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Evaluating of Different Types of Agricultural Nozzles Locally Used in Iraq

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Abstract

The experiment aimed to Manufacture a device for checking the nozzles and testing its efficiency and to study the effect of research factors on the studied traits. The device was manufactured locally through using materials available in the Iraqi market. The system is Both Hydraulic and electronic (ISO 5682-1)[1] relay on sensors technology and the test platform was built and designed on a movable trolly at the department of Agricultural Machines and Equipment / College of Agricultural Science / University of Baghdad. The design includes the use of mechanical water pump and electrical AC water pump. The design includes a nozzle holder that can accommodate three nozzles per test. The design also consists of spreading wings and stationary wing that can accommodate 50 vessels and 50 ultra-sonic sensors. All that is controlled by a main control unit which consists of three branch modules (each one of them is responsible to collect and analyze data from several sensors on each of the wings. The idea behind the design is to merge between actual spraying and the use of electronic sensors to analyze the size of the sprayed liquid in each of the vessels, the concept of the design is based upon Volumetric distribution of the liquid.

The concept of the device was based on using ultra sonic sensors to measure the volumetric distribution of liquids. The experiment aimed to determine the effects of these factors on flow rate, spraying angle, sprayed area, spraying swath, volumetric distribution (CV), and symmetry. The experiment was conducted at the college of Agricultural science, Baghdad University. The results showed that the spraying pressure had a non-significant effect on flow rate. However, increasing the pressure from 3.0 to 5.0 and then to 7.0 bar resulted in flow

[1] International Standard for the methods to test sprayer Nozzles /third edition May 2017

rates of 1.314, 1.286, and 1.36 l/m, respectively. The status of the nozzle (new or worn) did not significantly affect the flow rate, with new nozzles registering a slightly higher flow rate of 1.327 l/m compared to worn nozzles (1.312 l/m). On the other hand, the type of nozzle had a significant impact on flow rate, with plastic, brass, and steel nozzles registering flow rates of 1.243, 1.422, and 1.29 l/m, respectively.

Regarding the spraying angle, the results indicated that the spraying pressure had a significant effect. Increasing the pressure from 3.0 to 5.0 and then to 7.0 bar resulted in spraying angles of 132, 132, and 136 degrees, respectively. The nozzle status significantly affected the spraying angle, with worn nozzles resulting in a higher angle of 137 degrees compared to new nozzles (130 degrees). However, the type of nozzle did not significantly affect the spraying angle.

For the sprayed area, the spraying pressure had a significant effect, with higher pressures resulting in larger sprayed areas. Worn nozzles also significantly increased the sprayed area compared to new nozzles. The type of nozzle had a significant impact on the sprayed area, with plastic, brass, and steel nozzles resulting in areas of 70.4, 80.44, and 89.16 cm2, respectively.

The experiment proved that nozzles must be tested periodically, otherwise they start to perform beyond the parameters they were designed to perform with.

Keywords: Flow rate, spray angle, spray swath, pesticide application, sustainable agriculture

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Pesticides are chemical substances used to control or kill pests, including insects, weeds, fungi, and rodents. They are widely used in agriculture, forestry, and urban environments to protect crops, forests, and buildings from damage caused by pests. However, the use of pesticides also has essential negative impacts on human health and the National Institute of Environmental Health Sciences (National Institute of Environmental Health Sciences (1)One of the main concerns with pesticides is their essential to cause harm to non-target organisms, including humans, wildlife, and beneficial insects such as pollinators. Pesticides can be toxic to humans through direct exposure, such as inhalation or ingestion, or through the consumption of contaminated food or water. According to a review by the World Health Organization (WHO), long-term exposure to pesticides has been linked to a range of health problems, including cancer, neurological disorders, and reproductive problems (2).

New nozzles typically have a higher spray angle and a more consistent performance compared to used nozzles. This is because new nozzles have not undergone wear and tear from use, which can affect the spray angle. For example, a study conducted by (3) found that new air induction nozzles had an average spray angle of 120°, while used nozzles had an average spray angle of 105°.However, some used nozzles may still have a high spray angle depending on the level of wear and maintenance they have undergone. For example, a study conducted by (4) found that used nozzles that had undergone regular cleaning and maintenance had a higher spray angle compared to nozzles that had not been maintained.

different materials may have different physical properties that can impact the way in which the nozzle sprays. For example, nozzle materials that are more rigid or have a smooth surface may produce a more consistent and controlled spray pattern, while softer or more porous materials may produce a more variable or dispersed spray pattern (5).

