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Effect of spraying height, pressure, and nozzle type on flow characteristics of a field sprayer

Abdallah E. Elwakeel [a,*], Saad F. Ahmed [b], Abdalla M. Zein Eldin [b], Loai Nasrat [b]

[a] Department of Agricultural Engineering, Faculty of Agriculture and Natural Resources, Aswan University, Aswan, Egypt.
[b] Department of Agricultural and Biosystems Engineering, Faculty of Agriculture, Alexandria University, Alshatby, Alexandria, Egypt.
[c] Department of Electrical Engineering, Faculty of Energy Engineering, Aswan University.

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ABSTRACT

Accurate pesticide application from sprayers, is essential in modern farming practice as it increased pest control, reduced pesticide costs and wastage, and greater environmental safety. Evenness of flow characteristics of liquid from a sprayer nozzle is one of the requirements of accurate pesticide application. Hence, a study was undertaken to evaluate the flow characteristics of liquid from four different spray nozzles (hollow cone ceramic nozzle (HCC)) 422HCC02, 422HCC025, 422HCC03, and 422HCC05 on a horizontal spray patternator. The discharge rate, spray distribution pattern, spray swath of all the types of nozzles were measured with a pressure range from 6.0 to 9.5 bar at three different nozzle heights (30, 40, and 50 cm). Considerable variations in pattern occurred between successive runs with individual nozzles: The maximum coefficient of variation (C.V.) for the average of nozzle discharges was within the permissible limits because it is less than 10%. It was observed that with the increment of operating pressure and spraying height, the swath width was found to be increased. The average discharge from hollow cone ceramic nozzles has been increased as a result of the increased operating pressure of the pump where the average discharge for 422HCC02 nozzle ranged between (0.98 to 1.35 L/min), for 422HCC025 nozzle ranged between (1.15 to 1.65 L/min), for 422HCC03 nozzle ranged between (1.23 to 1.76 L/min), for 422HCC05 nozzle ranged between (1.35 to 2.03 L/min) when the pump pressure increased from 6.0 bar to 9.5 bar.

1. Introduction

In this agriculture sector, there is a lot of field works, such as weeding, reaping, sowing, etc. Apart from these operations, spraying is also an important operation to be performed by the farmer to protect the cultivated crops from insects, pests, funguses, and diseases for which various insecticides, pesticides, fungicides, and nutrients are sprayed on crops for protection. The growing concern to control plant diseases, insects, and weeds for a qualitative yield of agricultural products is increasing speedily in many developing countries (Singh et al., 2018). The nozzle type not only determines the amount of spray applied but also the uniformity of the applied spray, the coverage obtained on the sprayed surfaces, and the amount of drift that might occur (Sumner, 2009). In pesticide application, accuracy and uniformity of application are most important to avoid adverse effects of pesticides on the environment and crop injury and reduce pest management. Flow rate, operating pressure and pressure losses, nozzle material, nozzle spray angle, nozzle positioning, spray height, spray width, spray thickness, breakup length, atomization degree or droplet size, impact, spray drift, velocity, spray pattern, etc. are some parameters that affect the nozzle performance. Each nozzle type has specific characteristics and is designed to be used for different applications. Selecting a nozzle based on

*Corresponding author.
E-mail address: abdallah_elshawadfy@agr.aswu.edu.eg (Abdallah E. Elwakeel).

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the spray pattern and other spray characteristics that are required generally yields good results (Padhee et al., 2019). Keeping in view of the above discussions, an attempt was made to evaluate the spray characteristics with different nozzles used in agricultural sprayers in a horizontal spray patternator which could help in selecting the appropriate nozzle for plant protection of any agricultural crop. The data from this study could be used by the nozzle manufacturers to recommend a spacing of their nozzles on the booms, operating pressure, and other spray parameters that farmers use to treat their field crops during spraying using different hydraulic sprayers.

2. Materials and methods

The prototype spraying machine was tested in the faculty of Agriculture and Natural Resources – Aswan University - Aswan - Egypt. Tests were carried out to evaluate the machine performance in terms of the laboratory. The laboratory tests are conducted to assess the discharge rate, spray distribution pattern, and spray angle. The sprayer was operated at different heights of (30, 40, and 50 cm) at different operating pressures of (6.0, 7.0, 8.0, 8.50, and 9.5 bar).

2.1. Uniformity of spray distribution

The uniformity of the spray distribution across the boom or within the spray swath is essential to achieve maximum chemical effectiveness with minimal cost and minimal non-target contamination. The uniformity of the nozzles was calculated by using a patternator. A patternator normally consists of several channels aligned perpendicular to the nozzle spray and can be of any convenient length provided that it encompasses the area of the spray.

Spray volume distribution pattern was noted on a patternator of size 600 cm x 67 cm. The patternator has many curved grooves at equal spacing and a rack carrying spray-collecting tubes, which were mounted below the collecting endpoints of the grooves. The spraying boom was placed horizontal direction above the patternator, at the height of 30 cm, 40 cm, and 50 cm. The sprayer was operated for 20 s in each situation was able to obtain a measurable amount of spray from the collecting tubes and this was replicated thrice for each flow rate (Padhee *et al.*, 2019).

