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THE EFFECT OF NOZZLE DIAMETER ON MOSQUITO FOGGING SPRAY DROPLET SIZE CHARACTERISTICS

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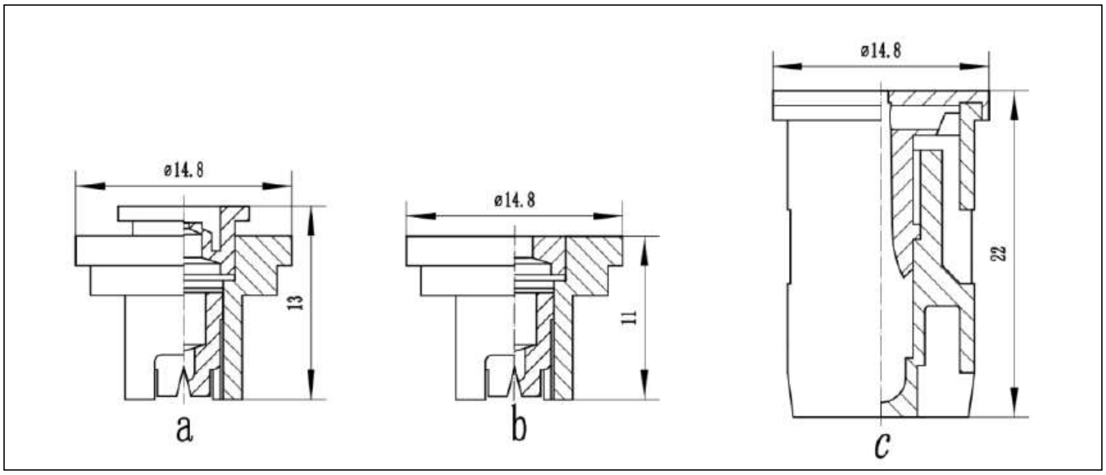
Abstract
Fogging technology is used in space spray applications to control adult mosquitos. A forger is a device that uses very small droplets to disperse liquid chemicals over large areas and due to the small droplet size, the chemicals are able to disperse and penetrate deep foliage, killing mosquitos in narrow spaces. Hence, the aim of this study is to investigate the relationship between the effect of nozzle diameter on the flow velocity pattern and droplets size distribution. A convergent-divergent nozzle is designed and designed to understand the basic concept on how a nozzle works. The convergent and divergent part are analysed separately to understands its velocity pattern and droplets size distribution to identify the best and effective nozzle size which can able to deep foliage and kill adult mosquitoes effectively. The nozzles are designed using the CATIA V5 software implanted in the ANSYS software to analyses complex problems involving gas and fluid-gas interaction and to study the droplets distribution. Furthermore, MATLAB software will be used to observe the morphology of the droplets and identify the density of the droplets. In the first phase of study, the analysis of the nozzle design has been carefully and theoretically investigated. Based on theoretical calculations, a nozzle with the concept of convergent-divergent nozzle was designed with correct diameter on fluid-flow and droplets size distribution will be numerically investigated in the following phase of research

Keywords: Fogging nozzle, nozzle design, velocity pattern, droplets size distribution.

