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المجلة العراقية لبحوث السوق
وحماية المستهلك

EFFECT OF SPRAY PRESSURE AND VERTICAL BOOM POSITION ON THE SPRAY QUALITY

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ABSTRACT

The research to focuses on spraying the plant leaves from the bottom and top by developing a sprayer. The sprayer was making a sprayer made of aluminum with a movable arm containing a nozzle holder divided into three pieces. Each piece contains a nozzle of the type Flat Fan 120-C3. The tasting of the sprayer was done in one of the greenhouses of the Department of Horticulture and Forestry. The study has two factors, the first is changing eff changing the positions of the nozzle holder tube to two levels A1, A2. The second factors were the spray pressure with three levels P1=2, P2=3, P3=4 bar. The spraying speed was 3.12 km/h. The effect of the previous factors on the following characteristics namely: spray losses, spray penetration, and spraying homogeneity. The research began in 2021.The experimental design was Randomized Complete Block Design (RCBD) according to the SPLIT-PLOT system and with three replications using a significant difference LSD with a probability level of 0.05. The results showed that the study factors at the level of A1 position and pressure 4 bar were superior to the losses and penetration. The level of A2 and P3 pressure achieved the highest result with the uniformity of the spray.

Key words: Agricultural nozzles, eggplant plant, greenhouses, nozzle holder positions, spray pressure.

تأثير ضغط الرش وموضع حامل الفوهات الرأسي على جودة الرش

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الخلاصة

يهدف البحث إلى التركيز على رش أوراق النبات من الأسفل والأعلى عن طريق عمل مرشة مصنوعة من الألمنيوم بذراع متحرك تحتوي على حامل فوهة مقسم إلى ثلاث قطع وتحتوي كل قطعة على فوهة من نوع Flat Fan 120-C3 وتجربة الآلة في أحد البيوت المحمية التابعة لقسم البستنة والغابات ودراسة تأثير تغيير مواضع أنبوب حامل الفوهة إلى لمستويان A1, A2 وتأثير تغيير الضغط على ثلاثة مستويات P1=2،P2=3،P3=4 بار بمتوسط سرعة سحب 3.12 كم\ساعة عند دراسة تأثير العوامل السابقة على بعض خصائص الدراسة وهي خسائر الرش واختراقه الغطاء النباتي مع تجانس الرش. بدأ البحث في عام 2021. والتصميم التجريبي هو RCBD وفقا لنظام SPLIT-PLOT ولثلاث مكررات باستخدام فرق معنوي LSD بمستو ى احتمالية 0.05 أظهرت النتائج أن عوامل الدراسة عند

*The article is taken from a master's thesis by the first researcher.

مستوى وضعية A1 وضغط 4 بار كانت متفوقة الضائعات و الاختراق كما حقق مستوى A2 وضغط 4 بار أعلى نتيجة مع تجانس الرش واختراقه الغطاء النباتي مع تجانس الرش.

الكلمات المفتاحية: البيوت المحمية ، ضغط الرش ، الفوهات الزراعية ، نبات الباذنجان ، وضعيات حامل الفوهات.

INTRODUCTION

Growing vegetable crops is essential in human life because it is part of daily food. Each crop has a certain service process; the essential process for plants is the addition of chemical liquids of all kinds (pesticides, fertilizers or growth regulators) to it **(Sanaa, *et al*, 2020; Sura &Al-Hilfy, 2022; Alrawi *et al.*, 2023; Al-Karawi & Al-Jumaily, 2022; Shaymaa,*et al*, 2022)**.

Saving spray while continuing its quality leads to a reduction in the material costs of service operations **(Yarpuz-Bozdogan *et al.*, 2011; Subr, *et al*, 2020).** The sprinkler irrigation method instead of surface irrigation has overcome increasing production and reduce water consumption **(Hassan, *et al*, 2021).**

Eggplant is an agricultural crop which is grown in the off-season in greenhouses. Eggplant is called *Solanum melongena* L and is the Solanaceae family. The eggplant crop is grown in the Mediterranean region in Central Asia and reserves, while in the northern regions, it is not grown because it needs daylight hours within (14-12) hours of sunlight, and the optimum temperatures are (30-21) degrees Celsius as for the temperature (35<temperature<15), the temperature above (35) degrees Celsius reduces the flowering contract and thus reduces the number of fruits on one plant, while the temperature below (15) degrees Celsius negatively affects growth and production **(Koller *et al*., 2016) & (Baudoin *et al*., 2017)**.