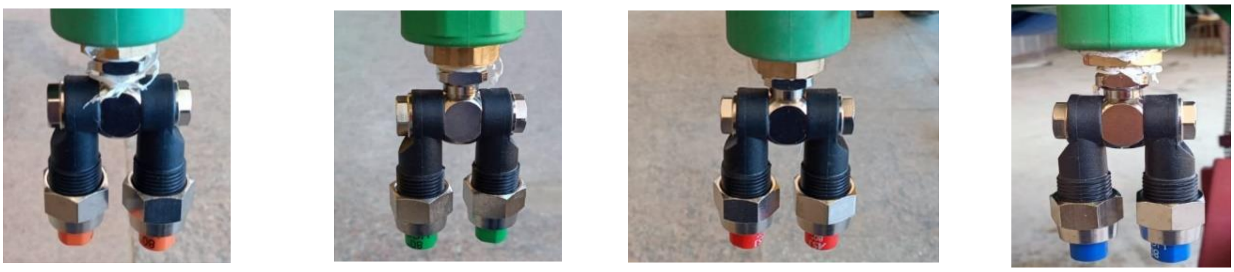
2.2. Spray swath width

According to Indian Standard. IS: 8548 – 1977, test code for the power-operated hydraulic sprayer, the working width (the distance between the outer edges of the outermost channels which at the operating pressure received 50% or more of the largest quantity of liquid collected from anyone channel) in millimeters shall be measured for each of the nozzle height (Jassowal, 2016).

2.3. Statistical analysis

The statistical analysis was carried out using IBM SPSS statistics 25, PC statistical software. Each experiment in triplicate was repeated at least twice and the values were presented in terms of coefficient of variance (S´anchez-Hermosilla *et al.*, 2011)

Figure 1. Shows a patternator consists of a number of channels during the uniformity test.



422HCC02 422HCC025 422HCC03 422HCC05

Figure 2. The different types of hallow cone ceramic nozzles are used in the current study.

3. Results and discussions

The tests were carried out in the Agricultural and Bio-Systems Engineering Department – Faculty of Agriculture and Natural Resources – Aswan University – Aswan- Egypt, during the period from 9 to 31 October 2020.

3.1. *The laboratory tests include*

1. Effect of operating pressure on single nozzle discharge rate on spraying boom.
2. Uniformity of spray distribution.
3. Effect of spraying pressure and spraying height on coefficients of variation of the patternator test data.

3.1.1. Effect of operating pressure on single nozzle discharge rate on spraying boom

The test was performed to find out the actual discharge rate produced by a single nozzle in the boom at different pressures. The discharge obtained from four different nozzle types was collected for different pressures with three replications and the average data was tabulated in Table 1 and Figure 3.

Table 1

Average actual discharge rate produced by a single nozzle in the boom.

Average pump pressure, (bar)	Average discharge from hollow cone ceramic nozzle, (L/min)			
	422HCC02	422HCC025	422HCC03	422HCC05
6	0.98	1.15	1.23	1.35
7	1.09	1.25	1.37	1.52
8	1.16	1.44	1.52	1.74
8.5	1.22	1.51	1.64	1.83
9.5	1.35	1.65	1.76	2.03

It can be inferred from Table 1 and Figure 3 that, as the operating pressure increased from 6 bar to 9.5 bar, the discharge rate for a hollow cone nozzle type (422HCC02) increased from 0.98 to 1.35 L/min while for a hollow cone nozzle type (422HCC025) the discharge increased from 1.15 to 1.65 L/min, also, we found that the discharge rate increased for a hollow cone nozzle type (422HCC03) from 1.23 to 1.76 L/min while for a hollow cone nozzle type (422HCC05) the discharge increased from 1.35 to 2.03 L/min.

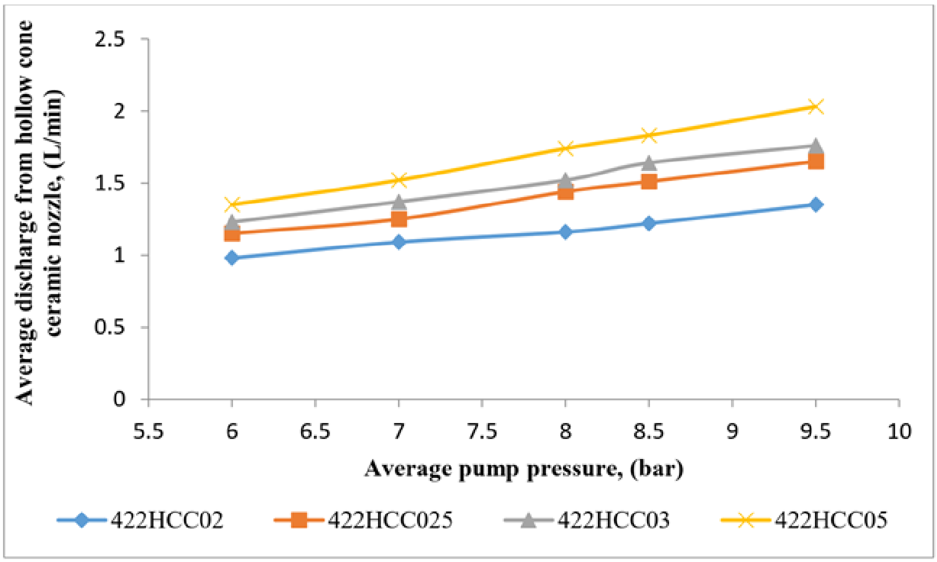


Figure 3. Effect of operating pressure on single nozzle discharge rate in the boom.