1. INTRODUCTION

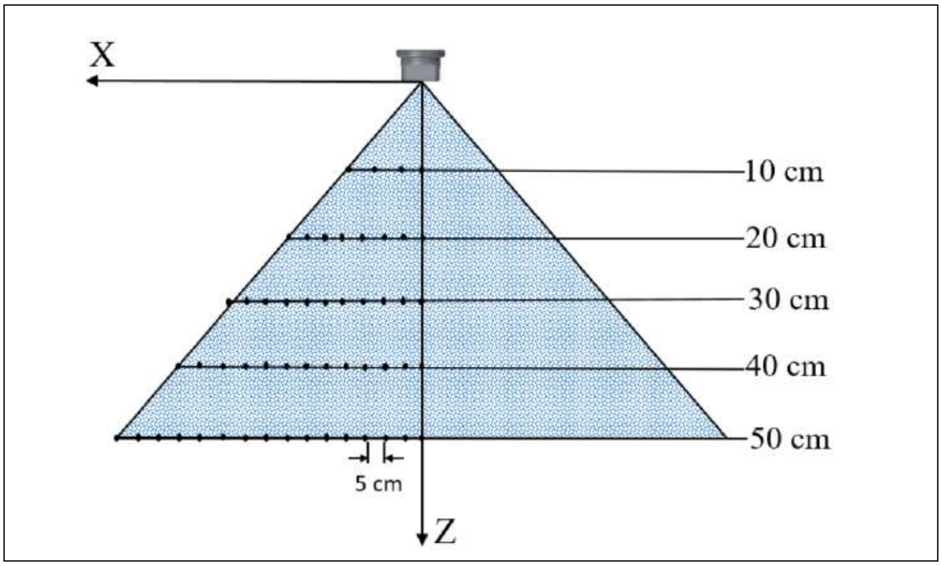
Adult mosquito is the primary factor which brings in many issues in term of transmit disease such as dengue and eliminating them in specified affected area is a must in order to control the breeding of the mosquito. Simultaneous treatment of adult and larval stages is excellent in mosquito vector management programmes to reduce the overall vector mosquito population and, as a result, minimise or disrupt disease transmission. The application of pesticides as a space spray is considered to be a complex task, which involves many important factors, such as the divergence of the equipment, type of forging, spraying method, density of the fluid, spray volume and droplets size distribution, which can be the most important parameters to be look into in order to come up with a better application of the space sprays [1]. Flow velocity pattern or working pressure plays a significant role in the effectiveness of fogging process as its characteristics influences its dispersion and its ability to work at different circumstances. Droplet size dispersion is an also affected by the nozzle size, liquid properties and its pressure as well [2]. Sprayer operating pressure influences droplet size in the opposite direction, the greater the pressure, the smaller the droplet size. However, the size of the droplets generated does not necessarily follow a regular distribution, and a single nozzle might create droplets of varying sizes [3]. All this parameter needed to be considered as this foster in limiting the adult mosquito as the primary target even at different surrounding and adjoining such as any narrow areas. Therefore, this study aimed to analyse and investigate on how the nozzle size is affecting the flow velocity pattern and droplets size distribution which brings to limiting the adult mosquito.

2. NOZZLE TYPE IDK120-003, LU120-03, AD120-03



The experimental nozzles were the air induction flat fan nozzle IDK120-003, multi-range flat fan nozzle LU120-03 and anti-drift flat fan nozzle AD120-03 from LECHLER, Germany. Spray angles are all 120 degrees. The three type of nozzles used in the experiment was conducted out in the Aviation Spraying Technology Laboratory of National Agricultural Intelligent Equipment Engineering Technology Research Centre **Error! Reference source not found.** where there was no wind, the temperature and humidity were kept constant, and the evaporation of droplets was not taken into account. As a result of taking into account the force of gravity, the nozzle was positioned such that it faced downward, as shown in Figure 2-1. Additionally, the X-axis and Z-axis coordinate systems were formed using the centre of the nozzle output as the origin of the coordinates **Error! Reference source not found.**. Along the Z-axis, five horizontal spray portions were chosen at intervals of 10 cm, ranging from 10 to 50 centimetres **Error! Reference source not found.**. The measuring point for gathering data along the horizontal X axis was decided to be at an interval of 5 centimetres, and the pressure values were determined to be 150, 200, 250, 300, and 350 kPa, respectively **Error! Reference source not found.** Basically, characteristic points on the droplet diameters distribution curve, also known as the characteristic diameter of droplets, are generally used to represent the particle size of spray droplets **Error! Reference source not found.**. This dimension is called the characteristics diameter of droplets. It is a representation of the percentages of the total volume of all droplets that are stated in terms of a particular dimension in the overall volume of all droplets **Error! Reference source not found.**. Figure 2-2 shows the sample of point diagram of spray surface used.

3. M VERTICAL Z-AXIS DROPLET SIZE DZ DISTRIBUTION



There is a difference in the pressure that is experienced on the inside and outside of the nozzle exit [23]. Because of the difference in pressure between the inside and the outside of the nozzle exit forced, the liquid sheet to break more completely, which results in smaller droplets.

4. DISTRIBUTION OF DROPLET SIZE ON Z AXIS AT DIFFERENT NOZZLES

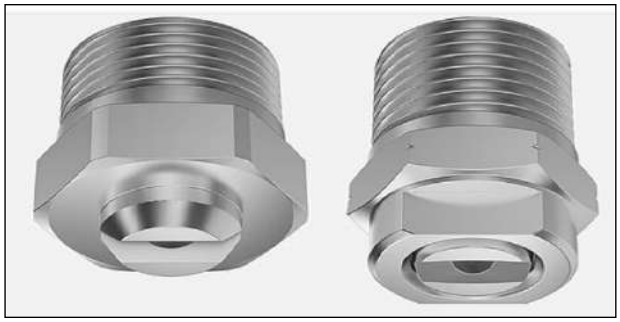
the range in droplet size distribution over a range of nozzle designs. The IDK120-03 nozzle had the largest droplet volume diameter under the same conditions as the LU120-03 nozzle [3]. The liquid film is broken in the LU nozzle because the slit plate spacing is smaller than in the IDK and AD nozzles, leading to smaller droplets [3].

