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Developing and testing of automated sprayer for agrochemicals application trials in Iraq

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Abstract

The field experiment was conducted with the aim of developing and testing an automatic sprayer for agricultural spray experiments and studying the effect of spray pressure, spray speed and spray height on the spraying process. The effects of the major spraying factors (pressure, speed, and height) on the spraying performance of the automatic sprayer were studied. This study included several traits: First - the drop sizes - Second - the penetration of the spray into the vegetation cover - Third, the spray wasted. The results showed: - First: - Increase in coverage percentage when using the first speed, 2 km / h, which amounted to 26.85%. An increment in the spraying penetration of the vegetation cover was observed at the second speed, 4 km/h, reaching 70%. Second - Pressure: The increment in pressure was accompanied by an increment in the coverage trait at the third pressure 3 bar, which amounted to 24.37%. The penetration trait was 81% at pressure of two bar, and wastage increased at the second pressure of two bar, which amounted to 25%. Spraying height: - Height) 40 & 50 cm (have no significant effect on the trait of coverage. However, it was significant in the trait of spraying penetration of the vegetation cover, as it reached at the first height (40 cm) 53% and at the second height (50 cm) 74%, and the trait of the lost at the first height, 40 cm was 13%, and at the second height, 50 cm, it reached 23%. It is concluded from the data, the extent of the effect that the spraying factors show on the studied trait, as The factors value increased is accompanied by an increment in some trait, in contrast to others. So, it becomes clear the necessity of coordinating the values of the factors with each other to obtain an equal spray.

Key words: spraying losses, droplet coverage, spraying penetration, spraying pressure, spraying height, spray speed