3.1.2. Uniformity of spray distribution

The uniformity of spray of the hollow cone ceramic nozzles was evaluated through a patternator at spraying pressures of (9.5, 8.5, 8, 7, and 6 bar) and spraying heights of (30, 40, and 50 cm). The four types of nozzles were tested at different pressure and height combinations. The discharge obtained from different channels of the patternator was measured for a single nozzle.

The coefficients of variation were calculated for the above data using SPSS.25 to determine the variability within the data. The volumetric distributions of the nozzles obtained from the patternator test were presented through trend lines Figure 4. Each trend line represents the average discharge collected from the channels of the patternator at a particular height and pressure. A precise nozzle should produce uniform spray, i.e., discharge collected at both sides of the nozzle axis should be equal, and there should be the least coefficient of variation within the data, but in actual the concentration was more at the center and declined to both the sides.

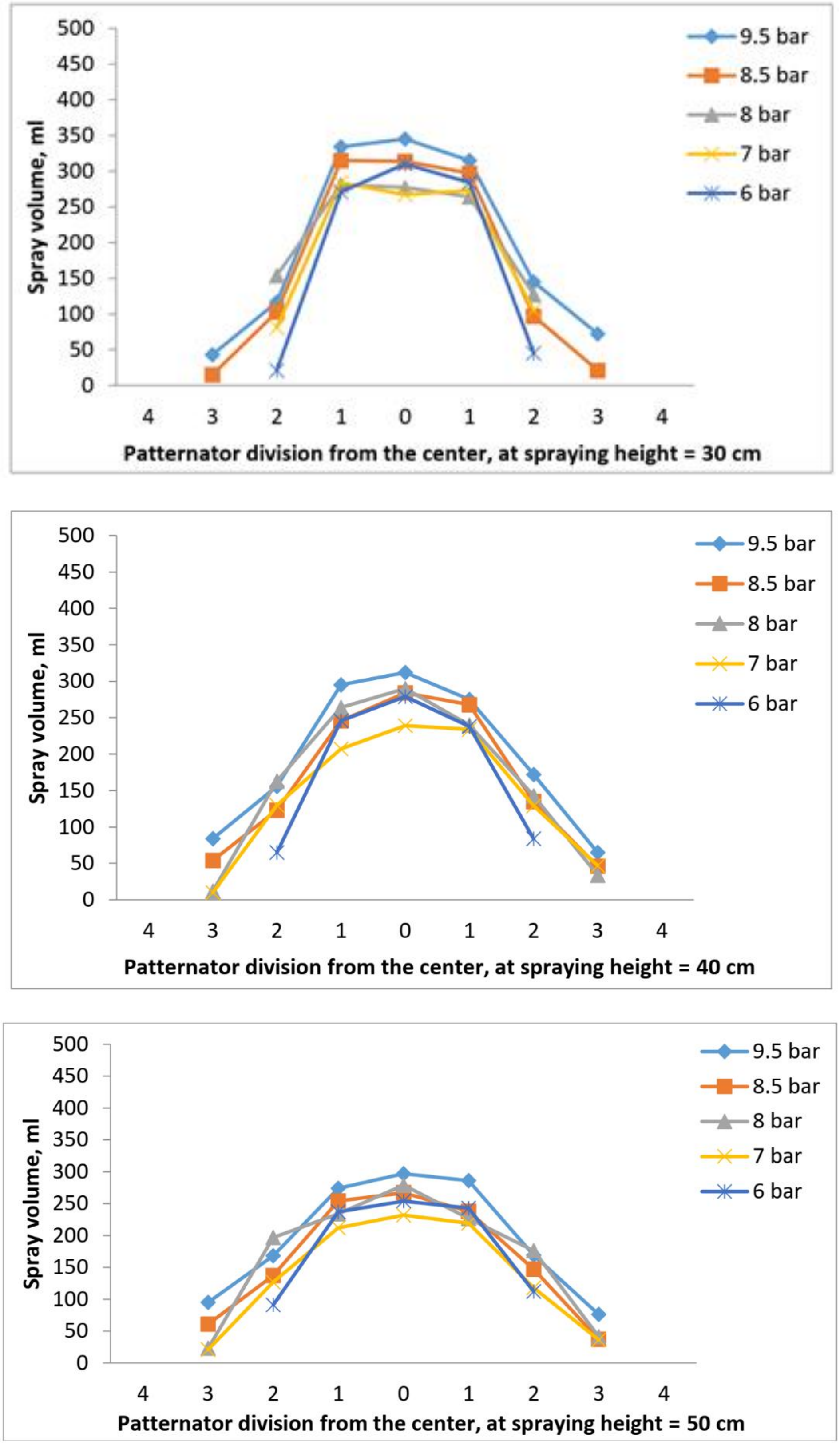


Figure 4. Effect of pump pressure on spray volumetric distribution of 422HCC02 nozzle.