The material of the nozzle may affect the durability and wear resistance of the nozzle, which can in turn affect the spraying angle over time. For example, a nozzle made of a more corrosion-resistant material may have a longer lifespan and maintain a consistent spraying angle, while a nozzle made of a less durable material may degrade more quickly and result in a changing spraying angle (6).

There is currently limited research available on the specific impact of using new versus used agricultural nozzles on the covered spray area. However, some studies have shown that the performance of agricultural nozzles can decline over time due to wear and tear, which may affect the coverage of the spray area.

One study conducted by (7) found that the spray patterns of used nozzles were more irregular and had lower flow rates compared to new nozzles. This resulted in decreased coverage of the spray area, which could essentially affect the efficacy of the applied chemicals.

In contrast, another study by (8) found that the performance of used nozzles was not significantly different from that of new nozzles in terms of spray distribution and coverage. However, the authors note that this may have been due to the relatively short time frame in which the nozzles were used (2-3 seasons).

For example, a nozzle made of a softer material, such as rubber or plastic, may produce larger droplets with a wider spray pattern, resulting in a larger covered area. On the other hand, a nozzle made of a harder material, such as stainless steel or ceramic, may produce smaller droplets with a narrower spray pattern, resulting in a smaller covered area (9)

Selecting the right type and size of a nozzle is crucial for effective pesticide application. The nozzle plays a central role in determining various factors. Nozzles play a crucial role in controlling the application of liquid sprays, whether in agricultural, industrial, or other settings. They affect numerous factors like spray volume, uniformity, coverage, and drift potential. By breaking the liquid into droplets and forming a spray pattern, nozzles enable precise application to the target area. The spray volume can be regulated by adjusting operating pressure, travel speed, and spacing between nozzles.

Minimizing drift is essential to avoid unintended spray dispersion, which could harm neighboring crops or the environment. Choosing nozzles that produce larger droplet sizes can reduce drift potential while still providing sufficient coverage at the intended application rate and pressure. This balance is crucial in ensuring effective and responsible use of liquid sprays in various applications (10). Low-pressure agricultural sprayers commonly employ various nozzle types, such as flat, flood, air induction, raindrop, full-cone, full-cone, and others. Some nozzle types also come with specific features or subtypes, like the "extended range," which expands the recommended operating pressure range (10).

The Full Cone pattern involves distributing droplets within a limited volume, forming a cone-shaped spray originating from the nozzle orifice. This spray pattern finds extensive application in various industrial processes, particularly when even water flow distribution on a surface is required. The flat fan spray pattern involves spraying liquid droplets in the form of a flat liquid layer, with varying thickness depending on the spray generation principle. These nozzles are designed for spraying surfaces or objects moving perpendicular to one of the jet surfaces, as seen in car washing tunnels, for example. The Hollow Cone Spray Pattern, characterized by droplets concentrated on the outer surface of a conical volume, does not contain any droplets inside the conical jet shape (11).

Materials and methods

Studied factors :

- **Spray Nozzles Materials (types)**

Nozzles are manufactured using various materials, with the most common options being brass, nylon, stainless steel, hardened stainless steel, tungsten carbide, thermoplastic, and ceramic. Ceramic and tungsten-carbide nozzles are known for their exceptional durability and high resistance to corrosion. Stainless-steel nozzles outlast brass or nylon counterparts and maintain a consistent spray pattern over extended periods.

- **Pressure :** Pressure plays a significant role in the operation of nozzles and the spraying process, affecting factors like spray pattern, droplet size, flow rate, and overall performance. Here's an overview of how pressure affects nozzles and spraying, along with some references for further reading:

1. **Spray Pattern**: The pressure of the fluid passing through the nozzle affects the shape and width of the spray pattern. Higher pressure generally results in a narrower spray pattern, while lower pressure produces a wider pattern. This can be crucial for achieving even coverage in agricultural and industrial applications (12).
2. **Droplet Size**: Pressure affects droplet size in a sprayed stream. Higher pressure tends to produce smaller droplets, which can be advantageous for

applications like pesticide spraying, where uniform coverage of small droplets is desired (13)

3. **Flow Rate**: Pressure is directly related to the flow rate through the nozzle. Increasing pressure typically results in higher flow rates. This relationship is essential for controlling the amount of material applied in various applications (14).
4. Atomization: Pressure is a key factor in atomizing the liquid into fine droplets as it passes through the nozzle. Proper atomization is crucial for applications like fuel injection in engines and industrial coating processes (15).
5. Nozzle Selection: Pressure compatibility is a key consideration when selecting a nozzle for a specific application. Nozzles are designed to operate within a particular pressure range, and operating outside this range can result in inefficient spraying and nozzle wear (16).
6. Pressure Loss: Pressure drop occurs as fluid passes through the nozzle, which should be considered in the overall system design. Pressure loss can affect the efficiency of the spraying process and may require additional pumping power (17).
7. Safety: High-pressure systems used in some spraying applications can pose safety risks. Proper training and safety measures are essential to prevent accidents and injuries (18).