Introduction

Chemical control is one of the most widely used methods it is used to combat various pests, because of the rapid efficacy process. So, (Bailey, 2002) showed that the operations of spraying chemical pesticides in inaccurate ways and quantities will cause: -First - pollution of the surrounding environment. Second, it affects sprayer operators (Nuyttens et al., 2004, 2009), droplet coverage means the area covered by the spray liquid (Bateman, 1999). Whereas (Ferguson et al., 2016) showed that consistent spray coverage evenly distributed throughout the vegetation cover is necessary to control the numbers of pests that can negatively affect the crop. As shown in (Cieniawska and Pentos, 2021), maximum coverage can be achieved using a droplet size between (300-352 VMD µm), with a low driving speed. The coverage is affected by the following factors, First-Pressure: - As the spray pressure has a significant effect on the coverage of the spray (percentage) at different distances from the nozzle location. Second: Speed: Where the horizontal movements of the nozzle holder are considered important in the adjective of coverage, in terms of the relative forward speed of the holder (fast / slow). These speeds vary by plant (plant cover). The movements of the horizontal nozzle holder may result in a variation of several hundred percent in the fluid distribution under the nozzle holder (Hardi, 2007). Third - Height: - As the height of the nozzles arm depends on the spraying pressure, whenever the pressure increases and the height increases, they make wider spraying angle so the covered area increases. Moreover, with the lower the boom height and the lower the pressure, they make smaller spray angle, and so the smaller the area covered. It was observed there is a relationship between spray height and spray pressure, as the coverage area increases with increasing spray pressure, which is accompanied by a proportionate increase in spray height. This was explained by) Alheidary, 2019). The main objective of the coverage is to know the amount of efficiency and the extent of its biological effect on the pests and not the amount of drops on the surface of the plant leaf (Hamilton, 2001). In addition, Adams et al. (1990) showed there is an inverse relationship between coverage and droplet size, as increasing droplet size reduces coverage and a positive relationship between increasing coverage and increasing pesticide dose. and to get the best coverage, should be used that nozzle give us droplets of (VMD) sizes (225-325) microns, as the sizes of these droplets provide better coverage for the leaves of the plant. Wolf (2000) has shown that adequate coverage can be provided by controlling droplet sizes with simultaneous reduction of variance using a medium droplet size (VMD = 300 µm) and coarse droplet size (VMD = 352 µm), with low driving speed and nozzle angle in the direction opposite to the direction of movement. The size of the droplets has an important role in coverage if the diameter is halved, the result is about 8 times more than the droplets and so the coverage potential increases significantly (Cieniawska and Pentos, 2021). The penetration of the spraying into the vegetative cover is one of the important trait, as it has a significant impact on the efficiency of the spray and the pesticide. As explained by (Hardi, 2007): - First - Speed :- Slower driving speeds from 3 to 5 km / h reduce turbulence around the nozzle boom, so the droplets maintain a more vertical path and thus increase the penetration of the vegetation. Second - Pressure: With less pressure, the size of the drops has increases; large drops have a relatively lower surface area compared to smaller drops and it of course heavier. Therefore, with the use of conventional nozzles, the best way to get good penetration in a dense crop is by combining the use of larger conventional nozzles and relatively coarse atomization with higher pressure, which will increase the speed of the drops. However, as always, weather conditions must be taken into account, especially at high pressures. Spray pressure has an important role in crop penetration, as spray pressure affects the effectiveness of spraying in crops in three ways: First - the pressure effects on the spray angle: higher pressure makes the wider spray angle. Second - the increased pressure in general helps penetration and increases the bottom deposits. Third – higher pressure makes the smaller droplets. These smaller droplets are also more sensitive to wind movement. Hardi (2007) showed that the use of high pressures did not improve sedimentation or penetration into the vegetative aggregate and that losses on the ground were not significantly different. Generally, the results indicate that the use of high pressure in the manual sprayer did not improve the vegetative aggregate sedimentation or penetration of the plant. On the other hand, total losses were greater for the highest pressures, although losses on the ground were slightly greater for lower pressures (Rincon, Víctor J et al., 2017). from the foregoing, it was found there is a difference in the results, which previous studies showed that the coverage of droplets and penetration of vegetation cover through a group of types of nozzles (Knoche, 1994; Zhu et al., 2004; Derksen et al., 2008; Hanna et al., 2009). (Wolf and Daggupati, 2009) found discrepancy in the results. The results are generally divided into: smaller droplets penetrate the vegetation cover better (Knoche, 1994 , Wolf and Daggupati, 2009), or smaller droplets do not penetrate the vegetation cover better than larger droplets (Zhu et al., 2004; Derksen et al., 2008). (Hanna et al., 2009) and there is a difference in the activities of pesticides that depend on the rate of penetration as shown by (Knoche, 1994). The extent of herbicide efficacy is closely related to the extent of penetration into the vegetation cover of crops. Therefore, there must be almost complete control over the spraying process, as the results showed (Brakeman, Pascal, et al., 2010): - In general, the performance of the nozzle boom for the standard vertical spray was better than the traditional spray equipment in (spray gun). The results of (Braekman et al., 2010) also showed that the decrease in the average speed of volumetric droplets, led to a decrease in momentum, so, the penetration capacity is weak. (Hoffmann and Salyani, 1996) showed that sufficient penetration is a worry for some spray applications, and this may lead to the inefficiency of the application system. (Farooq et al., 2002) there is more precipitation and deeper droplet penetration at the lower elevation than at the higher elevation. Higher volume ratio resulted in higher deposition at 0.0–1.5 m depth at both heights. This was in contrast to the results of (Salyani et al., 1987, Juste et al., 1990, and Koo et al., 2000). These results may be different because of using absorbent tape (paper tape) instead of sensitive papers as a target for spraying. The use of portable dorsal sprayer whose efficiency depends on the efficiency of the worker. Automatic sprayer are important because of their control over the spray rate, which in turn depends on pressure factor, speed factor, and the spray height factor. The main problem on which the research was based was the result of the use of manual sprayer in agricultural spraying experiments, and it suffers from the following problems: - Irregular spraying height, irregular spraying speed, and irregular spraying pressure. There was a need to provide an automatic sprayer that regulates and stabilizes the three factors mentioned above in order to get a constant spray rate, a consistent spray distribution and a consistent droplet size throughout the spray period. The research aims to manufacture a robotic sprayer that ensures stability of pressure, speed and spray height, and consequently the establishment of the spray rate and testing of the robotic sprayer after its manufacture. Therefore, the purpose of developing and testing the machine is to get a consistent spraying by covering and penetrating the droplets into the vegetative cover and reducing spraying losses.