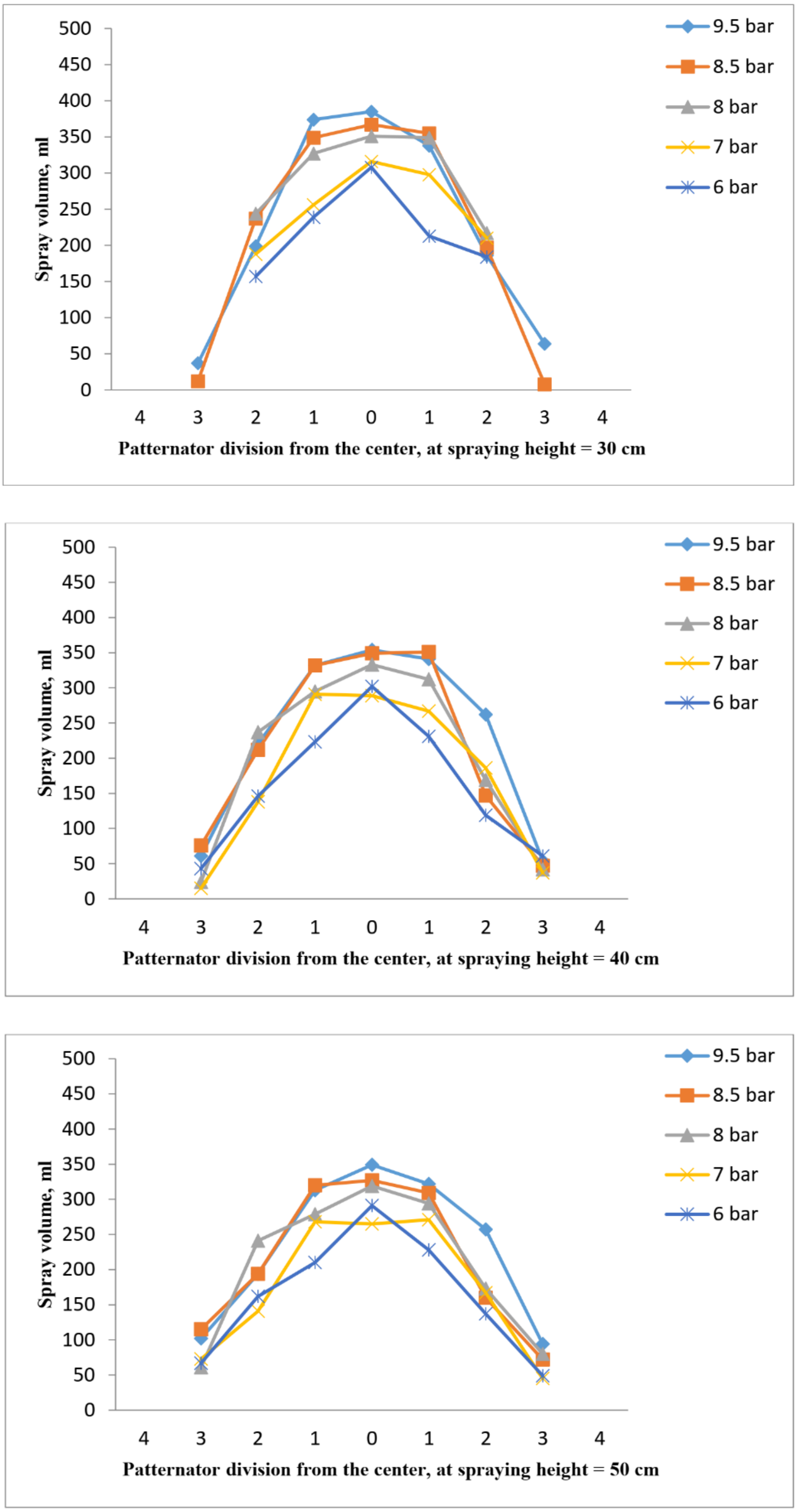


Figure 5. Effect of pump pressure on spray volumetric distribution of 422HCC025 nozzle.

The trend lines for Figure 5 showed that the effect of nozzle height on spray volumetric distribution of hollow cone ceramic nozzle (422HCC025) at different pressures (9.5 to 6 bar) and different heights (30, 40, and 50 cm). The distribution pattern showed that the channels present in the center received more discharge as compared to the channels at both ends. This confirms that while spraying, the central part of the nozzle received a good spray amount compared to both the ends. Therefore, overlapping is done to counteract the phenomena.