Understanding the relationship between pressure and nozzle performance is crucial for achieving desired outcomes in various industries and applications. The references provided cover a range of topics related to fluid dynamics, atomization, and spraying techniques, offering in-depth insights into the subject matter.

- **Status of the nozzle (new& worn):** The status of a nozzle, whether it is new or worn, can significantly affect the spraying process in various ways. Nozzles are crucial components in spray systems, and their condition can impact spray pattern, flow rate, droplet size, and overall spray efficiency. Below, I'll outline the key effects of nozzle status on the spraying process, with references included:

1. Spray Pattern and Uniformity:
   - New Nozzle: A new nozzle typically produces a consistent and uniform spray pattern, distributing liquid evenly. This is crucial for applications such as agriculture, where uniform coverage is essential.
   - Worn Nozzle: A worn nozzle may result in an uneven or distorted spray pattern, leading to uneven coverage. This can reduce the effectiveness of pesticide or fertilizer applications (19).
2. Flow Rate:
   - New Nozzle: New nozzles generally maintain their designed flow rate, ensuring accurate application rates.
   - Worn Nozzle: Worn nozzles can experience reduced flow rates due to erosion or clogging. This can result in underapplication, affecting the desired spray rate (20)
3. Droplet Size:
   - New Nozzle: New nozzles typically produce consistent droplet sizes, which can be important for controlling the drift of chemicals.
   - Worn Nozzle: Worn nozzles can produce larger or

irregular droplets, increasing the risk of drift and reducing the effectiveness of the application (20).

4. Efficiency and Operating Costs:
   - New Nozzle: New nozzles are more efficient and cost-effective in terms of achieving the desired spray results.
   - Worn Nozzle: Worn nozzles may require higher pressure to maintain desired flow rates, leading to increased energy consumption and operating costs (19).
5. Maintenance and Replacement:
   - Regular Maintenance: Proper nozzle maintenance, including cleaning and replacement of worn nozzles, is essential to ensure consistent spray performance (20)).
   - Periodic Inspection: Regularly inspecting nozzles and replacing them when needed can prevent issues associated with worn nozzles (20)

The platform Design.

the experiment aims to test nozzles of different design, materials and status and see if the above mentioned factors in addition to pressure affect the flow rate , spraying angle ,the covered area , spraying width , symmetry of the spray and the volumetric distribution of spraying in agricultural nozzles.

The system is Both Hydraulic and electronic (ISO 5682-1)[2] relay on sensors technology and the test platform was built and designed on a movable trolly at the department of Agricultural Machines and Equipment / College of Agricultural Science / University of Baghdad. The design includes the use of mechanical water pump and electrical AC water pump. The design includes a nozzle holder that can accommodate three nozzles per test. The design also consists of