Material and methods

The device (Figure 1) was manufactured locally, and used in the experiment. It is a robotic sprayer with an electronic control system, as it is controlled remotely or through the installed control panel. The structure of the sprayer is made of lightweight aluminum, that the sprayer is easy to transport because of its design that allows it to be a box or a travel bag. The device is fed with energy by means of the battery, and an electric motor. An electric pump and a spray nozzle were used. The specifications of these parts were as shown in the Table 1

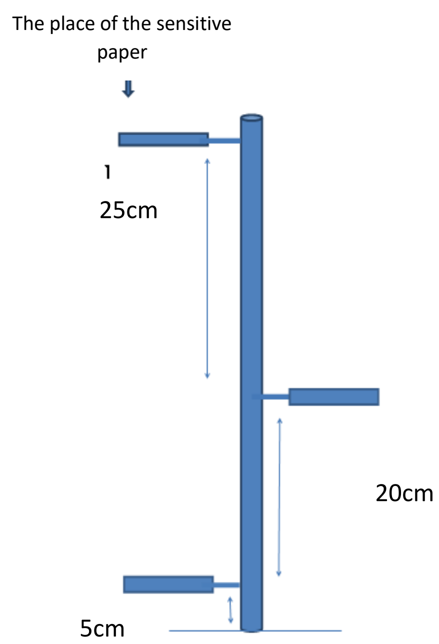
Table 1. Spray pump, nozzle and motor specifications

1-Specification of the pump			
Pump model	RS-15	the amount of current consumed	2 amps
Pump discharge	3.1 liters / minute	Maximum pump pressure	4 bar
The amount of voltage	12 volts	the type of current	DC
2- Nozzle specifications			
Nozzle type	Flat fan	working width	1.14-1.43 m
Made of	Plastic	drain rate	0.693-1.549 l/min
Working pressure	1-5 bar		
3- Engine Specifications			
Engine Model	MY1016Z2	Consumed Current	9.78 Amps
Motor revolutions	3300 rpm	current type	DC
The current	24 volts		

Figure (1) spraying device

The sensitive papers have been placed on a column with appropriate distances to measure the trait to be studied.

The field experiment was executed out in the fields of the College of Agricultural Engineering Sciences / University of Baghdad. On the date of 11/4/2021, the temperature was 25°C and the wind speed was between (3-2) km/h. The experiment was executed out using the split- split plot system under a completely randomized block design with three replications were used to estimate the significant differences in order to compare the means of parameters at 0.05 level ($p<0.05$). The purpose of the experiment is to test the automatic spraying device that was manufactured and whose purpose was to control the main spray factors: spray speed, spray pressure, spray height. Study factors: - First - height of the spray: - It is a distance between the plant and the nozzle and includes two levels of height: -H_1= 40 cm, H_2=50 cm. The height was controlled by a nozzle holder, which has a gradient of holes for fixing the level. The height is determined from the top of the plant to the bottom of the nozzle (Bell, 1997) the height of the spray must be determined after determining the average heights of the field plants, where the heights of a sample group of plants must be taken. The length of the sample or the height of the sample is measured by taking the measurement from the surface of the ground to the top of the plant (NDSU, 1997). The heights of plants start from 35-40 cm. second- Spray pressure: Three levels of pressure were used when conducting the experiment: P_1=1 bar, P_2=2 bar, P_3= 3 bar. The spray pressure was controlled by controlling the pump power through the electronic system or through the pressure control valve.



Third - Spraying speed: Two speeds were used in the experiment: S_1=2 km/h, S_2=4 km/h. The speed was controlled and determined through the electronic system that divides the engine power and speed regulation from the control of the electric motor voltage, as the voltage increases, the motor speed increases. Before starting the experiment, the device was equipped and its systems were valid. The field was divided into three lines, where each line represented a repeater. The sensitive leaves were distributed among the plants of the same line, where the sensitive leaves were installed on iron columns, and three columns were placed inside each repeater with three levels (in the top of the plant, the middle of the plant and the near-ground area). The dimensions of the sensitive papers were (76×26) mm. The papers produced by (Syngenta) of Switzerland were used. Upon completion of the spraying process, the sensitive papers were collected and classified, and then the sensitive papers were scanned using a scanning device, through which we scan all the experimental papers with an accuracy of 600 dpi, thus turning the papers into digital images, then these digital images were entered into Depositscan. The software consists of a set of custom plug-ins that are used by ImageJ processing software to produce a number of measurements suitable for describing the distribution of spray deposits. The software worked with the sensitive paper scanner to scan the spray deposits on the collectors (papers). After the collectors (papers) are scanned, individual droplet sizes and their distributions, total number of droplets, droplet density, spray deposit amount and spray coverage percentage are displayed on a computer screen. Then, saved in a spreadsheet where the average droplet diameter, spray coverage (%) and spray intensity are calculated by the software and the data is kept, the image of sensitive papers has been converted into digital data. The accuracy of the analysis used in the program can reach 2400 dpi (Zhu, Masoud Salyani, et al., 2011). Where percentage coverage refers to the ratio between the total droplet area and the WSP area. Spray intensity refers to the total number of droplets in one square centimeter of WSP. Then, the obtained data is entered into the Genstat program, where it works on data analysis.