The spraying in Iraq does not follow international standards, especially in terms of calibration and type of nozzle **(Subr,*et al*, 2019).** The methods used to serve crops are still evolving. Considering their pattern, whether it is exposed or protected, as they affect the machines and manage the crop. The eggplant crop is important in the requirements of daily per capita consumption. Because its leaves are wide and drooping, they do not allow spraying from below, which makes the frequency of spraying increase the consumption of liquids with an increase in the costs of the spraying process with the survival of toxic deposits on plants and the ground and their impact on human and animal health alike **(Nansen *et al*., 2015)**.

In Iraq, three types of sprayers are used in greenhouses plastic sprayers which were shoulder bag, drawn and hanging on the tractor. The common between the spray holder is manual, which makes the spray ununiformed. The loss of volatile spray and its penetration is into the vegetation system with the amount of homogeneity of the spray. All of these are characteristics of the study associated with their overlapping factors, namely the pressure and the position taken by the nozzle holder and directly affected spraying processes.

They worked **Foque & Nuyttens, (2011)** On increaseing spraying on crops in greenhouses to rise penetration and strengthen spraying on the underside of the leaf using three types of nozzles. They use of two pressures (6,3) bar, but due to the density of vegetation cover, there is a discrepancy in the results, especially with penetration and spraying of the underside of the plant leaf, and more experiments were recommended.

They did **Derksen *et al.*, (2009)** Spraying ornamental crops in greenhouses with a nozzle holder horizontal from the top of ornamental plants to cover their leaves from the bottom and top. It has increased coverage on the top side of the leaves but not significantly on the lower side of the leaves.

Similarly, crops are threatened by pests that feed on the lower surface of the leaves, such as whitefly and aphids **(Derksen *et al.*, 2010 a)**.

The experiment was conducted on ornamental plants of one of the greenhouses by nozzles that operate using air induction of five different companies and a normal flat nozzle. The result was the deposition of the spray on the upper surface increased by (500%) while the lower surface of the leaves results showed a difference in the result. The researcher recommended further research in this area in to cover the lower surface of the leaves of the plants with increased penetration of the spray to the vegetative parts. The operator's skill to deposit with manual spraying devices is the most reliable on him to reduce fluctuations in spraying **(Derksen *et al.*, 2010 a; Derksen *et al.*, 2010 b).**

In order to prove the concept of spraying in new ways, the coverage of ornamental plants from the three sides to preserve the environment with increased sedimentation and penetration and to reduce the sprayed material, the three nozzles were placed for spraying, with different spray angles. The first and second are on both sides of the plant, and the third is on the top. The result was more coverage on the upper and lower surface of the leaf than if traditional methods, such as manual spraying, were used to perform **(Zwertvaegher *et al.*, 2017)**.

Illing, (1997) stated that the exposure of workers in greenhouses increases to volatile and dangerous residues of chemicals and pesticides sprayed with an unclear indication caused by the fluctuation of the number of workers, workers in greenhouses with other causes, so it is not possible to limit the number of real workers in greenhouses and for this it is not possible to predict the real percentage of the number of injured, although it is found at least for every 10,000 workers two in greenhouses.

Vertical patterns were used to determine and adjust the most appropriate form of spraying, adapt the faucet openings settings in terms of direction and position of the nozzle on the nozzle holder and create a training system for plant spraying personnel and adapt to the stages of plant growth grown by the Plant Protection Preparation Program (PPP) Plant Protection Products **(Garcera *et al*., 2022; Dereń *et al*., 2017)**.

Spraying eggplant plants was carried out in one of the greenhouses to study three working pressures which were (5,3,2) bars with four spray patterns. Moreover studies, the properties of these drops using a program to analyze the smudges ImageJ has shown that the pattern of spraying and pressure directly affect the amount of spray reaching the parts of the vegetative system and the extent of homogeneity and penetration with its distribution to most plant parts **(Braheem & Alheidary, 2022)**.