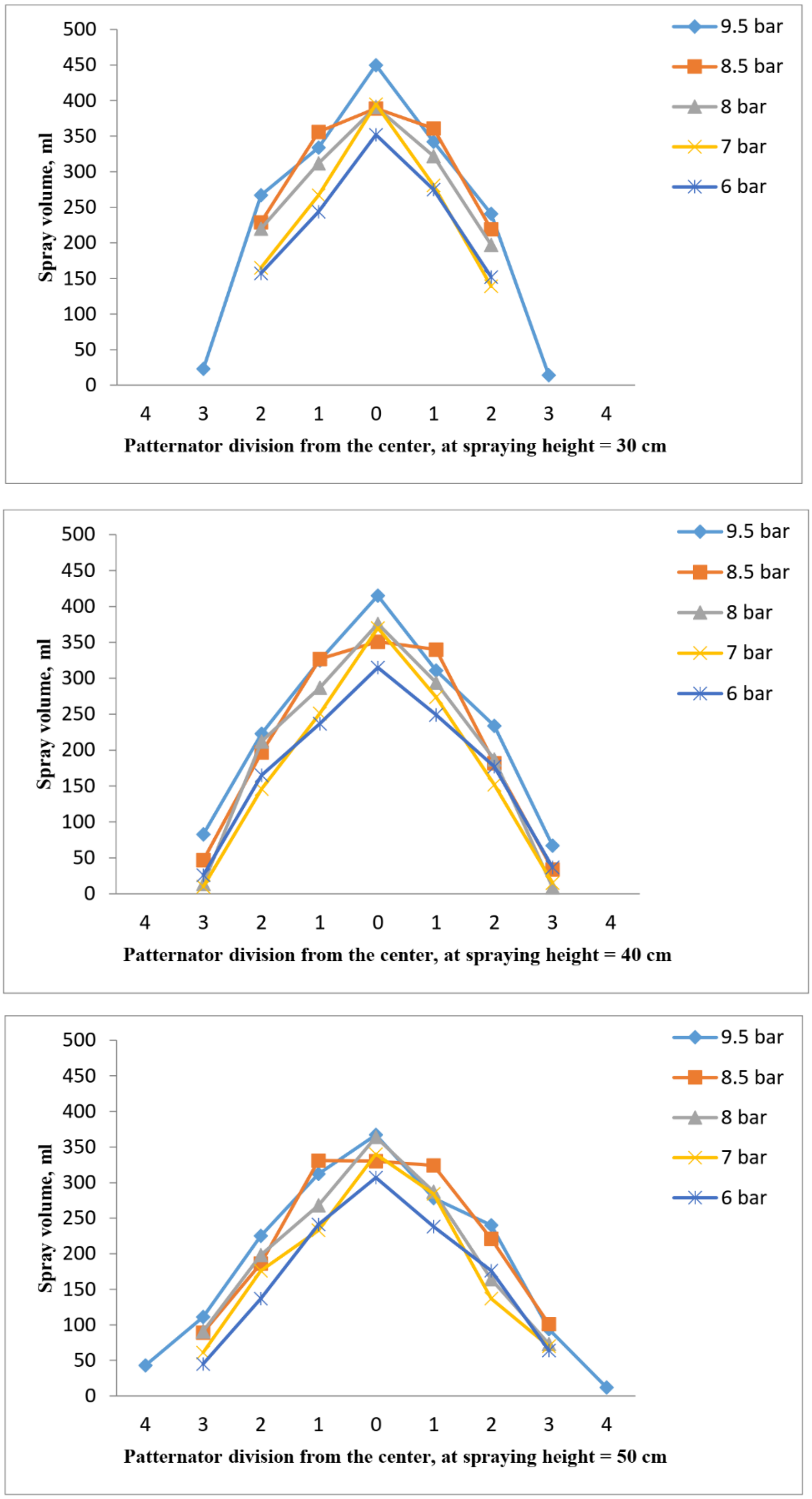


Figure 6. Effect of pump pressure on spray volumetric distribution of 422HCC03 nozzle.

Figure 6 represents the volumetric distribution of hollow cone ceramic nozzle (422HCC03) for different pressures (9.5, 8.5, 8, 7, and 6 bar) and heights (30, 30, and 40 cm). Also, the results in Figure 6, indicated that with the increase in pressure at a constant height the peak discharge at any channel increased along with total discharge. From the figures, it was shown with the increase in height the number of channels receiving the spray increased in number. The trend lines increased in length both vertically and horizontally with the increase of pressure. The trend lines followed a similar pattern i.e., the distribution on both sides of the peak declined gradually. This revealed that maximum discharge was concentrated just below the nozzle and farther areas received less spray.

Figure 7 depicts the volumetric distribution of spray from the hollow cone ceramic (422HCC05) nozzle at previously mentioned pressures and heights. Any particular figure shows the spray distribution at one height and five different pressures. Figure 69 describes the distribution pattern obtained for different operating pressures at 30 cm height. That clearly indicated that, as the pressure was increased the discharges were increased, and also it was inferred that with the increase in height the number of channels receiving the spray increased. Figures 7 show good distributions in the middle. There are some deviations for all these graphs as the very little spray was obtained from the channel next to the peak one.