Nozzles with IDK120-03 and LU120-03 droplet sizes are opposites in this position [3]. Droplet velocity decreases with increasing distance in the vertical and horizontal directions [10], but increases with increased pressure at a given point [11].

5. HORIZONTAL X-AXIS DROPLET SIZE DX DISTRIBUTION

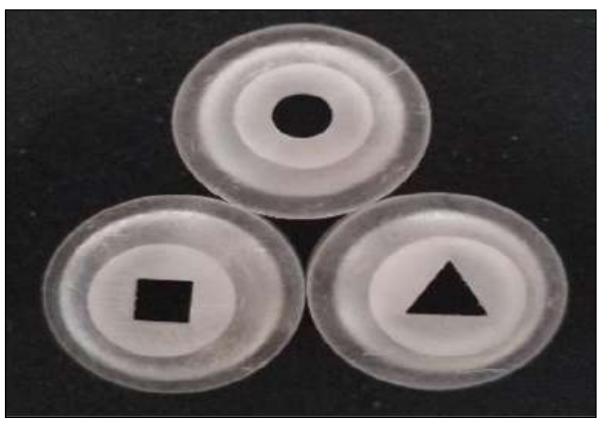
The following Figure 2-4 presents a representation of the distribution of droplet size Dx along the X-axis for each kind of nozzle. The average size of the droplets increases as the distance between them increases in the horizontal plane [9]. Of the three types of nozzles, the IDK120-03 nozzle produces the largest droplets, with the LU120-03 nozzle producing the smallest droplets [3]. The results come from checking out the differences between the three distinct nozzle designs. As described in detail in reference [3], IDK120-03, the air-induced nozzle makes use of the Venturi suction structure and operates in line with the Venturi Law. A large droplet with a special air and liquid mixed aeration [3] is produced when a high-velocity liquid flow is established in the front nozzle and air is sucked in through the side hole. The term "special air and liquid mixed aeration" is used to describe this technique. When compared to droplets created by other nozzles, this one creates a larger one [24].

6. CHARACTERISTICS OF THE SCAN TRAJECTORY FOR DIFFERENT NOZZLE TYPES



The characteristics of the scan trajectory of the three type of nozzle are been showed in droplet size may vary widely, from a few micrometres to hundreds of micrometres [4], depending on the nozzle type and size. For a given nozzle size and pressure, cone nozzles provide the smallest droplet size range and the highest percentage of droplets prone to drift [31]. First come cone nozzles, then standard flat fan nozzles, then low-drift flat fan nozzles, and finally air injection nozzles (cone). Furthermore, there is a robust correlation between the droplet's size and its velocity. Higher droplet velocities often result in bigger droplet sizes, which in turn result in higher droplet volumes [4]. This means that, at the same pressure and nozzle size, droplets created by anti-drift flat fan nozzles tend to move at a faster rate [4]. When using air injection nozzles, the droplet velocity is often lower than expected. The considerable pressure decrease within the nozzle is mostly responsible for this .

7. NONCIRCULAR NOZZLES



Three nozzles with various orifice forms were created and installed on a self-created uniform rotating sprinkler in order to explore the impact of nozzle orifice shapes on water droplet characteristics [5]. Two types of tests were then conducted under low-intermediate pressure circumstances. Both qualitative and quantitative analyses of the droplet diameter distribution parameters, including the distribution of droplet diameter, velocity, kinetic energy, and specific power, were conducted. Empirical formulae for the droplet distribution features of noncircular nozzles are presented based on the measured droplet spectrum and taking into account the operating pressure and orifice shape coefficient [5]. These equations offer the foundational elements for developing a modified spraying model and serve as a guide for applying noncircular sprinklers in an irrigation system [3]. Figure 2-7 shows the noncircular nozzles used in the research.