Grisso *et al*.,(1988); Alheidary, (2018) have explained. The nozzle holder pattern used during spraying (the shape of the nozzle holder) significantly reduce loss and completing work efficiently.

In a study conducted by **Hanafi, *et al*., (2016)** to prove that when placing pairs of three twin nozzles, Type the flat fan type at an angle of (110) degrees and inclined at an angle to the nozzle holder in the upward direction (45) degrees, and placing water-sensitive leaves on pea plants on the lower surface of the leaves of plants, the results of sedimentation, coverage, and elimination of the red spider showed one of the pests spread on the aforementioned plant. The results were better when compared to some of the results of previous experiments with the current study.

Whit the increase in operating pressure caused increases with the coverage, and the penetration of the plant canopy increases with the use of the appropriate speed **(Marwan & Subr, 2022)**

In a study by **Coelho *et al.*, (2021)**, the result was more droplets at the highest pressure, resulting in better coverage of the plant canopy. This resulted in the coverage of vegetation at the highest rate. To increase the pressure from (approximately one bar) 15psi to (approximately three bars) 45psi, both the percentage of coverage and the spray rate (l/ha) with the number of drops almost doubled.

Gavali & Kalashetty, (2018); Liu *et al*., (2020) The causes of off-target spraying losses are primarily due to large differences in vegetative density, plant sizes, arrangement and spacing of planting sites, the rate of delivery of pesticides with their continuity for spraying, as well as the spraying machine, used when spraying, as most of the work is related to the type of traditional sprayers, which in turn cause many losses during spraying. In order to increase the efficiency of spraying physically, practically, environmentally, and economically, the above points must take order achieve sustainable environmental development.

The penetration is one of the important characteristics of the spraying process as it gives us an indication of the amount of spray penetrating to most plant parts, especially in the center of the vegetative system of the plant. And that the closer the target is to be sprayed, the greater the penetration and sedimentation and vice versa

Failla & Romano, (2020); Oliveira *et al*., (2014) pointed out that the skill of the spraying person requires him to take Guidance regulations on the spraying machine, including getting as close as possible to the target to be sprayed to increase penetration and deposit on the plant canopy.

When using a spray cart with a four-nozzle spray arm was vertical. The distance between one nozzle and its adjacent (0.5 m) at an angle of inclination (15 °) of the nozzles is directed upward from the horizon level with a pressure of (20 bar = 2000 kPa and 12 bar = 1200 kPa) and a spray rate of (1500 l / ha) increased the total sedimentation and its percentage is about (33.9%) and (40%) for the same efficiency, pressures. Homogeneity of spraying and minimization of loss on the soil. Furthermore, manual spraying produced lower values than the towed cart **(Sanchez-Hermosilla *et al.*, 2012)**.

Llop *et al.*, (2015) have confirmed Knapsack sprayer that when used in greenhouses, the spraying is heterogeneous, and cost-effective with a longer spraying time, and the spraying operator is exposed to more risk of sprayed chemicals. The researchers showed that using a vertical spray arm with a spray trolley is the opposite of what was mentioned above, with an increase in the homogeneity of the spray. Spraying inside greenhouses in Iraq still faces problems in delivering spray to some areas in the vegetation system (the surface of the lower face of the leaves). As the work of the second person is to extend the spray hose at the time, while the first person works to complete the spraying process by the manual spray arm, which in turn leads to irregular spraying of the plants to be sprayed. As this leads to the failure to cover the lower surface of the leaf. With spraying the worker to his body. As well as not using clean energy to complete the spraying process, and using more than one equipment for spraying according to the stages of plant life.

The spraying of liquid agriculture (Pesticides and liquid fertilizers) is common in many agricultural experiments in Iraq. That necessary to study the increased efficiency of these sprays and less than costs to raise recommendations for agricultural sprayers **(Al-Karawi &Al-Jumaily, 2022; Sara & Mohammed, 2022**)

The research aims to design and implement a sprayer for controlled spraying in greenhouses, with the sprayer -mentioned above testing and estimating the efficiency of its

spraying. And study the effect of the study factors on the characteristics to be measured, as well as finding the best combination between the levels of the studied factors.