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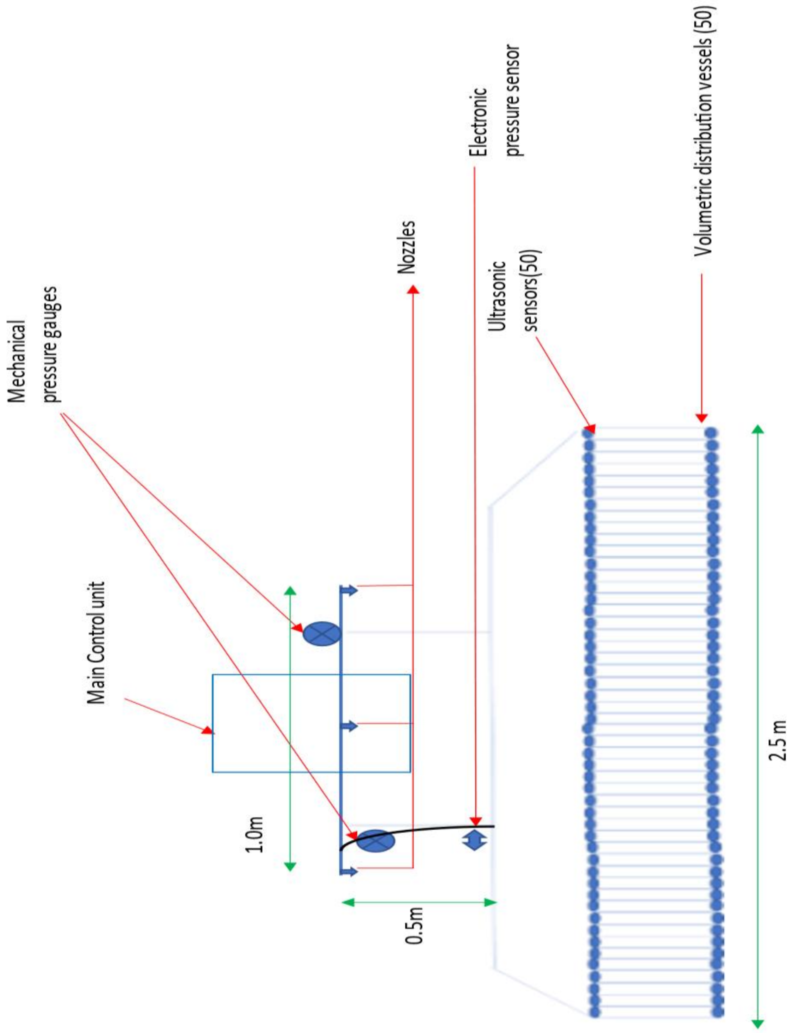
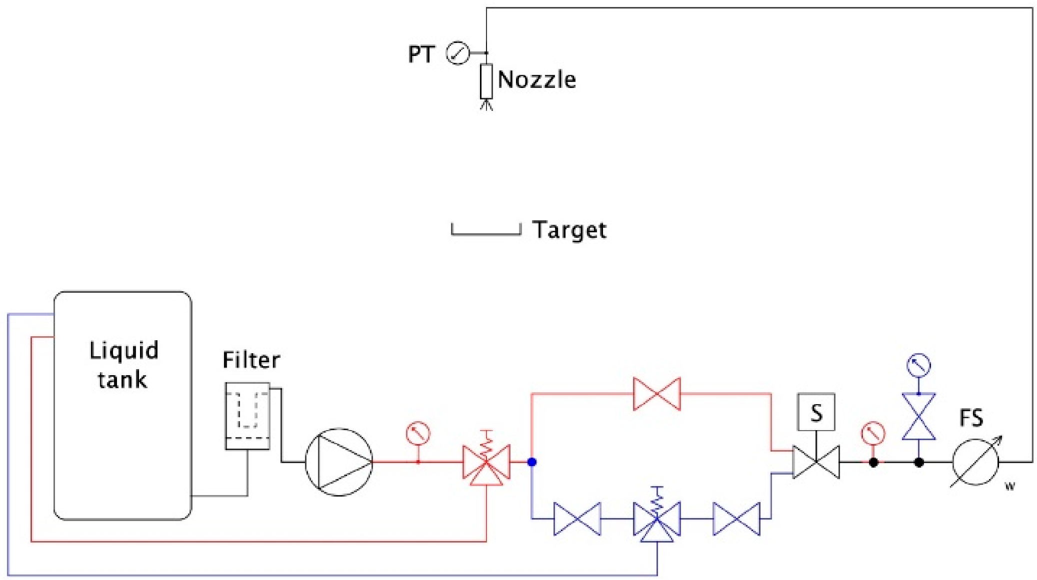
spreading wings and stationary wing that can accommodate 50 vessels and 50 ultra-sonic sensors. All that is controlled by a main control unit which consists of three branch modules (each one of them is responsible to collect and analyze data from several sensors on each of the wings. The idea behind the design is to merge between actual spraying and the use of electronic sensors to analyze the size of the sprayed liquid in each of the vessels, the concept of the design is based upon Volumetric distribution of the liquid.


Mechanical pressure gauges
Main Control unit
Nozzles
Electronic pressure sensor
Ultrasonic sensors(50)
Volumetric distribution vessels (50)
1.0m
0.5m
2.5 m

According to the aims of the research, the design of the hydraulic circuit was carried out in a way that is very similar to the standard spraying system installed on commercial sprayers, thus a 100 liter tank and a mechanical piston pump in addition to one electric pump were chosen. As the pump capacity is much higher than the flow rate of the nozzle under test, the surplus was recirculated to the main tank by means of a pressure regulator as it is in the sprayers to ensure continuous mixing of the liquid. system also include several Valves and pressure gages and pressure sensors, and one flow rate sensor as clarified in Figure 4. Gages and sensors give reading directly through sight and feedback to the main control unit which will be explained in detail later.