The studied trait s: - These traits were studied by taking measurements of the solution falling on (sensitive papers), which are yellow-colored papers that are sensitive to the solution. Once drops of the solution fall on the paper, the place of the drop turns blue. Droplet measurements are taken from sensitive papers after scanning the sensitive paper and fed into DepositScan, an image analysis program developed by (Zhu et al., 2011) that can rapidly assess the distribution of droplets on water sensitive paper. First - Covering: It is an trait used to indicate the area covered by the spraying liquid. The unit of measurement for coverage is (cm²). The droplet coverage trait was calculated in an area of 4 cm² by using sensitive papers or dye.

$CV = \%\frac{DS}{1CM} * 100\%$

CV% = coverage area cm^2

DS= Total spray area

Second - the spray penetration of the vegetative cover:

- It is a trait used to indicate (the arrival) or penetration of the spray of the sprayed liquid and its arrival to the different levels of the leaves of the plant. The drops were counted and their numbers were compared between the top of the plant and the middle of the plant depending on the results of spray coverage.

$PN\% = \frac{CVM}{CVU} * 100\%$

spray penetration =% PN

CVU%= Coverage on the upper leaf

Covering in the middle leaf =% CVM

Third - Spray losses: - It is a trial used to indicate the amount of unused liquid as a result of falling on the surface of the soil. Wastes were calculated by comparing the amount of drops between the top of the plant and the drops falling on the ground.

$SW\% = \frac{QD}{QU} * 100$

SW % =Spray wasted

QU= Amount on top

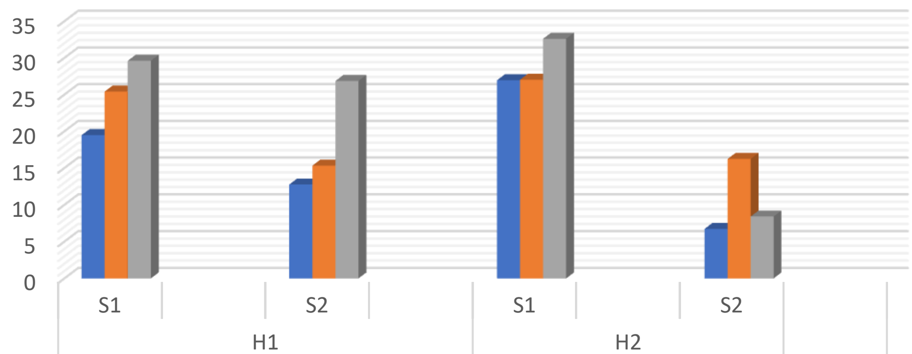
QD= Quantity on the ground

3. Results and discussion

3.1. Spray coverage: -

The coverage trait is important because of its essential role in controlling the targeted pests in the spraying process through consistent spraying. When the coverage increased, the efficiency of the spraying process increased with it. The results of the statistical analysis are shown in Figure (3). The effect of the triple interference of spray pressure, spray height and spray speed on covering the droplets. The effect of the triple interaction between spray pressure, spray speed and spray height insignificantly on the coverage of drops. The triple interaction between the first pressure 1 bar and the second speed 4 km / h and the second height 50 cm gave the least coverage of the drops, which amounted to

6.73%. The main reason for the lack of drops is the use of the first pressure, which produces larger sizes and fewer drops , while the highest The coverage of the drops was at the triple overlap between the third pressure of 3 bar, the first speed of 2 km / h and the second height of 50 cm, where the volume of coverage of the drops was 32.61%,The main reason for the increase in coverage during treatment ($P_3H_2S_1$)is due to the high pressure and its proportionality with the velocity and thus leads to an increase in liquid atomization and an increase in the number of drops without the occurrence of erosion of the drops.