MATERIALS AND METHODS

1 The sprayer machine - its main components

The weight of the sprayer machine without the battery box and the tank is empty (36 kg), and the weight of the battery box alone is (11 kg), where as the total weight of the sprayer machine with the battery box and its tank is empty (47 kg), while its weight and the tank are full (77 kg). The sprinkler system consists of the following main parts: (four pumps, three spray nozzles, a line strainer, a tank, a manual-controlled valve, a nozzle tube, a splitter, pressure gauge, pressure control valve, a connecting pipe and a flexible high-pressure hoses). The pressure can be adjusted by the control panel switches and the regulation of the manual drain control valve to ensure constant pressure and discharge when spraying through the nozzles mounted on the nozzle tube. There are three imported nozzles produced by agroplast. Type (AP120-03C). They are called flat fan nozzles. The distance between one nozzle and another adjacent to it is (50cm), which is the same distance between the sprayed plants and the spray nozzles, according to the manufacturer's recommendations above. The spray angle is (120°) and (03C) it means the Spray nozzle discharge rate in gallon/minute. It operates with a pressure range ranging from tow bars to six bars, and the discharge is (0.98-1.70) l/m. The hydraulic system has three split pieces. Its usefulness is to connect and connect parts with each other when going out for pumps. It can also be used to connect the end parts of the wet stand without involving the middle part with them. The electrical system contains the battery box that is the source of energy supply to the equipment. The battery box can be charged from the solar charging kit supplied with the equipment. The stomach is equipped with two battery boxes that feed the stomach with electrical energy, the two battery sets can be charged together when the drop reaches half to preserve and extend battery life. Attached to the sprayer is a solar charging kit and consists of a solar panel with a capacity of (150W) installed on an iron structure and a plastic box is installed on it, inside the plastic case is a charging controller to control the charging process and disconnect the battery when charging is complete.

2. The Boom shape

The first factor consists of two positions, the first position resembles the shape of the letter (C) in English and its symbol A1 and the nozzles to the inside, while the second position is similar to the shape of the letter (I) in English and its symbol is 2A. The position affects the amount of substance the sprayed plants and the spray waste.

3. Operating pressure

The second factor was the pressure in the spraying process, which was consists of three pressures. The first pressure (P1=2bar), the second pressure (P2=3bar), and the third pressure (P3=4bar). Thus, it improves the reception of the sprayed substance by the plants because it is within the medium and minimum pressure limits of the nozzle used.

4. Carry out the experiment - and analyze the test papers

The experiment was conducted in one of the greenhouses of the Horticulture Research Department within the National Program for the Propagation of Seeds, Varieties and Hybrid

Strains of Local Vegetable Crops of the Department of Horticulture and Forestry of the Ministry of Agriculture and located in the district of Abu Ghraib. To checking and testing the sprayer machine operating inside the greenhouses. The greenhouse, was dimensions were (56 m), width (9 m) and height (3 m) and contains two gates, the first from the front and the second from the back. As in to analyze the distributions of spraying on glossy white sheets test papers. With known dimensions, then the samples are scanned with a scanner, i.e., the Scanner device, and with a resolution of up to (600dip), the previously taken image is converted to (8bit) images with a grayscale. Place the square on the sprayed white paper to take the exact measurement.

5. Studied qualities

5.1. Spray loss (amount of spray falling on the ground between plant lines)

It is a trait that can be calculated through test sheets placed on the planting line between plants of one experimental unit. This is shown by the percentage (%) of the number of stains per unit area of the test paper when sprayed with blue dye reaching the ground during the movement of the machine from in front of the plant of the experimental unit. The image processor software calculates this percentage. This adjective is denoted by the symbol (L).

5.2. Spray penetration of the vegetative canopy

It is a trait that shows the amount of penetration and penetration of droplets within the vegetative system **(Grisso,*et al*, 2019)**. This characteristic can be calculated by comparing the average percentage (%) of the coverage values on the face of the plant leaf, calculated by placing the test sheet at a height of (80 cm and 40 cm), which is denoted by the symbol (μ (f)) and the coverage values in the core of the plant by placing the test paper in the heart and on the upper side of the plant and symbolized by the symbol (H) at a height of (50 cm). The calculation of the spray for the vegetative total and the labeled Spray Penetration is the percentage of the quotient of the coverage (μ (f)) and for the same treatment on the coverage value (H) multiplied by (100%) for the same previous treatment to extract the penetration rate.
Whereas:

$$P\,n\,\% = \frac{H}{\mu\,(f\,)} \times 100 \ldots\ldots\ldots\ldots\ldots (1)$$