Devices (quantity):

- Flow rate sensor
- Pressure sensor
- Ultrasonic sensors
- Mechanical pump (1)
- Electrical pump (1)
- Flow rate sensor (1)
- Pressure sensors (2)
- Mechanical pressure gages (2)
- Pipes and connections ¾"
- Mechanical valves to control the flow of the liquid.
- Valves to control the pressure inside the system (check valve)
- Plastic Water tank (100 liters)

Calculating the flow rate:

The flow rate is calculated electronically through the use of the electronic Flow rate sensor and the data then fed back to the central control unit and the LCD . The embed software within the sensors main control unit calculate the flow rate using the following Formula:

Q = A * V (21).

where: Q = the flow rate (in liters per minute), A = the cross-sectional area of the pipe or channel through which the fluid is flowing (in square meters), V = the velocity of the fluid (in meters per second).

To convert the flow rate to liters per minute, you can multiply the flow rate (Q) by 60, as there are 60 seconds in a minute.

The angle of spray:

The angle is calculated using triangular mathematics through the flowing formula (22):

$$\frac{A}{\sin(a)} = \frac{B}{\sin(b)} = \frac{C}{\sin(c)}$$

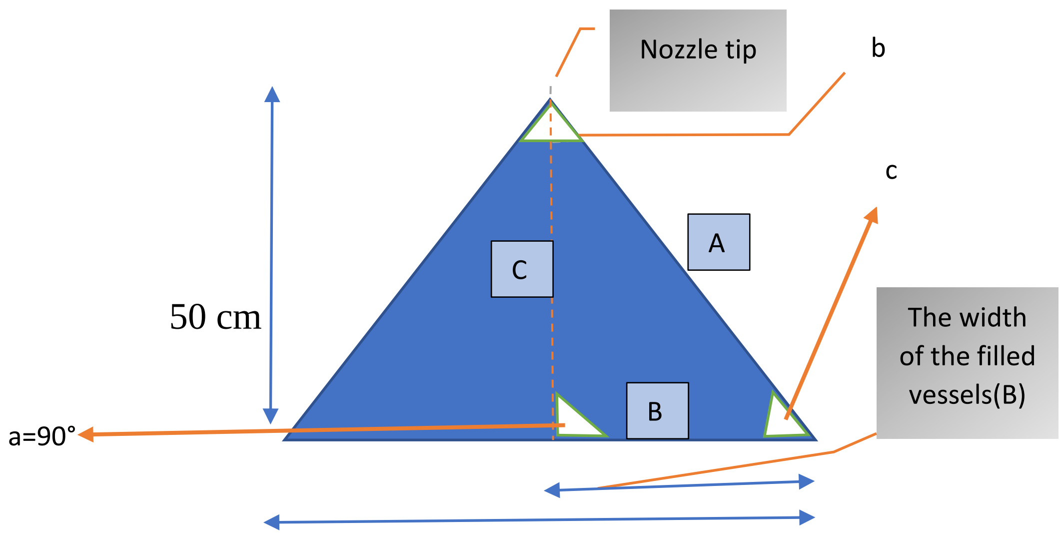


Figure 4 the rule to calculate the spray angle

A/sin(a) = B/sin(b) = C/sin(c), represents the Law of Sines in trigonometry. It is a mathematical relationship used to solve triangles. The equation states that the ratio of a side length of a triangle to the sine of its opposite angle is the same for all three sides and their respective angles.

The Law of Sines can be used to find missing side lengths or angles in a triangle when certain information is known. By rearranging the equation, we can solve for different unknowns depending on the given information (22). Knowing the diameter of one vessel is 5 cm and the thickness of the vessel wall is 0.2 cm, all we have to know from the sensors that how many vessels were filled. And then through the algorithm the triangle will be divided to two triangles to obtain the 90° angle and then apply the equation and then multiply the resulted angle by 2. All that is done electronically and appears on the LCD. the embed software within the sensors main control unit calculate the spray angle using the mentioned Formula.