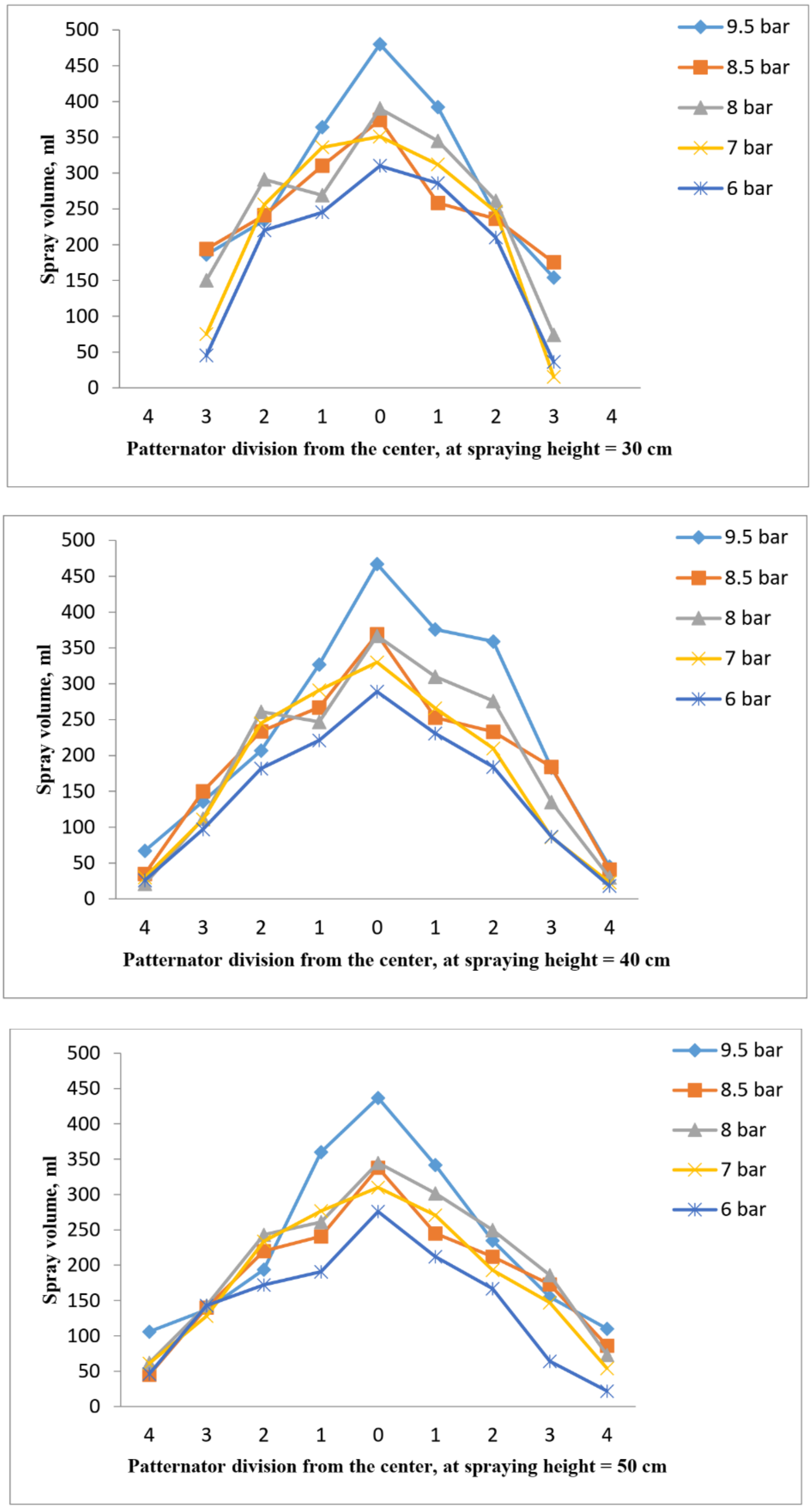


Figure 7. Effect of pump pressure on spray volumetric distribution of 422HCC05 nozzle.

3.1.3. Effect of spraying pressure and spraying height on coefficients of variation of the patternator test data

The coefficient of variation (C.V) was estimated at different heights (30, 40 and 50 cm) and pressures (6.0, 7.0, 8.0, 8.5 and 9.5 bar) for four different hollow cone ceramic nozzles (422HCC02, 422HCC025, 422HCC03 and 422HCC05) are shown in Figure 8.

Figure 8 illustrated the effect of pump pressure and spraying height on the coefficient of variation, the results show that there is no specific pattern in which it is possible to predict the values or method of predicting the value of the coefficient of variation for the performance of the nozzles under the influence of the different pressures and different spray heights mentioned above.

However, when comparing the values of the coefficient of variation for different nozzles at a height of 30 cm spraying, Figure 8a, we find that there is complete randomness between the different curves when comparing these differences with Figure 8b when spraying at a height of 40 cm. There is approximate stability was showed and the differences became almost close. In the case of relative stability, the difference value found gradually increases at a slight rate as shown in Figure 8c, when spraying at a height of 50 cm.