P n: percentage of spray penetration of vegetative total, %.
H: the coverage value of the test paper placed in the heart of the vegetative system of the plant.
μ (f): Percentage of height test sheets (80cm and 40cm) covered for experimental unit plant

5.3. uniformity of spraying

The homogeneity can be calculated vertically on the vegetative total of the plant by knowing the percentage of the spray coverage value of the test paper at the height of (80cm or 40cm) with a lower value after comparing it to the higher value of the same treatment at the height of (80cm or 40cm) multiplied by (100%) and as in the following equation:

$$\boldsymbol{Un}\ \% = \frac{(UPf)or\ (Mf)Highest\ Value}{(Mf)\ or(\ UPf)Minimum\ Value} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Whereas:
Un % Spray Uniformity percentage (%).
UPf: percentage coverage at altitude (80cm) (%).
M f: percentage coverage at height (40cm) (%).

6. Statistical analysis

In the experiment, the design of the Randomized Complete Block Design (RCBD) working with the split plot design system was used to experiment with its two factors consisting of two pressure factors and (3) levels and the position of the nozzle holder with (2) positions, so the number of factors becomes (6) factors. Using the program (Origin lab 2018).

RESULTS AND DISCUSSION

1. Amount of loss between plant lines

It is clear from Figure 1. That the effect of the nozzle holder positions is high significant by (LSD=6.07) at a significant level (0.05) on the characteristic of the amount of losses between plant lines at the level of (A1), as it gave the highest average percentage of losses between plant lines (44.3%) and this may be due to the fact that the droplets coming out of the nozzles due to the proximity of the upper and lower part of the nozzle holder from the route of the sprayed plants and thus increasing the concentration of spraying leads to the fusion of free droplets and their fall faster Between plant lines and this is consistent with **(Alheidary, 2018**; **Braheem & Alheidary, 2022)** and the effect of pressure was not significant at a significant level (0.05) on the characteristic of the amount of losses between plant lines at the pressure level (P3) as it gave the highest percentage of coverage (43.1%) and this may be due to the fact that the speed used is the same for all cases or the reason may be that the difference between the pressures used is small and this is consistent with (Cerruto et al., 2021).and (Gandolfo & Moraes, 2014). As for the bilateral interference, its effect is not significant at a significant level (0.05) in the aforementioned characteristic, it resulted in the interference of the position (A1) and pressure (P3) the highest percentage of losses between the lines of plants (45.7%) and the reason may be due to the position (A1), which gave the highest amount of spray and fusion of the droplets sprayed from the position (A2) and this is consistent with **(Cerruto et al., 2021; Gandolfo & Moraes, 2014).**

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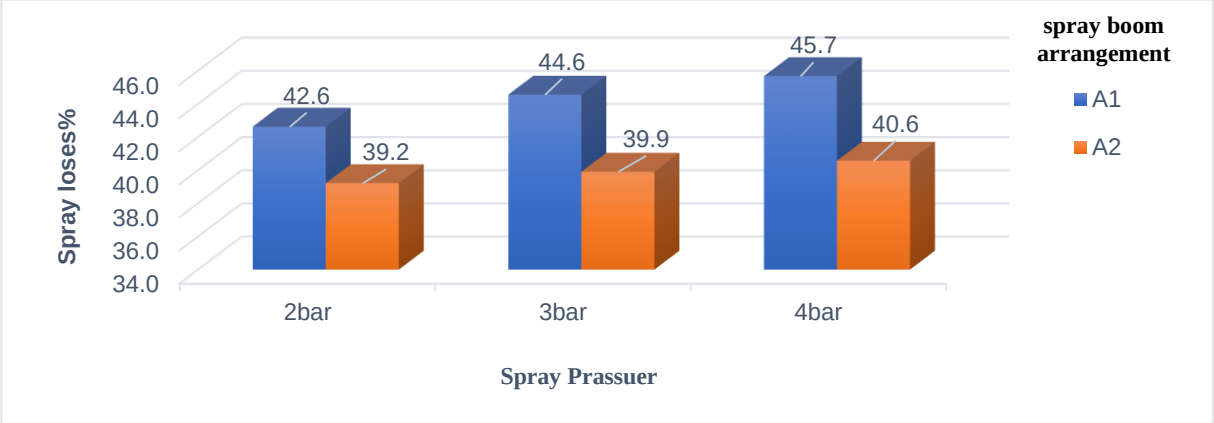

Figure (1): effect of spray boom arrangement and spray pressure on spray loses.

