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Evaluation of Cone and Flat Fan Nozzle used for Agricultural Drone Spraying and its Performance Assessment

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ABSTRACT: Pesticide application plays an important role in pest management. Proper technique of application of pesticide and the equipments used for applying pesticide are vital for the success of pest control operations. A spray patternator was created to test the spray liquid application rates of several drone spraying nozzle types. The spray distribution pattern for cone and flat fan nozzle was evaluated under various working pressuresand nozzle height. The nozzles are placed at different heights of 200, 300, 400, 500, 600 mm from the patternator surface and different operating pressures of 2, 4, 6 and 8 kg/cm^2. The distribution pattern demonstrates that the discharge reaches its highest value near the patternator's centre, and the spray volume received by the channel diminishes as the distance from the centre rises. The cone nozzle has a maximum discharge rate of 646.0 ml/min, while the flat fan nozzle has a maximum discharge rate of 827.0 ml/min at a working pressure of 8.0 kg/cm^2. The cone nozzle provided a spray that was uniform and had the lowest coefficient of variation at all pressures and heights tested. As long as the nozzle pressure is 8 kg/cm^2 at 54.46° and the height is 600mm, the optimum spray volumetric distribution and the lowest coefficient of variation may be achieved by utilising this model. Flat fan nozzle with 62.24° nozzle angle, 600 mm height, and 6 kg/cm^2 nozzle pressure provided the best spray volumetric distribution and the lowest coefficient of variation.In addition, the mean value of swath width increases with an increase in working pressure for both the nozzles. This evaluation supports using a flat fan and cone nozzle in drone spraying applications to improve spray distribution.

Keywords: Drone spraying, Flat Fan Nozzle, Cone Nozzle, Uniformity, Pressure, Droplets.

INTRODUCTION

Despite all actions aimed at sustainable agriculture, pests and disease problems are increasing due to the climatic factors resulting in adverse effects on human health, environmental quality, and the food chain (Leontopoulos *et al.,* 2021). While reducing pest populations that cause damage to individual fields is a primary goal, it is most effective when the chemical is sprayed cheaply on a scale indicated by the pest population and the urgency with which pest populations must be controlled while taking the environment into account (Matthews, 1992). More than 98% of the spray move towards the land, water, and air are contaminated by the use of chemicals. (Pimental and Levitan 2000). Approximately 80 percent of the total pesticides sprayed to plants may end up in the soil, where it might have a significant impact on the populations of non-target animals like earthworms, according to a study (Courshee, 1960). Many factors, such as droplet size and velocity distributions, wind speed characteristics, and spray volume distribution patterns influence agricultural spray nozzle performance (Miller and Ellis 2000; Sehsah and Kleisinger 2009). Performing spray testing at actual pressures is a difficult task. Optimizing the test setting and selecting the appropriate nonintrusive measuring methodologies provide a number of challenges (Ferguson *et al.,* 2016). There is a potential increase in related field concerns such non-uniformity, drift, and evaporation via airborne are if proper operational conditions are not provided. This means that pricey pesticides will be ineffective (Hassen *et al.,* 2013). Several variables influence the uniform distribution of chemicals over a field, including nozzle pressure, height, spray angle, travel speed, distance between nozzles, droplet size, and many others. Proper pesticide application requires careful consideration of both the nozzle type and size. Nozzles are critical to the volume of liquid sprayed, the consistency of application, and the amount of coverage achieved on the target surface. Flying insects and spray deposition on plant canopy and soil surface are both the result of inertial collision or gravitational sedimentation (Rahman 2010; Shirwal *et al.,* 2020). It was found that the co-efficient of variance in distribution throughout the spray pattern for various nozzle orientations at given nozzle spacing was affected by nozzle placement and the spray deposit uniformity (Bintner *et al.,* 1977). Nozzles with horizontal and vertical discharges (vertical downward discharge) showed lower spray pattern displacement values than those with vertical downwards and horizontal discharges (horizontal discharge) (Krishnan *et al.,* 1988). A test setup was created to examine nozzles used with sprayers in order to standardise the nozzle and its properties. Due to resource shortages and environmental harm caused by chemical overdoses, this study has particular importance for agriculture (Nawawi *et al.,* 2020). Spray application quantitative and qualitative evident from this study on deposit and coverage measures on artificial targets is relatively simple and quick in comparison to field research (Holownicki *et al.,* 2002). With a corrugated surface on a tilting table, spray patternators can be used to create many spray patterns using a single nozzle. It is necessary to record the volume of each cylinder manually or automatically in order to analyse the data. A spray boom's spray pattern may be accurately characterised and quantified using this technique (Ozkan and Ackerman 1992). In Agricultural Engineering College and Research Institute, Kumulur, the experimental patternator setup was created to explore the features and optimization of nozzle operating parameters for diverse crops in different sprayers. Studying and making adjustments to agricultural sprayers' spray patterns is usually done using the Patternator, a tool for measuring spray dispersion. When using agricultural sprayers, a variety of variables affect the pattern and dispersion of the spray, including: nozzle characteristics and orientation during application; air assist; spray bounce; and micro meteorology (Farooq and Landers 2004; Salyani, 2000; Salyani and Hoffman 1996).