8. TEEJET NOZZLES

An aerial spraying test was conducted with the same spraying rate and four TEEJET nozzles with different orifice sizes (these droplets had a volume median diameter (VMD) of 95.21, 121.43, 147.28, and 185.09 m, respectively) in order to study the effect of different droplet size parameters on droplet deposition distribution and drift of aerial spraying by using a plant protection UAV [5]. TEEJET 11001VS have better tiny droplets distribution compared to the other 3 nozzles which is because the design of the nozzle slit works better to produce tiny particles where the spray pressure can reach up to 0.50 Mpa [6]. This high pressure allows the nozzle produces tinier and effective droplets which can kill mosquito more easily

9. DROPLET SIZE CHARACTERISTICS

Droplets size distribution plays an important role as it influences the spread of the smoke through the designed nozzle slit. Study and analysis on the characteristics of the droplets' size distribution need to be emphasised since these characteristics impact the pressure, elevation angle, and spray velocity, liquid water content or solvent which in turn outputs to disperse the spray according to the space and area that is targeted [26]. The fogging spray has to be able to kill the target adult mosquito, not only the initial larva stages of a mosquito, which means that the very small micro-droplets need to be able to get to them. Research on how can liquid water content can influence the droplet size characteristics of two type of droplets. In an effort to delve deeper into the investigation of the microphysical processes, we look into the relationship that exists between the rate at which the LWC time increases with N_d (the slope value of the LWC, which is denoted by a 〖N〗_d) and the correlation coefficient that is associated with this progression [1]. A small value for the slope indicates that there is a significant amount of droplet growth occurring due to condensation and evaporation in comparison to fresh droplet activation and deactivation [1]. Because the value of the correlation coefficient is low, it seems to imply that this development is not at all linear and that processes besides activation/condensation and evaporation/deactivation are taking place. There is a substantial positive association between N_d and LWC, with the correlation factor hovering around 0.8 [1]. The correlation factor between N_d and LWC is low for eight different occurrences, with values that are less than or equal to 0.7 [1]

10. DROPLET SIZE EFFECTS ON DIFFERENT SPRAYER AND SOLVENT

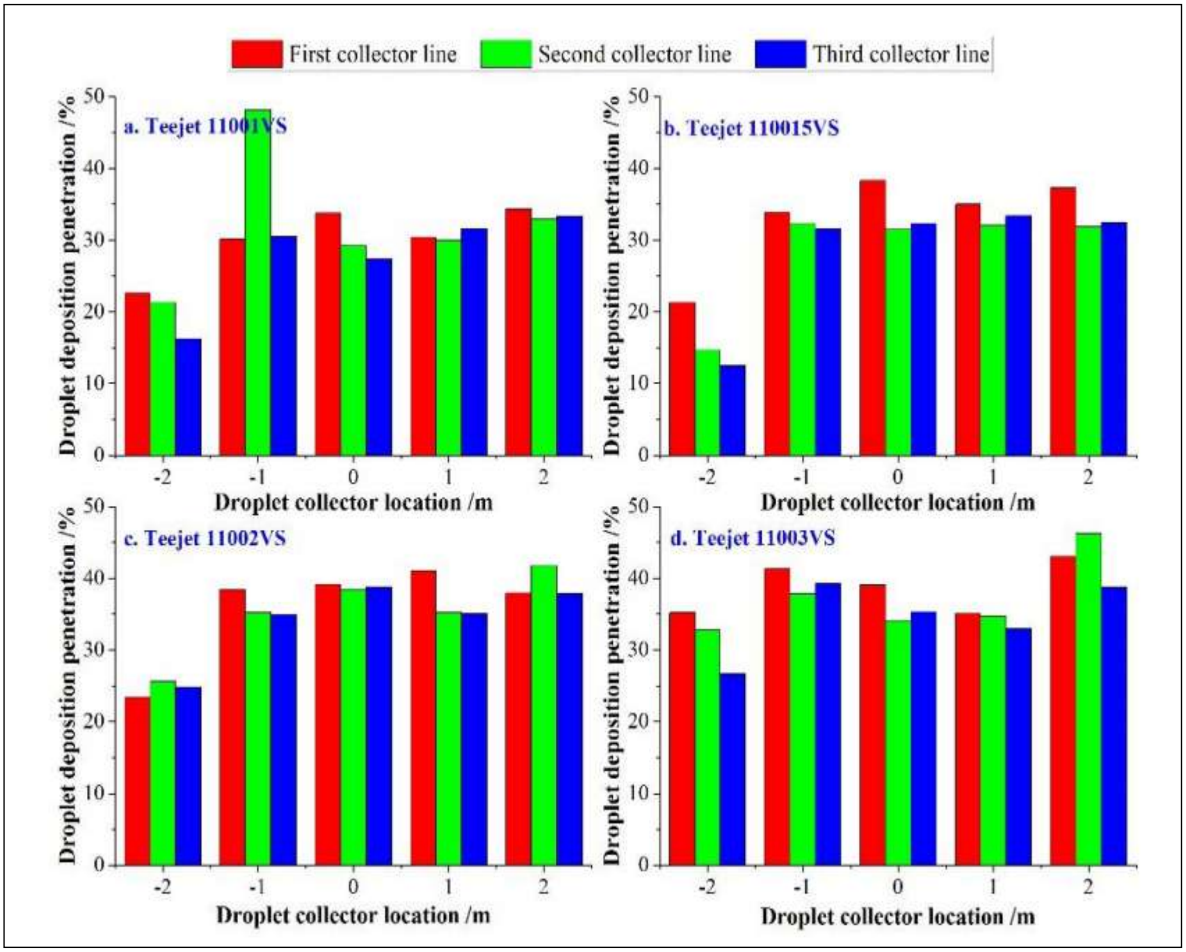
		Droplet data[a,b,c]				
Sprayer	Solvent	$D_{V0.1}$ (µm ± SD)	$D_{V0.5}$ (µm ± SD)	$D_{V0.9}$ (µm ± SD)	%Vol <20 µm	% <32 µm
Swingtec (Motan) Starlet	Water	7.0 ± 0.8 a	23.8 ± 2.5 a	44.3 ± 2.8 a	38.8 ± 4.8 a	99.0 ± 0.4 a
Swingtec SN 50	Water	6.5 ± 3.0 a	25.1 ± 2.9 a	37.7 ± 9.3 a	30.8 ± 6.9 a	99.2 ± 0.6 a
Swingtec SN 50	Gasoil	2.0 ± 0.6 b	11.8 ± 2.3 b	18.9 ± 4.4 b	81.2 ± 22.1 b	100 a
Swingtec SN 50	Biodiesel	3.2 ± 0.8 b	13.3 ± 4.1 b	19.4 ± 4.4 b	81.4 ± 13.9 b	100 a