	H1 S1	H1 S2	H2 S1	H2 S2
(bar)	19.48	12.76	26.95	6.73
(bar)	25.42	15.33	27.03	16.24
(bar)	29.61	26.86	32.61	8.41

(bar) (bar) (bar)

Figure (3) Effect of spray pressure, spray height and spray speed on coverage

3.2. Spray penetration of the vegetation: -

The trait of spray penetration is of great importance, as it is shown to what extent the sprayed liquid reaches the levels of the vegetation, and therefore this trait has a direct impact on the efficiency of spraying and the efficiency of the pesticide used. The results of the statistical analysis in Figure (4) showed the effect of the triple interaction between pressure, speed and height insignificantly on the percentage of drops penetration into the vegetation. It gave the highest rate of penetration at the triple interaction between the second pressure, first speed and first height, which amounted to 63%. The reason is due to the production of droplet sizes in numbers proportional to the speed and height, and therefore the droplets did not drift away from the target, and thus the penetration characteristic was not affected. , while it gave the lowest rate of penetration at the third pressure, second speed, and second height was 18%,The reason is due to the production of droplet sizes that are affected by speed and height, which led to the erosion of the droplets from the target, and thus the penetration characteristic may be affected.

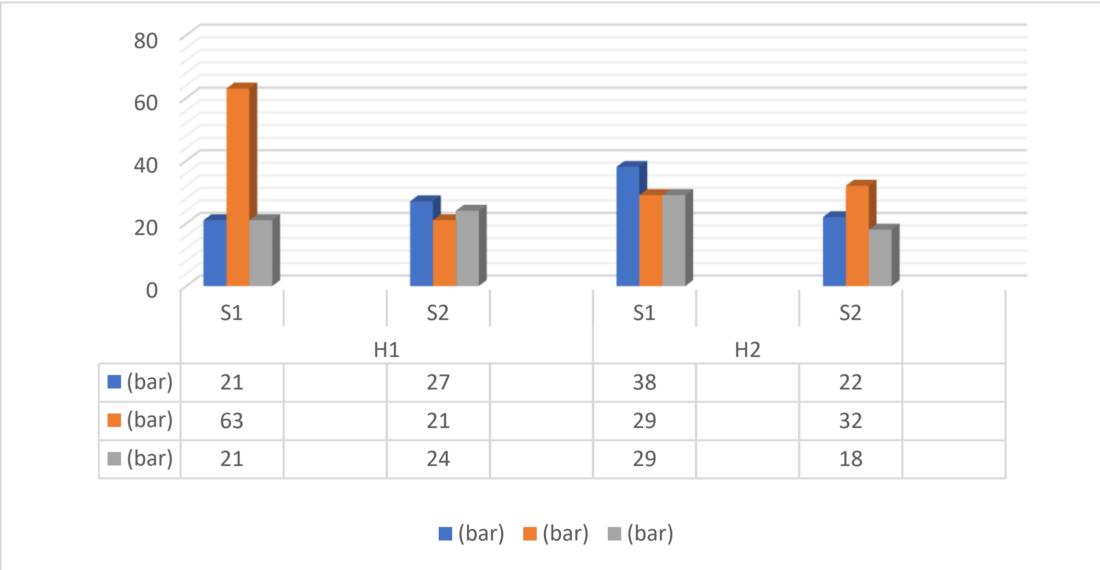


Figure (4) Effect of spray pressure, spray height and spray speed on spray penetration

3.3: - Spraying losses: -

The wastes are the difference between the amount of liquid sprayed on the surface of the plant to the amount of liquid falling on the soil. Figure (5) shows the percentages of waste and the extent of the impact of the factors related to the research. The results of the statistical analysis appear in the effect of the triple interference between pressure and speed and height, as it gave the highest rate of waste at the second pressure, second height, and second speed the wastage rate amounted to 46%. Because of the increase in the number of drops and their sizes resulting from this treatment and its proportionality with the speed and height used, while the lowest rate at the first pressure was one bar, the second speed was 4 km/h, and the second height was 50 cm, which amounted to 6%. Because of the increase in the sizes of the drops and the decrease in their resulting numbers at this pressure and their proportion to the speed and height used in this treatment.