METHODOLOGY

Spray Patternator. An angle iron mainframe of 40 × 40 × 5 mm is used to construct the Patternator arrangement, as seen in Fig. 1. In order to offer the forward slope to the corrugated sheet, the frame was made of 2100 mm long, 1050 mm broad, and 860 mm in back and 800 mm in front. Four 40 × 5 mm MS flat pieces were installed in the frame's top portion. 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 constructed from 31 channels, each measuring 6 cm in height and 5 cm in width. Spray liquid was delivered via a tube located at the front of the frame. A 5° forward tilt was maintained to enable water passage to the measuring test tubes. Greaves diesel engine of 3.7 kW capacity generates this power. Using a V-belt drive, the engine spins the piston pump at a maximum speed of 3600 revolutions per minute. Spray liquid was delivered at the appropriate pressure by a three-cylinder reciprocating piston pump. It's a positive displacement pump with a wide variety of discharge rates.It has 0-10 kg/cm^2 normal pressure, 15 kg/cm^2 maximum pressure, 950 rpm, 3 HP power demand, and a suction capacity of 36 litres per minute are all characteristics of the pump. Pumps are equipped with strainers to prevent extraneous material from entering the pump's suction hose. When water is discharged from the nozzles in the form of a fine spray, the optimal operating pressure should be maintained. As a result, a pressure control valve and a pressure release valve are installed between the pump and the nozzles. Excess water may also be sent back into the tank. The adjusted pressure of the fluid released is shown on a pressure gauge on the pump.

Fig. 1. Spray Patternator.

If the channels are long enough to cover the region of the spray, they should be set up perpendicular to the nozzle spray. The patternator's number of channels may be adjusted or lowered to fit the spray precisely (Singh *et al.,* 2006, Balachand and Shridar 2016). A blower was used to maintain a continuous flow of air. There is a pressure regulator and gauge near the nozzle in order to maintain a steady pressure. An further adjustment to the nozzle's height was created, and graded beakers were provided to collect spray water from the channels. 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. 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 (Wang *et al.,* 1995). The nozzle height must be taken into consideration in order to ensure that the nozzle's swath is evenly covered or dispersed (Juste *et al.,* 1990; Solie and Gerling 1985). But the width of spray has to be restricted to the projected width of plant canopy so as to increase the amount of deposition (Clijmans *et al.,* 2000; Debouche *et al*., 2000). 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 has an impact on spray liquid physical properties as well as spray characteristics. Proper nozzle selection and operating settings for pest control may reduce spray drift and enhance canopy penetration.

Fig. 2. Flat Fan and cone nozzle (0.5 mm orifice diameter) used in drone spraying.

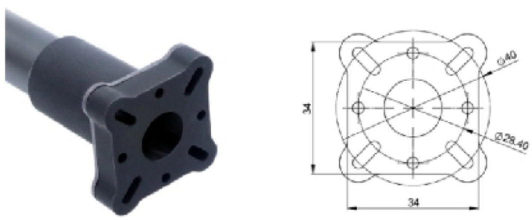

Fig. 3. Nozzle mounting holder.

Uniformity coefficient of the spray. A patternator was used to test the nozzles' spray uniformity. The nozzles were put through their paces under a variety of pressure and height conditions. Both nozzles had their discharge measured from several patternator channels. The formula was used to compute the spray's uniformity coefficient.

Uniformity coefficient = $1 - \sum_{i=o}^{n} \overline{x} - x_1$

x_1 is the volume collected in each beaker (in ml), n is the number of beakers used in the experiment, and x is the average spray volume collected across all beakers (in ml).