2. Spray penetration of the green group It is clear from Figure 2. at a significant level (0.05) that the effect of placing the nozzle holder is not significant with the penetrating characteristic of the spray of the vegetation system at the level of (A1), as it gave the highest percentage of penetration (71.9%) and this may be due to the inclination of the lower and upper part of the nozzle holder towards the inside and its approach to the sprayed plants, and this corresponds to **(Oliveira *et al*., 2014)** as well as the effect of operating pressure is not significant with the aforementioned characteristic with the level (P3) as it gave the highest percentage of penetration (76.4%) This may be due to the fact that the more pressure the more the amount of the sprayed substance increases, the smaller the volume of droplets and the more volatile of the sprayed material towards the sprayed target, and this is consistent with (**Alheidary, 2018; Braheem & Alheidary, 2022)**. As for bilateral interference, its effect is also not significant with the aforementioned characteristic. The interference of position (A1) and pressure (P3) resulted in the highest percentage penetration (79.3%) and this may be due to the tilt of the bottom and upper part of the nozzle holder towards the inside and its approach to the sprayed plants with increasing pressure, and this corresponds to **(Oliveira et al., 2014; Alheidary, 2018)** The reason for the convergence of the results is the probability of the speed used, which is 3.12 km/h, which may cause fluctuation in penetration with the above experiment factors. **(Braheem & Alheidary, 2022)**.

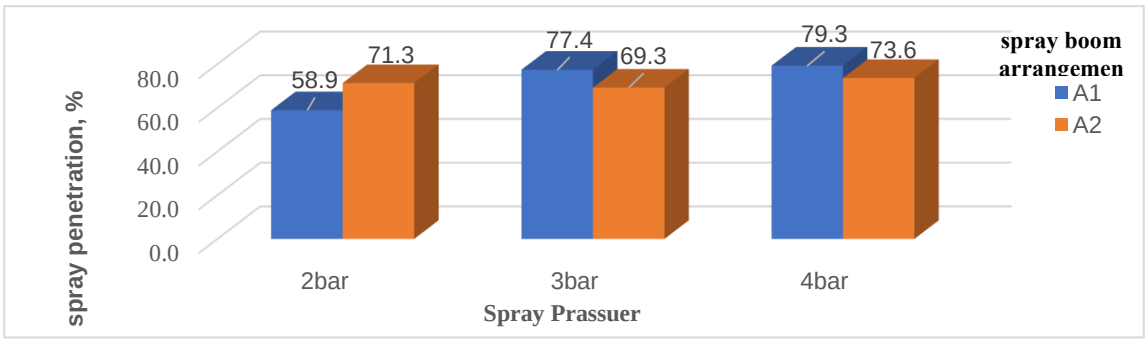

Figure (2): effect of spray boom arrangement and spray pressure on spray penetration.

7.3. Spray uniformity:

It is clear from Figure 3. Shows the effect of the position of the nozzle holder is not significant with the characteristic of homogeneity of spraying, but at the level of (A1) gave the highest percentage of homogeneity in spraying (83.9%) and this may be due to the approach of the bottom and upper part of the nozzle holder and the inclination of the spray nozzles towards the sprayed plants and this corresponds to **(Grisso *et al*., 1988; Alheidary, 2018)** As well as the pressure did not have a significant effect with the aforementioned characteristic at the pressure level (P3) if it gave the highest percentage of homogeneity in the spray (85.3%) and this may be due to the fact that the high pressure gives more discharge and water and the most distance by which the sprayed material flies towards the sprayed target and this is consistent with **(Grisso *et al*., 1988; Alheidary, 2018)** As for the inside of the duo, its effect is also not significant, as it resulted from the interference of the position (A1) and pressure (P2) On the sprinkled plant and this agrees with **(Hanafi, *et al*., 2016; Braheem & Alheidary, 2022).**