Calculating area of spray:

To calculate this character, the platform will be turned on for (5 – 10 seconds) and the following steps will be followed:

1- If the sprayed areas are circles, the software is embedded with below formula:

$A = \pi r^2$

Where: A = is the area of the circle, π (pi) = is a mathematical constant equal to 3.14159 (although it has many more decimal places), r = is the radius of the circle. This formula states that the area of a circle is equal to the square of its radius multiplied by pi. (23).

2- If the sprayed area is oval shaped that the calculation of the sprayed area will be dome manually through turning on the platform for (5-10 seconds) and then applying the following formula: **Area = π * a * b** (24)**.** Where: **π (pi)** is a mathematical constant approximately equal to 3.14159, **a** is the length of the semi-major axis (half of the longest diameter),**b** is the length of the semi-minor axis (half of the shortest diameter).as clarified in figure 9.

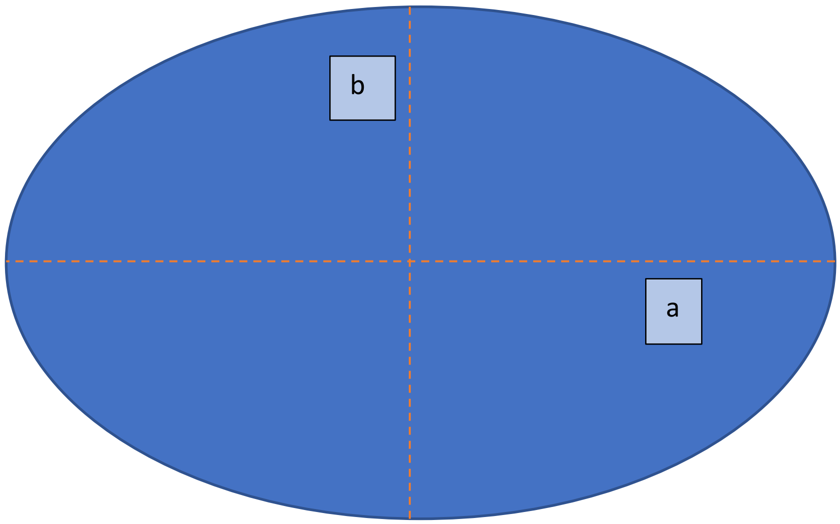


Figure 5 the oval area

Here's

how to use this formula:

1- Measure the length of the semi-major axis (a), which is the longest diameter of the oval.
2- Measure the length of the semi-minor axis (b), which is the shortest diameter of the oval.
3- Plug these values into the formula.
4- Multiply π by the product of a and b to calculate the area.

Flowrate

Table 1 shows the impact of the pressure, status of the nozzle and the type of nozzle on the flowrate. The spraying pressure has a non-significant effect on the flowrate. Increasing the spraying pressure from 3.0 to 5.0 and then to 7.0 bar registered a flowrate of 1.314, 1.286, and 1.36 l/m respectively. Using the worn nozzles did not significantly affect the flowrate which was registered 1.312 l/m compared with the flowrate of new nozzles (1.327

l/m). The type of nozzle significantly affected the flowrate in which plastic, brass and steel nozzles registered a flowrate of 1.243,1.422 and 1.29 l/m respectively.

Table 1. the Flowrate (litter per minute) for different types of nozzles (new and worn) at different spraying pressures.

Type of nozzle (T)	Status (S)	Pressure (P)			T * S	
		3 bar	5 bar	7 bar		
Plastic/flat fan	new	1.179	1.312	1.312	1.268	
	worn	1.218	1.123	1.312	1.218	
Brass/full cone	new	1.596	1.218	1.407	1.407	
	worn	1.312	1.596	1.407	1.438	
Steel/Full cone	new	1.266	1.438	1.218	1.307	
	worn	1.312	1.028	1.504	1.281	
LSD $_{T*S*P}$		0.2034			LSD $_{T*S}$	0.117$^{N.S}$
T * P						
Type of nozzle		3 bar	5 bar	7 bar	Mean Nozzle	
Plastic /flat fan		1.268	1.218	1.312	1.243	
Brass /Full cone		1.407	1.407	1.407	1.422	
Steel /Full cone		1.307	1.233	1.361	1.294	
LSD $_{T*P}$		0.143 $^{N.S}$			LSD $_{T}$	0.083
S * P						
Status (S)		3 bar	5 bar	7 bar	Mean status	
new		1.347	1.323	1.312	1.327	
worn		1.281	1.249	1.408	1.312	
LSD $_{S*P}$		0.1174 $^{N.S}$			LSD $_{S}$	0.067 $^{N.S}$
P						
Pressure (P)		3 bar	5 bar	7 bar		
Mean Pressure		1.314	1.286	1.36		
LSD $_{S}$		0.83 $^{N.S}$				

Spraying angle:

Table 2 shows the impact of the pressure, status of the nozzle and the type of nozzle on the spraying angle. The spraying pressure has a significant effect on the spray angle. Increasing the spraying pressure from 3.0 to 5.0 and then to 7.0 bar registered a spraying angle of 132, 132, and 136 respectively. Using the worn nozzles significantly affected the spray angle which was increased to 137 degrees comparing with the angle of new nozzles (130 degree). The type of nozzle did not affected the spray angle significantly.