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 (Pillai *et al.* 1999; Womac *et al.*, 1999; Watson and Wolff 1986). 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. It was determined by the working width and nozzle height in compliance with Indian Standard IS: 8548–77. The formula was used to determine the nozzle's spray angle.

$$W = 2h \tan\frac{\theta}{2}$$

W is the spray width in millimetres, h is the spray height in millimetres, and θ is the 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 (Khtar and Yule 1999; Kihm and Chinger 1991). After collecting the discharge fluid for one minute in a measuring jar (v), the discharge rate for that minute (t) was computed as litre/minute.

$$Q = \frac{v}{t} \text{ (litre/minute)}$$

Fig. 4. Spray distribution from flat fan and cone nozzle.

RESULTS AND DISCUSSION

The volumetric distribution of the nozzles was depicted using trend lines in the patternator test (Figs. 5 to 12), and the effect of height and pressure on the volumetric distribution was examined. The average discharge from the patternator's channels at a specific height and pressure is represented by each trend line.

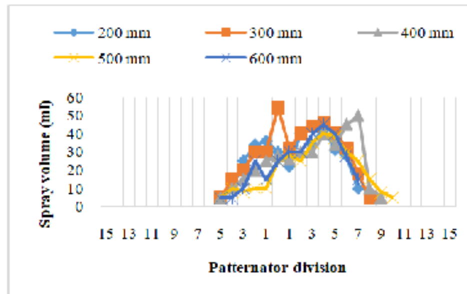

Fig. 5. Spray volumetric distribution on cone nozzle with different height at 2.0 kg/cm^2 working pressure.

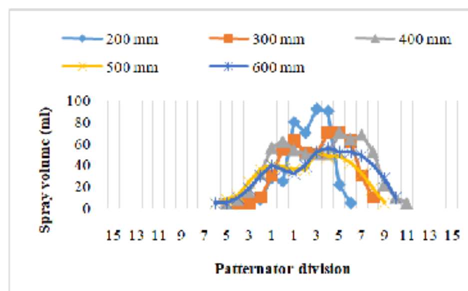

Fig. 6. Spray volumetric distribution on cone nozzle with different height at 4.0 kg/cm^2 working pressure.

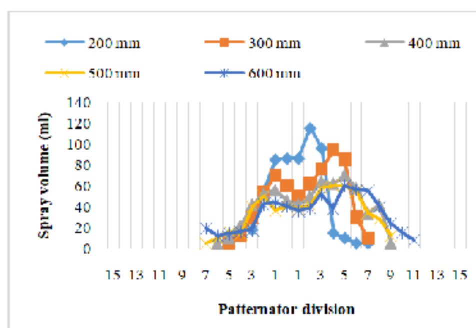

Fig. 7. Spray volumetric distribution on cone nozzle with different height at 6.0 kg/cm^2 working pressure.

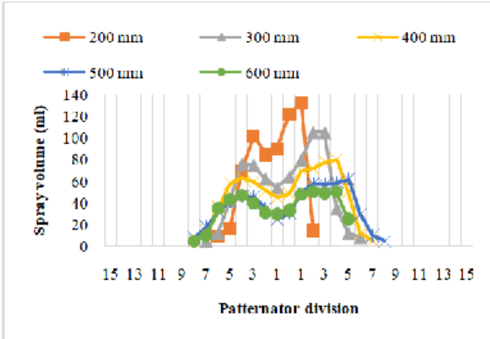

Fig. 8. Spray volumetric distribution on cone nozzle with different height at 8.0 kg/cm^2 working pressure.

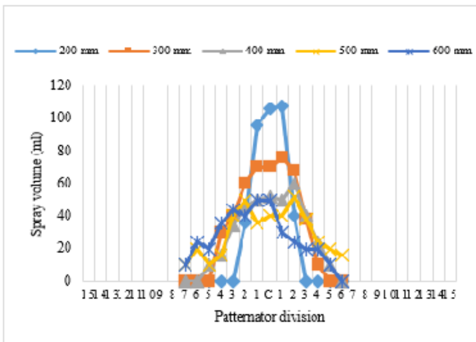

Fig. 9. Spray volumetric distribution on flat fan nozzle with different height at 2.0 kg/cm^2 working pressure.

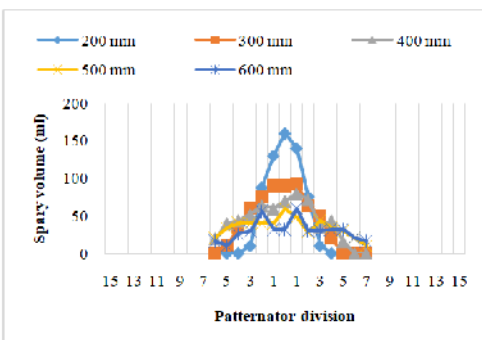

Fig. 10. Spray volumetric distribution on flat fan nozzle with different height at 4.0 kg/cm^2 working pressure.