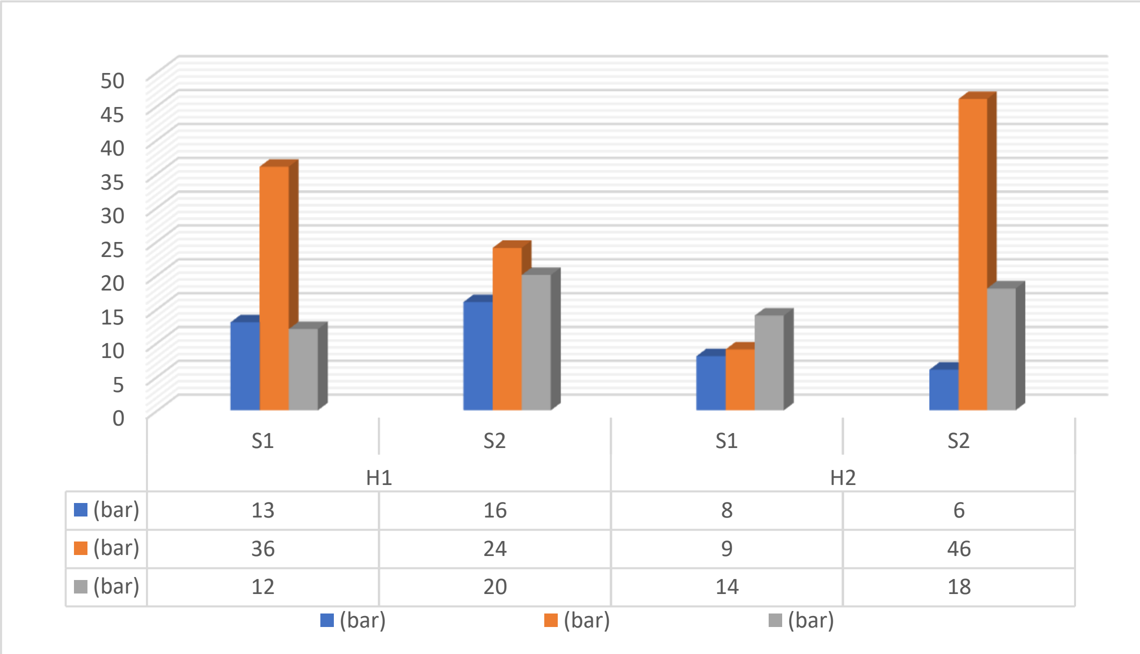


Figure (5) The effect of the triple interference of spray pressure, spray height and spray speed on spray waste

Comparison between the automatic sprayer and the back sprinkler:

- The studied factors (pressure, speed, height) were determined to compare between the dorsal sprayer and the automatic sprinkler, where the dorsal sprayer was random, as the calibration of the factors was based on the experience of the sprayer operator, while the automatic sprayer was calibrated for the three factors. The sprayer rate for the automatic sprayer was 42.33 liters / dunum, while the sprayer rate for the back sprayer was 90 liters / dunum. The comparison between the automatic sprayer and the dorsal sprayer with regard to the studied trait s showed the following results: - **Coverage**; - The average coverage rate for the automatic sprayer was (20.6%), while the average coverage rate for the back sprayer was (2.88%). **Spraying losses:** - The average spray losses for the automatic sprayer were (17.4%), while the average rate for the back sprinklers was (68%). **The spray penetration of the vegetation**: - The penetration rate of the sprayed liquid of the dorsal sprayer was 27%, while the rate of the sprayed liquid penetration of the dorsal sprayer was (15.4%). From the previous results of the dorsal sprayer and the automatic sprinkler, the superiority of the use of the automatic sprayer in all the studied trait s, and this shows the importance of controlling the three sprayer factors: pressure, speed, and height.

Conclusions

Increasing the spray pressure rate led to a significant increase in droplet coverage, spray penetration into the vegetation, and spray losses. The effect of high spraying significantly on the characteristic of spray losses. The speed had a significant effect Drop coverage and spraying penetration trait of the vegetation. Previous results showed the success of the automatic sprayer in controlling the spraying pressure, speed and height. The results showed the superiority of the automatic sprayer over the dorsal. Agricultural, where it is possible to control the pressure, speed and height of the spray.

Experiments, where it is possible to control the pressure, speed and height of the spray.

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