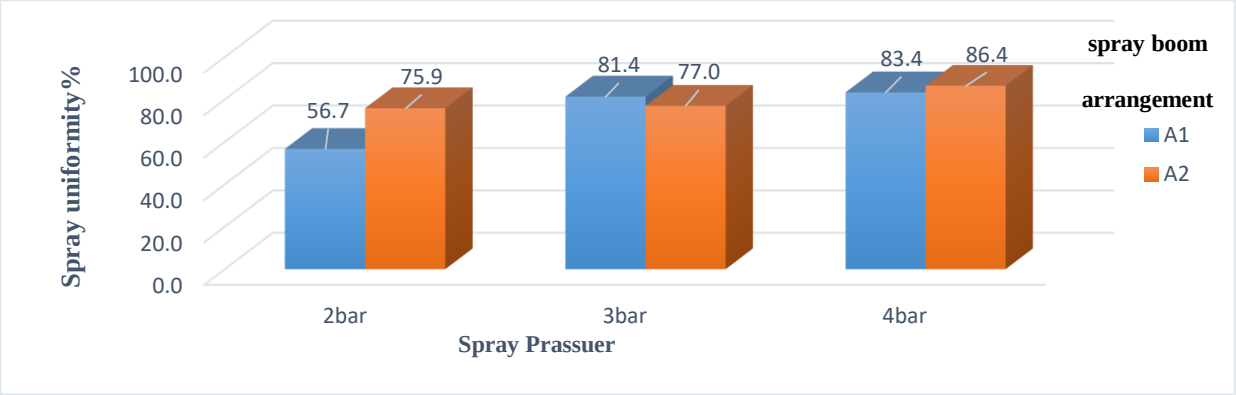

Figure (3): effect of spray boom arrangement and spray pressure on spray uniformity.

8. Efficient of use the sprayer machine

Table (1): Comparison of the costs of using the traditional spraying methods and the developed sprinkler spraying methods for five greenhouses per season.

Seq	Paragraph	Traditional spraying methods	Developed sprayer
1	The cost of buying the sprayer	Spraying (withdrawn + backpack) 350.000 IQD.	One sprayer machine 450,000 IQD
2	Spray operators' fees for (20) spraying times	600,000 IQD	300,000 Iraqi dinars
3	Fuel and maintenance for (20) times spraying	(50,000 fuel + 50,000 maintenance) IQD per season	(75,000 batteries and solar panels + 15,000 maintenance) IQD per season
4	The average price of pesticides and fertilizers for (5) plastic houses per season	About 1,500,000 Iraqi dinars.	About 750,000 Iraqi dinars.
Grand Total Cost		2,550,000 IQD/Season	1,590,000 IQD/season

Table (2): Comparison between the efficiency of using the traditional spraying methods

and the developed sprayer to the five of greenhouses in one season.

Seq	Paragraph	Traditional spraying methods	Developed sprayer
1	Type of energy used	One of the oil derivatives	Solar Energy
2	Its relationship to the environment	Harmful to the environment	Eco-friendly
3	The time Completion for the one line	2 min	1 min
4	It is estimated that one house needs pesticides and fertilizers diluted with water in one spray.	(100-120) liters / house.	(33-45.5) liters/house.
5	The effect of spraying on the operator.	The operator affects the middle and lower part of his body	They affect less on the operator's body because they pull.
6	Spray type.	Heterogeneous	Relatively homogeneous
7	The Stages of using	The dorsal sprayer is used at the beginning of the plant's life after its growth, the sprinkler with a push cart or carried behind the puller is used	Used with all stages of growing plant
8	Number of operators	You need 2 operators for the cart-mounted sprayer, while mounted the sprayer on the tractor needs 3 operators.	Its only need one operator.

THE CONCLUSIONS

1. The sprayer machine is designed successfully, and the sprayer machine is tested using study factors.
2. Treatment A1 and compression P3 showed superiority over the rest of the study levels in the characteristics of penetration and loss. The A1 level with pressure P2 achieved the highest result with the spray homogeneity characteristic. I recommend using the sprinkler with smallholder greenhouse farmers who suffer from water scarcity.

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