Table 2. the spray angle (degrees) for different types of nozzles (new and worn) at different spraying pressures.

Type of nozzle (T)	Status (S)	Pressure (P), bar			T * S	
		3.0	5.0	7.0		
Plastic /flat fan	New	119	124	134	126	
	Worn	137	143	144	141	
Brass /Full cone	New	126	134	135	132	
	Worn	143	128	141	138	
Steel /Full cone	New	132	133	133	133	
	Worn	129	133	132	132	
LSD $_{T*S*P}$		7.4			LSD $_{T*S}$	4.3
T * P						
Type of nozzle		3 bar	5 bar	7 bar	Mean Nozzle	
Plastic /flat fan		126	131	138	133	
Brass /Full cone		132	131	138	135	
Steel /Full cone		133	133	132	132	
LSD $_{T*P}$		5.2 $^{N.S}$			LSD $_{T}$	3.0 $^{N.S}$
S * P						
Status (S)		3 bar	5 bar	7 bar	Mean status	
New		128	129	134	130	
Worn		137	135	139	137	
LSD $_{S*P}$		4.3 $^{N.S}$			LSD $_{S}$	2.5
P						
Pressure (P)		3 bar	5 bar	7 bar		
Mean Pressure		132	132	136		
LSD $_{S}$		3				

Sprayed Area

Table 3 shows the impact of the pressure, status of the nozzle and the type of nozzle on the sprayed area . The spraying pressure has a significant effect on the sprayed area. Increasing the spraying pressure from 3.0 to 5.0 and then to 7.0 bar registered a spraying area of 78.54,80.02 and 81.44 Cm^2

respectively. Using the worn nozzles significantly affected the sprayed area which was increased to 82.14cm^2 comparing with the sprayed area of new nozzles (77.86 cm^2). The type of nozzle significantly affected the sprayed area when using different types of nozzles for plastic, brass, and steel respectively registered 70.4,80.44 and 89.16 cm^2 .

Table 3. the sprayed area (cm^2) for different types of nozzles (new and worn) at different spraying pressures.

Type of nozzle (T)	Status (S)	Pressure (P) 3 bar	5 bar	7 bar	T * S	
Plastic /flat fan	1	66.48	68.46	70.12	68.35	
	2	71.16	72.32	73.84	72.44	
Brass/Full cone	1	75.66	77.3	79.26	77.41	
	2	81.43	83.58	85.39	83.46	
Steel /Full cone	1	86.83	87.84	88.78	87.82	
	2	89.68	90.61	91.24	90.51	
LSD $_{T*S*P}$		0.847 N.S			LSD $_{T*S}$	0.489
T * P						
Type of nozzle		3 bar	5 bar	7 bar	Mean Nozzle	
Plastic /flat fan		68.35	70.39	71.98	70.4	
Brass /Full cone		77.41	80.44	82.33	80.44	
Steel /Full cone		87.82	89.23	90.01	89.16	
LSD $_{T*P}$		0.599			LSD $_T$	0.346
S * P						
Status (S)		3 bar	5 bar	7 bar	Mean status	
new		76.32	77.87	79.39	77.86	
worn		80.76	82.17	83.49	82.14	
LSD $_{S*P}$		0.489 N.S			LSD $_S$	0.282
P						
Pressure (P)		3 bar	5 bar	7 bar		
Mean Pressure		78.54	80.02	81.44		
LSD $_S$		0.346				

Conclusion

1. The locally designed and manufactured platform effectively tested and examined agricultural nozzles, indicating its potential for future sprayer inspections in Iraq.
2. Plastic flat fan nozzles performed the best among those studied, with pressure at 3 bar and interactions among (pressure, status, type) significantly affecting flow rate, spraying angle, spray swath, and symmetry.
3. Dual interventions between (type, status) significantly impacted spraying angle, sprayed area, spray swath, and symmetry, while having an insignificant impact on volumetric distribution.
4. Dual interventions between (type, pressure) had a significant impact on sprayed area and symmetry, while (status, pressure) had a significant impact on volumetric distribution and symmetry of the spray.
5. Higher pressure led to increased flow rate, spray symmetry, spraying angle, volumetric distribution, spray width, and sprayed area, affecting nozzle lifespan, with steel nozzles showing higher wear due to their higher resistance.