[a] Data are the mean of four replicates.
[b] $D_{V0.1}$, $D_{V0.5}$ and $D_{V0.9}$ are the droplet diameters (µm) when 10, 50 and 90%, respectively, of the spray volume is contained in droplets smaller than this value; %Vol <20 µm is the percentage of spray volume contained in droplets of <20 µm.
[c] Diameters followed by the same letter within the same column are not significantly different (ANOVA, $P < 0.050$).

A hot-wire anemometer was used to measure the size of the droplets. For both counting and measuring droplets, this piece of equipment makes use of a hot-wire probe as the sensing element. Each droplet that comes into contact with the probe brings the temperature of a section of wire down by an amount that is proportional to the diameter of the droplet, which in turn brings the electrical resistance of the probe down by an amount that is proportionate to the size of the droplet [16]. The unit's regular operating procedures were followed in order to get accurate readings for the measurements. The probe was positioned three metres in front of the machine's nozzle, and the wind speed was between 1.5 and 2.5 metres per second. There were a total of four different replications carried out for each different combination of sprayer and solvent. The data on the spray droplet spectra of permethrin and pyriproxyfen aerosol EC distributed from portable generators (Swingtec (Motan) Starlet and SN 50) using a variety of solvents.

As can be seen, there was a clear discernible difference between sprays that were water-based and those that were oil-based. The size of the droplets produced by EC based on water was greater than those produced by sprays diluted in gasoil or biodiesel [16]. However, when water was utilised as the solvent, there were no discernible variations in the droplet size between cold and heat foggers.

11. DROPLET DEPOSITION PENETRABILITY



The penetration results of the droplets with four distinct size parameters (T1, T2, T3, & T4) are shown in table above. With the exception of the collection location at -2 m, the penetration results of the droplets at each collecting location in the target area were almost identical throughout the test [6].

Furthermore, the variability of droplet deposition penetration in the four experiments (T1, T2, T3, and T4) was less than 10% (8.36%, 6.79%, 3.29%, and 4.01%, respectively). It was found that the droplet deposition results in each test were consistent and effective, and that the results tended to be more stable as the droplet size increased [6]. The increase in droplet size was also accompanied by an increase in droplet deposition penetration, which suggested that the increase in droplet size had a role in enhancing the droplet deposition penetration. The vast majority of the smaller droplets are free in the air, and as a result, they are able to more readily reach the lower canopy of the crop [6]. Therefore, droplets of a lower size may have greater ground penetration than droplets of a larger size for the ground spraying apparatus.

12. CONCLUSION

As the present day, proper readings on the literature have been done to gain a better understand of the subject matter. Based on the readings, appropriate methodology has been chosen to aid the current study's objectives. The nozzle design was also created using the correct specifications via theoretical calculations. The nozzle is also analysed separately and specifically with different parameters to get a good output. A questionnaire has also been conducted in order to get a justification and clarifications of this research under many important parameters.

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