Figs. 5 to 12 show how nozzle height (200 to 600 mm) affects the distribution pattern for cone and flat fan nozzles. Curves for flat fan nozzles reached their peak around the centre and began to fall toward the ends. For a height of 600 mm, all working pressures resulted in maximum collection from each channel. Each channel had a maximum collection at all operating pressures of 400mm, according to the trend lines. Increasing the nozzle height decreased peak discharge values, but the curves became flatter and wider, as seen in Figs. 5 to 12. When the height of the nozzle changes, the swath width changes as well. The pattern of distribution demonstrates that discharge is at its highest near the centre and that the spray volume absorbed by the channels reduces as the distance from the centre rises.

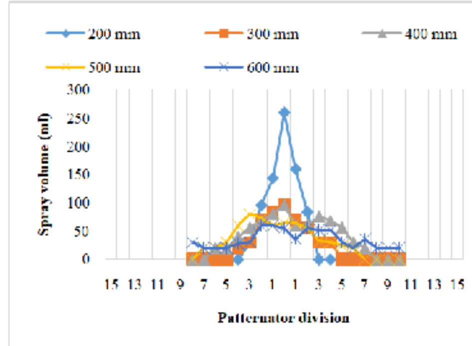

Fig. 11. Sray volumetric distribution flat fan nozzle with different height at 6.0 kg/cm^2 working pressure.

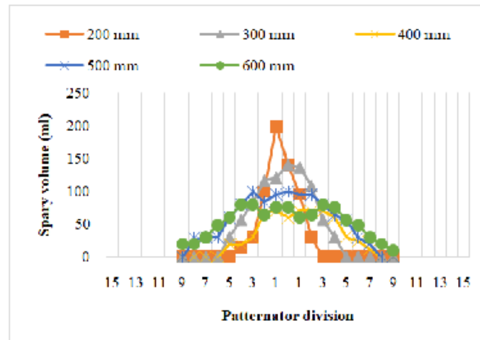

Fig. 12. Spray volumetric distribution on flat fan nozzle with different height at 8.0 kg/cm^2 working pressure.

Effect of working pressure and nozzle on discharge rate. The discharge rate of the two nozzles at different operating pressures is shown in Fig. 13. On average, it was discovered that higher operating pressure improved the discharge rate for both nozzles. By raising the operating pressure from 2.0 kg/cm^2 to 8.0 kg/cm^2, the cone nozzle's discharge rate went from 352 ml/min to 646 ml/min. The flat fan nozzle's discharge rate rises from 406 ml/min to 827 ml/min when the working pressure is increased from 2.0 kg/cm^2 to 8.0 kg/cm^2. The discharge rate of the chosen nozzles steadily rises with increasing pressure, which is in accordance with the findings stated by (Sridhar and Asokan 2019).

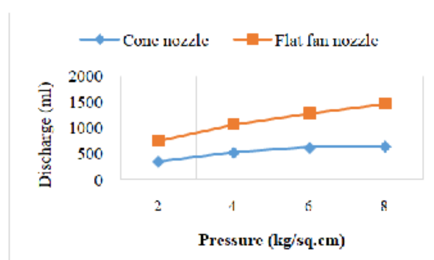

Fig. 13. Effect of working pressure on discharge ratein cone and flat fan nozzle.

Effect of working pressure and nozzle height on swath width. Fig. 14 and 15 show the swath width of the spray pattern formed by cone and flat fan nozzles at different operating pressures and from various nozzle heights. Increases in operating pressure lead to wider vast areas at both nozzles. With an increase in nozzle mounting height from 200 to 600 mm above the patternator and an operating pressure from 2.0 kg/cm^2 to 8 kg/cm^2, the cone nozzle's swath width ranges from 540 to 1140 mm". Increasing the mounting height from 200mm to 600mm above the patternator increases the working pressure of flat fan nozzles from 2.0 kg/cm^2 to 8 kg/cm^2.

Uniformity of spray distribution. Coefficient of Variation of the patternator test for cone and flat fan nozzle are presented in Tables 1 and 2, respectively.

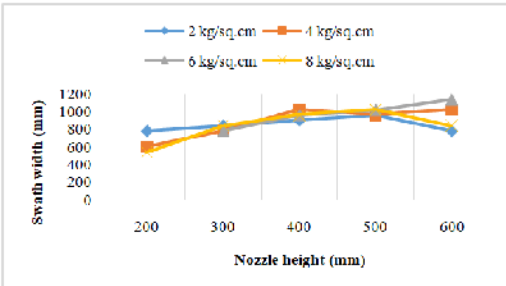

Fig. 14. Effect of pressure on swath width of cone nozzle with different operating height.