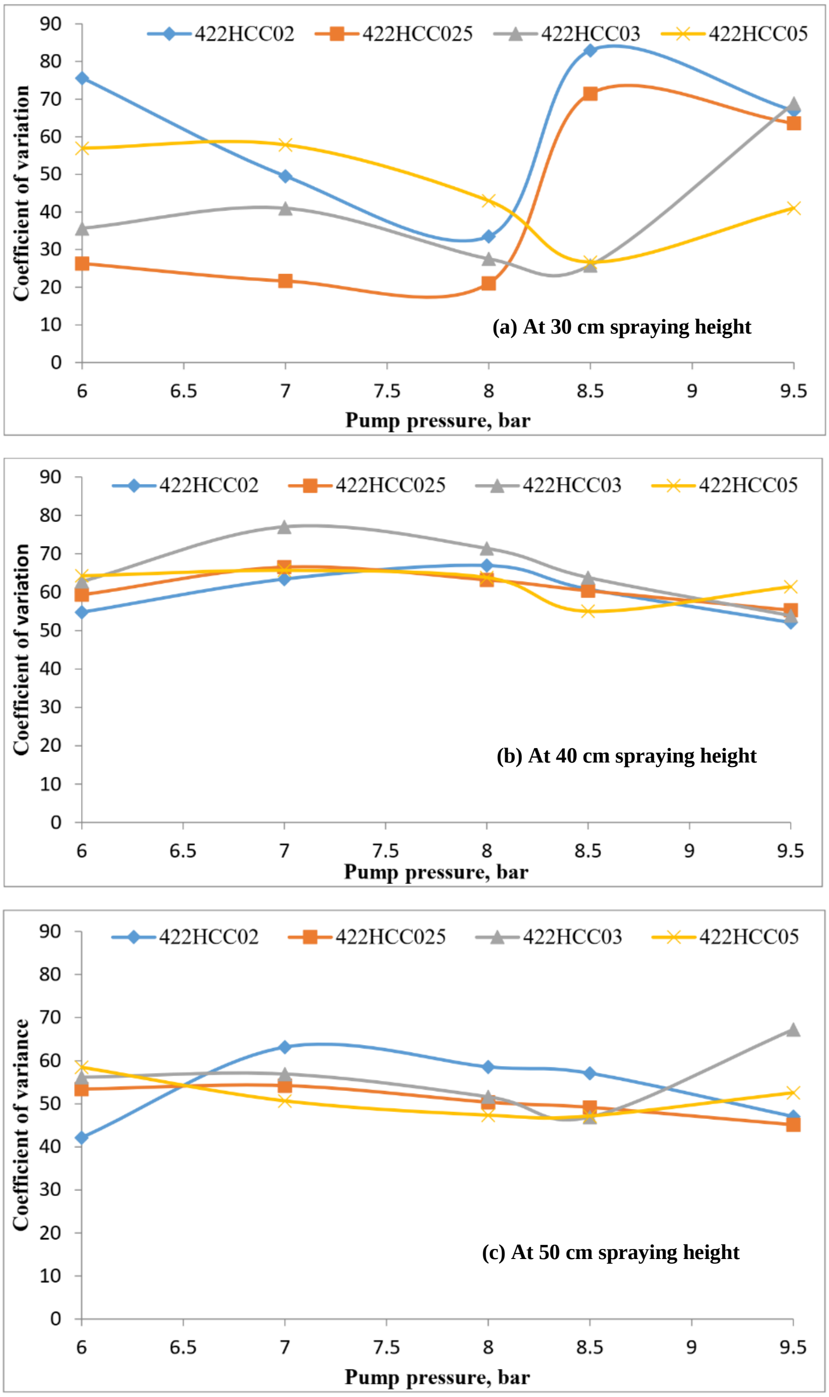


Figure 8. Data of coefficient of variation of the hollow cone ceramic (HCC) nozzles at different pump pressures.

3.1.4. Effect of spraying height, pump pressure, and nozzle type on length of spraying (Swath width)

Figure 9 shows the effect of operating pressure and spray height on the length of spray. It was observed that the spray length varied from 6.58 to 6.95 m and maximum length was observed for boom height of 30, 40, and 50 m at operating pressure of 9.5, 8.5, 8.0, 7.0, and 6.0 bar. From Figure 9, the swath was calculated for different pressures and heights for the different types of hollow cone ceramic nozzles.

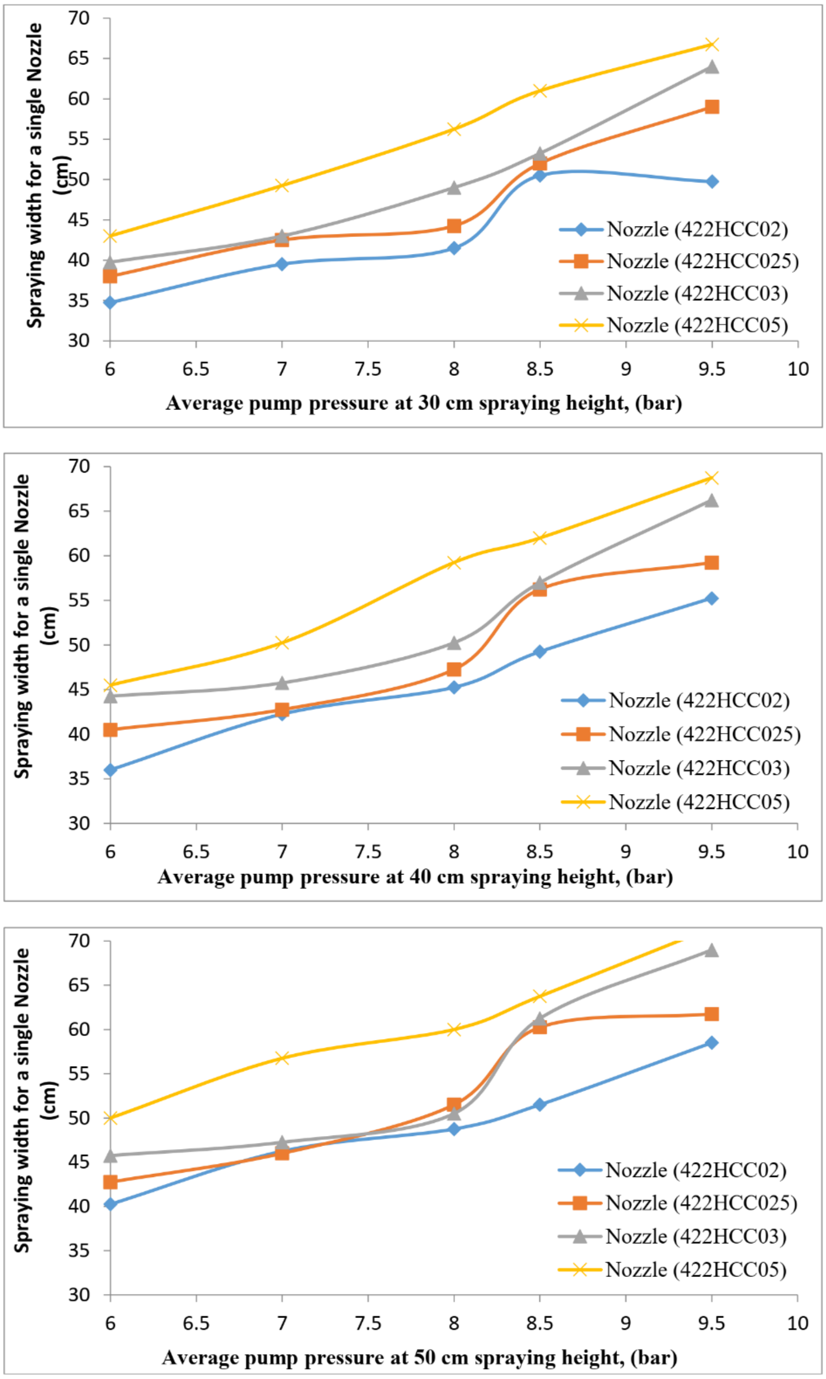


Figure 9. Effect of operating pressure on spraying length.

