFFERENT OPERATING HEIGHT

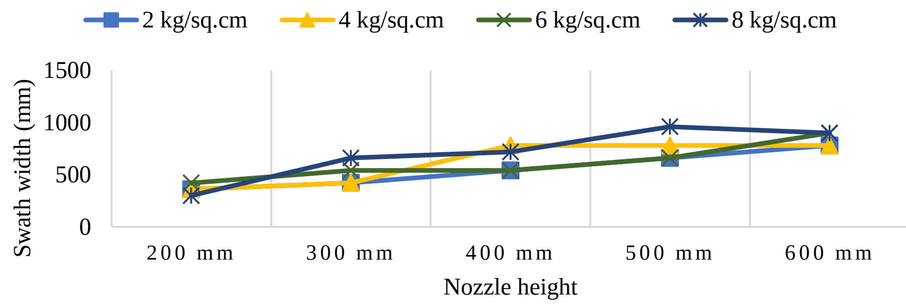

FIGURE 10 EFFECT OF PRESSURE ON SWATH WIDTH OF NTM NOZZLE WITH DIFFERENT OPERATING HEIGHT

Effect of pressure on spray angle of NMD and NTM Nozzle

The effect of operating pressure on the spray angle of the nozzles was described through bar diagrams in Figure.11 and Figure.12. The operating pressure was increased from 2 kg/cm^2 to 8 kg/cm^2, the spray angle for the NMD nozzle existed between 52° to 67°. This slight increment caused due to the minimum operating pressure and height of the nozzle mounting. Similarly, the spray angle for the NTM nozzle existed between 52° to 65°. This slight increment caused due to a gradual increase in operating pressure and height of the nozzle mounting.

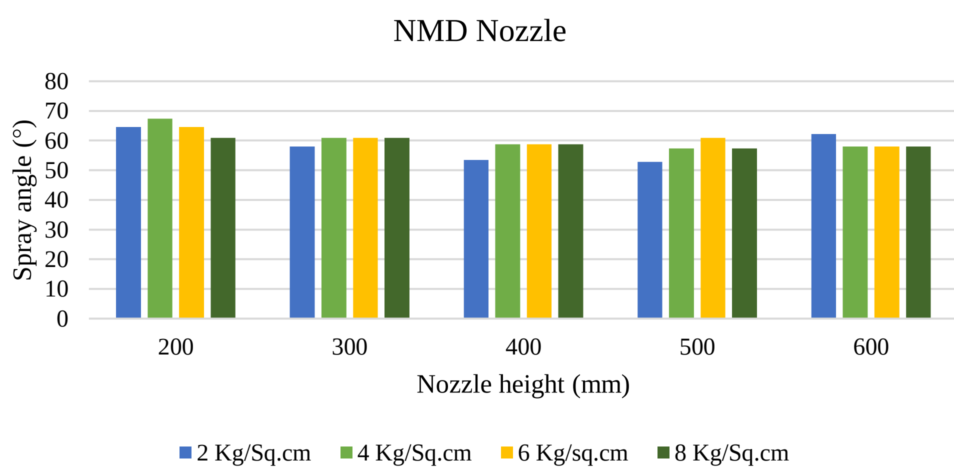

FIGURE 11 EFFECT OF PRESSURE ON SPRAY ANGLE OF NMD NOZZLE

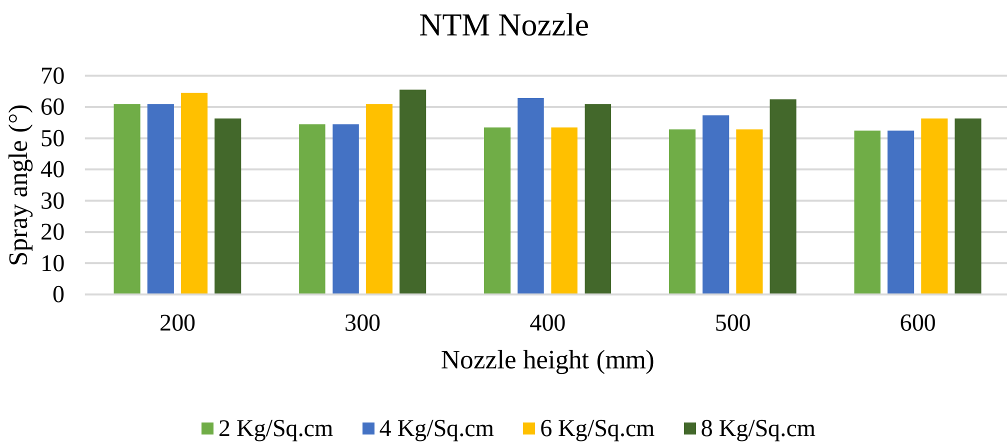

FIGURE 12 EFFECT OF PRESSURE ON SPRAY ANGLE OF NTM NOZZLE

Uniformity of spray distribution

Coefficient of Variation of the patternator test for NMD and NTM Nozzle are presented in Tables 1 and 2, respectively. The increasing nozzle angle and pressure reduce the value of the coefficient of variation CV% [9]. The data reveals that the NMD nozzle at 8 kg/cm^2 pressure and nozzle mounting height of 500 mm gave the most uniform distribution with a coefficient of variation of 12.52%. Similarly, for NTM nozzle at 6 kg/cm^2 pressure and nozzle mounting height of 600 mm gave the most uniform distribution with a coefficient of variation of 9.74% which was in close agreement with the results reported by [31].

TABLE 1. COEFFICIENT OF VARIATION FOR NMD NOZZLE

NMD Nozzle	**Coefficient of Variation (%)**			
Working Height (mm)	**2.0 kg/cm^2**	**4.0 kg/cm^2**	**6.0 kg/cm^2**	**8.0 kg/cm^2**
200	18.92	31.70	21.04	32.21
300	23.12	20.28	27.43	27.18
400	19.76	15.15	22.01	17.38
500	25.19	23.55	17.20	12.52
600	19.96	18.00	14.73	19.48

TABLE 2. COEFFICIENT OF VARIATION FOR NTM NOZZLE

NTM Nozzle	**Coefficient of Variation (%)**			
Working Height (mm)	**2.0 kg/cm^2**	**4.0 kg/cm^2**	**6.0 kg/cm^2**	**8.0 kg/cm^2**
200	33.61	37.90	36.32	27.69
300	39.61	16.46	27.32	44.30
400	29.84	27.92	10.73	46.05
500	24.52	20.21	15.69	39.60
600	30.42	20.71	9.74	50.14

CONCLUSION

A spray patternator was fabricated to select a suitable nozzle type, its angle and pressure to provide uniform distribution of spray liquid to the crop. A spray analysis system or patternator measurement would probably be sufficient to evaluate the static spray volumetric distribution accurately. From the results, the NMD nozzle is recommended for wider spraying and NTM nozzle which was specifically for converged spraying. Also, it was noted that the NMD nozzle gave the best spray uniformity with the minimum coefficient of variation at all nozzles heights and pressures. The NMD nozzle at nozzle angle 57°, at 500 mm height and nozzle pressure of 8 kg/cm^2 gave the best spray volumetric distribution and minimum coefficient of variations 12.52 per cent .The NTM nozzle at nozzle angle 65°, at 600 mm height and nozzle pressure of 6 kg/cm^2 gave the best spray volumetric distribution and minimum coefficient of variations 9.74 per cent. Increasing nozzle angle and pressure improve spray uniformity of all broadcasting and banding nozzles. This evaluation supports the use of NMD and NTM nozzle in drone spraying application as a means for improving spray distribution and also the selection of nozzle for suitable crops.

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