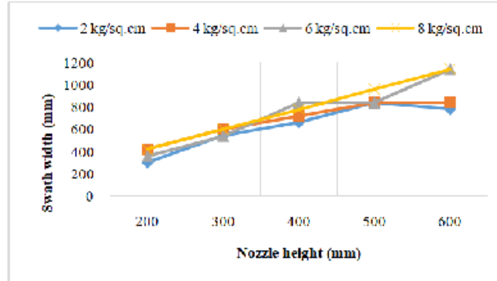

Fig. 15. Effect of pressure on swath width of flat fannozzle with different operating height.

Coefficients of variation (CV) are reduced when nozzle angle and pressure are raised (Hassen *et al.*, 2013). The most uniform distribution was achieved at 8 kg/cm^2 pressure and a nozzle mounting height of 600 millimetres, with a coefficient of variation of 34.41 percent. The flat fan nozzle at 6 kg/cm^2 pressure and a nozzle mounting height of 600 mm produced the most uniform distribution, with a coefficient of variation of 32.76 percent (Padhee *et al.*, 2019).

Table 1: Coefficient of variation for cone nozzle.

Cone 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	36.49	56.45	51.77	50.02
300	40.93	44.91	47.38	46.75
400	47.97	52.11	40.28	38.86
500	45.74	37.40	38.34	51.36
600	42.56	39.90	46.31	34.41

Table 2: Coefficient of variation for flat fan nozzle.

Flat fan 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	49.48	42.79	49.99	51.52
300	45.25	44.01	49.16	54.85
400	46.16	41.88	45.11	44.08
500	41.10	33.65	54.88	43.65
600	38.79	40.78	32.76	33.67

Effect of pressure on spray angle of cone and flat fan nozzle. Fig. 16 and 17 show how the nozzle spray angle changes depending on the operating pressure. Between 52.43° and 75.60° was the spray angle for the cone nozzle, which had an operating pressure of 8 kg/cm^2 at 2 kg/cm^2. This modest increase was brought on by the nozzle mounting's height and the low operating pressure. Similarly, the flat fan nozzle's spray angle ranged from 52° to 64.53°. Operating pressure and mounting height gradually increased over time, resulting in a modest rise in operating pressure.

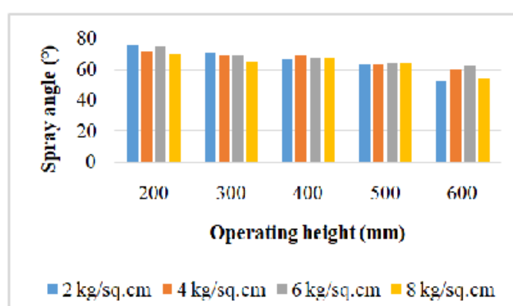

Fig. 16. Effect of working pressure on spray angle at different heights in cone nozzle.

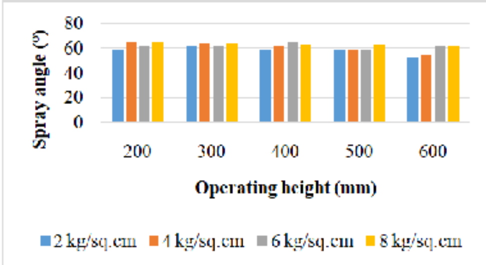

Fig. 17. Effect of working pressure on spray angle at different heights in flat fan nozzle.

CONCLUSION

A spray patternator was created with the purpose of choosing the ideal nozzle type, angle, and pressure to guarantee an uniform application of spray liquid over the field. A spray analysis tool or patternator measurement may be used to properly assess the volumetric distribution of static spray. According to the findings, the cone nozzle works best for concentrated spraying while the flat fan nozzle is ideal for wide spraying. The cone nozzle produced a spray that was uniform and had the lowest coefficient of variation at all pressures and heights tested. Using this model, for the cone nozzle, best spray volumetric distribution and the lowest coefficient of variation may be achieved as long as the nozzle pressure is 8 kg/cm^2 at 54.46° and the height is 600mm. We employed a flat fan nozzle at a 62.24° nozzle angle, 600 mm height, and a pressure of 6 kg/cm^2 to get the optimum spray volumetric distribution and the lowest coefficient of variation. According to this study, cone and flat fan nozzles may aid increase spray dispersion and the choice of nozzle for certain crops during drone spraying.

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Conflict of Interest. None.

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