Figure 9 showed the relationship for the swath of different types of hollow cone nozzles at different heights and pressures. The different colored trend lines are for different types of hollow cone nozzles. The results showed that the swath increased due to increasing the spraying height or pump pressure or both of them. From the above table and figures, we found that the swath for the hollow cone ceramic nozzle (422HCC02) was increased from 49.75 to 58.50 cm with increasing the spraying height from 30 to 50 cm at 9.5 bar, respectively.

Also, the maximum swath for the hollow cone ceramic nozzle (422HCC025) was 61.75 cm at 50 cm height and 9.5 bar while the minimum swath was 38.00 cm at 30 cm height and 6 bar. On the other hand, we found that the swath for the hollow cone ceramic nozzle

(422HCC03) was increased from 64.0 to 69.0 cm with increasing the spraying height from 30 to 50 cm at 9.5 bar with 7.81 %. Finally, the results, illustrated that the maximum swath for the hollow cone ceramic nozzle (422HCC05) was 71.5 cm at 50 cm height and 9.5 bar while the minimum swath was 43.00 cm at 30 cm height and 6 bar.

4. Conclusions

This study was undertaken to evaluate the flow characteristics of liquid from four different spray nozzles (hollow cone ceramic nozzle (HCC)) 422HCC02, 422HCC025, 422HCC03, and 422HCC05 on a horizontal spray patternator. The discharge rate, spray distribution pattern, spray swath of all the types of nozzles were measured with a pressure range from 6.0 to 9.5 bar at three different nozzle heights (30, 40, and 50 cm). From this study, we can conclude that:

- Average discharge, from hollow cone ceramic nozzle, is directly proportional to the average pump pressure for all experimental nozzles.
- The best volumetric distribution for all experimental nozzles was under 9 bar and 50 cm spraying height.
- length of spraying (Swath width) is directly proportional to both spraying height and pump pressure.

Finally, we can say that the main contribution of this paper is to study the effect of spraying height, pressure, and nozzle type on the flow characteristics of a field sprayer. The results obtained in this study can be used to provide a broad base for the design of modern pesticide spraying machines, whose role is to reduce the quantities of pesticides used and reduce the costs of spraying by knowing the appropriate conditions of operating pressures and spraying height for the desired process based on the type of nozzle used.

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تأثير ارتفاع الرش وضغط الرش ونوع الفوهة على خصائص تدفق البخاخ الميداني

عبدالله الشوادفي الوكيل [١]، سعد فتح الله أحمد [٢]، عبدالله مسعد زين الدين [٢]، لؤي سعد الدين نصرت [٣]

[١] قسم الهندسة الزراعية، كلية الزراعة والموارد الطبيعية، جامعة أسوان، أسوان، مصر.
[٢] قسم الهندسة الزراعية والنظم الحيوية، كلية الزراعة، جامعة الأسكندرية، الشاطبي، الأسكندرية، مصر.
[٣] قسم الهندسة الكهربائية، كلية الهندسة، جامعة أسوان، أسوان، مصر.

الملخص العربي

يعد الرش الدقيق لمبيدات الآفات باستخدام آلات الرش أمراً ضرورياً في الممارسات الزراعية الحديثة حيث إنه يزيد من مكافحة الآفات ويقلل من تكاليف المبيدات والفاقد ويزيد من السلامة البيئية. حيث يعد خصائص تدفق السائل من فوهة الفواني أو الرشاشات أحد متطلبات الرش الدقيق لمبيدات الآفات. ومن ثم، أجريت دراسة لتقييم خصائص تدفق المبيد من أربعة أنواع من فواني رش مختلفة من النوع المخروطي الخزفي وهي 422HCC02، 422HCC025، 422HCC03 و 422HCC05 على جهاز patternator الأفقي. تم قياس معدل التصرف ونمط توزيع الرذاذ وعرض الرش لجميع أنواع الفواني السابقة بمدى ضغط ٦,٠ الي ٩,٥ بار عند ثلاثة أرتفاعات مختلفة للفوهة (٣٠ و ٤٠ و ٥٠ سم). وجدت اختلافات كبيرة في نمط التوزيع عند الضغوط المختلفة للتشغيل. وجد أن الحد الأقصى لمعامل الاختلاف (CV) لمتوسط تصريف الفوهة ضمن الحدود المسموح بها لأنها أقل من ١٠٪. لوحظ أنه مع زيادة ضغط التشغيل وارتفاع الرش، يحدث زيادة في عرض الرش الكلي. تم زيادة معدل التصرف من الفواني نتيجة زيادة ضغط التشغيل للمضخة حيث تراوح متوسط التصرف بين (٠,٩٨ - ١,٣٥)، (١,١٥ - ١,٦٥)، (١,٢٣ إلى ١,٧٦)، (١,٣٥ إلى ٢,٠٣) لتر/دقيقة للفواني السابقة على التوالي، عندم زيادة ضغط التشغيل من ٦,٠ إلى ٩,٥ بار.