References

1. **National Institute of Environmental Health Sciences(NIEHS).** Pesticide exposure on Thai farms mapped by NIEHS-funded scientists. [Online] february 2022. https://www.niehs.nih.gov/health/topics/agents/pesticides/index.cfm.

2. **World Health Organization (WHO).** *https://www.who.int/news-*

room/fact-sheets/detail/pesticides. [Online] 2020. https://www.who.int/news-room/fact-sheets/detail/pesticides.

3. *Comparison of Spray Characteristics of Air Induction and Conventional Nozzles.* **Sharma, R.,, Paudel, A., and Dhungana, D. .** 2019, American Journal of Agriculture and Forestry, pp. 7(5), 119-123.

4. *Spray Angle and Droplet Size of Flat Fan Nozzle.,.* **Kottai;, et al.** 2015, International Journal of Advanced Research in Engineering and Technology (IJARET), pp. 6(3), 269-275.

5. . *Effects of Nozzle Materials on the Spray Quality of Agricultural Sprayers. , .* **Hakim, M., Abbasi, M., & Hamid, M.** (2011), American Journal of Agricultural and Biological Sciences, pp. 107-112.

6. *Impact of Nozzle Type and Wear on Sprayer Performance.* . **Tuttle, A. D., Daugrois, J. H., & Kustas, W. P.** (2014). , Transactions of the ASABE,, pp. 57(6), 1761-1770.

7. *Performance of used and new spray nozzles. ,.* **Zhang, J., , Hu, X., and Lü, H. .** 2015, Transactions of the ASABE, pp. 58(1), 185-190.

8. *Comparison of spray distribution of new and used nozzles in vineyard spraying.* **Kaus, C.,, Rauch, S., and Schmid, V. .** 2013, Journal of Agricultural Engineering, pp. 44(3), 15-22.

9. *Influence of nozzle type and pressure on the spray characteristics of aqueous solutions.* **Daugrois, J. H., Tran, Q. T., & Ahn, K. J. .. ,.** (2018), International Journal of Spray and Combustion Dynamics, pp. 10(2), 193-203.

10. **Robert N. Klein.** Nozzles — Selection and Sizing. Lincoln, Nebraska , USA : Institute of Agriculture and Natural Resources at the University of Nebraska.

11. *Nozzles: Selection and Sizing.* **Grisso, Robert.** 2013, Virginia Tech, p. 4.

12. **Bengstone, H.H.** *Introduction to fluid Mechanics.* 2016.

13. **Miller, P.C.** *Pestcide application Techniques for Field Crops.* 2011.

14. **Master, J.** *Spray Drying handbook.* 2001.

15. **Lefebvre, A.H. and McDonell,V.G.** *Atomization and sprays.* 2017.

16. **ASABE.** S572.1. *spray nozzles classification by droplet size* . 2016.

17. **pipes, L.A.** *Applied Fluid Mechanics* . 1998.

18. **EPA.** *Best Managment Practices for Pestcide Use to prevent Ground*

and Surface water Contamination. 2015.

19. *Influance of Nozzle type and wear on potential drift.* **Weaver, M.A., Burton,M.G and Reddy,k.N.** 2003.

20. *Spray nozzles Selction and Maintanace for crop Application.* **Hoffman, W.C.** 2005.

21. **Munson, B.R., Young, D.F., Okiishi, T.H., & Huebsch, W.W.** *Fundamentals of Fluid Mechanics.* s.l. : John Wiley & Sons, 2012.

22. **Sullivan, Michael.** *Trigonometry: A Unit Circle Approach.* s.l. : Pearson, 2014.

23. **Stewart, James.** *Calculus: Early Transcendentals.* s.l. : Cengage Learning. ISBN-13: 978-1285741550., 2015.

24. **Mungan, C.E.** United states naval Acadmy . [Online] 2013.

25. *Influence of nozzle type and pressure on spray characteristics in orchard.* **Jin, Y., Zhang, Y., & Lu, Y.** 2004, Transactions of the Chinese Society of Agricultural Engineering, pp. 20(6), 91-95.