COMPARISON OF TWO TYPES OF SENSORS AND THEIR EFFECT ON SPRAY QUALITY PEAR TREES

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ABSTRACT
This study was aimed to reduce the amount of the sprayed solution lost during trees spraying. At the same time, the concentration of the sprayed solution on the target (tree or bush) must be ensured and to find the best combination of treatments. Two factors controls the spraying process: (i) spraying speed (1.2 km/h, 2.4 km/h, 3.6 km/h), and (ii) the type of sensor. The test results showed a significant loss reduction percentage. It reached (6.05%, 5.39% and 2.05%) at the speed (1.2 km/h, 2.4 km/h, 3.6 km/h), respectively. It was noticed that when the speed becomes higher the loss becomes less accordingly. The interaction between the 3.6 km/h speed and the type of Ultrasonic sensor led to a decrease in the percentage of the spray losses reached to 1.69. For the coverage percentage, the increase in the spraying speed from 1.2 km/h to 2.4 km/h, and then to 3.6 km/h led to a significant decrease in the percentage of coverage (from 17.73% to 13.14%, and then to 11.12%), respectively. The interaction between the type of sensor and the speed has significantly affected the spray density. The speed was 3.6 km/h, and the type of Ultrasonic sensor was superior in obtaining the highest spray density of 83.2 drops/cm^2.

Key words: spray coverage, spray density, spray losses, orchard sprayers, sensors, agricultural nozzles, spray speed
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مقارنة نوعين من المتحسسات وتأثيرها في جودة الرش على أشجار الاجاص

باسل رجب خلف الجبوري **علاء كامل صبر**
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المستخلص
هدفت هذه الدراسة إلى تقليل كمية محلول الرش المفقود أثناء رش الأشجار. في الوقت نفسه ، يجب التأكد من تركيز المحلول المرشوشة على الهدف (شجرة أو شجيرة) وإيجاد أفضل توليفة من المعاملات. يتحكم عاملان في عملية الرش: (1) سرعة الرش (1.2 كم / ساعة ، 2.4 كم / ساعة ، 3.6 كم / ساعة) ، و (2) نوع المتحسس. أظهرت نتائج الاختبار نسبة انخفاض معنوية في الضائعات. وصلت (6.05٪ ، 5.39٪ ، 2.05٪) بسرعة (1.2 كلم / س ، 2.4 كلم / س ، 3.6 كلم / س) ، على التوالي. لوحظ أنه عندما تصبح السرعة أعلى ، تصبح الضائعات أقل وفقًا لذلك. أدى التداخل بين سرعة 3.6 كم / ساعة ونوع حساس الموجات فوق الصوتية إلى انخفاض نسبة فاقد الرش التي وصلت إلى 1.69. بالنسبة لنسبة التغطية ، أدت الزيادة في سرعة الرش من 1.2 كم / س إلى 2.4 كم / س ، ثم إلى 3.6 كم / س إلى انخفاض معنوي في نسبة التغطية (من 17.73٪ إلى 13.14٪ ، ثم إلى 11.12٪) على التوالي. أثر التفاعل بين نوع المتحسس والسرعة بشكل كبير على كثافة الرش. كانت السرعة 3.6 كم / ساعة ، وكان نوع المتحسس بالموجات فوق الصوتية متفوقًا في الحصول على أعلى كثافة رش تبلغ 83.2 نقطة / سم 2.

الكلمات المفتاحية: تغطية الرش، كثافة الرش، ضائعات الرش، مرشات البساتين، المتحسسات، النافورات الزراعية ، سرعة الرش
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INTRODUCTION

The spraying technique of perennial tree plants has been poorly researched. Some shortcomings of spraying techniques concerning spraying tree plants have been listed in the reference (15). In addition, operators cannot stop spraying during the gaps between trees within a row. Thus, a sprayer that automatically adjusts spray volume based on sensor foliage size is expected to achieve two goals. First, maximizing efficiency by applying the optimum amount of spray to the target trees and second control of inter-tree spraying (14). During the spraying process, the trees spacing should not be high in order to avoid any additional insecticides to be consumed and also to avoid the harmful substances to be added to the soil. Thus, production costs increases and efficiency decreases, pesticide residues transferred from soil to plants caused health problems (32). Micro-spraying is a modern crop management strategy that helps to manage decisions according to the discretionary diversity in the field to reduce agricultural inputs. The basic concept of fine spraying is to adjust the spray volume by controlling the nozzle flow rate (19). Precision spraying is when the spraying process is conducted with reducing the spray amount or making the spray amount limited to spraying the trees themselves without spraying the spaces between the trees. One of the precision spraying techniques is remote sensing LiDAR (Light Detection and Ranging). It is an active laser-scanner-based remote sensing technology applied on a large scale to characterize the foliage of trees (6, 11, 12, 23). The signal generated by the sensor is used in several fields to develop the technique of spraying trees. The LiDAR sensor emits an electromagnetic signal that can bounce off the vegetative system of the plant, allowing the visualization of the external structure and providing 3D information of the tree (8, 5, 7, 13). Mahmud et al, (19) reported that using the LiDAR sensor, created a vegetative density map in order to provide a graphical display of the vegetative density of trees in different sections. To reduce the excessive use of pesticides in orchards. Tewari et al, (29) stated that the use of the Ultrasonic Sensor led to a low cost and accuracy. In particular, when spraying pesticides, and thus reduced costs and environmental pollution through plant protection products. Jejčič, et al, (10) showed that evaluating an electronic Ultrasonic control system for a proportional spray application resulted in an overall spray saving of 20.2% per nozzle, and unit area. Li et al, (17) stated that the natural precipitation in vegetation with variable spraying amounts is higher than traditional sprinklers by adopting a high-resolution laser scanning sensor (Light Detection and Ranging, LIDAR), indicating that the electronic sprayers are more efficient than the conventional sprayer. Fessler et al, (9) mentioned that the technique of using the sensor (sensing technology) and applying the variable rate work to adjust the spraying output based on the size of the crop and that the target spray works to cover the foliage. The forward speed of the spray determines when the tree is sprayed. Operating speeds lead to increased spraying per unit area of plant canopy. Thus, increased droplet density. The forward speed must be such that the shoot receives adequate deposition spray for effective pest control (24). Spray receptors usually measure the quality of spray application in the field (eg, water-sensitive paper or a Kromekote card). They attached to target areas or selected leaves and collected after spraying (28, 30). During pesticide spraying, pesticide droplets might fall down. Thus, the land loss is an (important indicator) to evaluate the operation of spray machines (18). The condition of the spraying nozzle could affect the spray quality (25). Moreover, the physical properties of the sprayed materials must be considered because they might affect the droplets number (20) and droplets size (21) which in turn may influence the incorporation of adjacent spots. Consequently, might affect the values measured by the image processing software. The effect of the nozzle height on the spray droplet properties was more than that of increasing the operating pressure (2). Spraying agrochemicals, extracts and other liquids is popular practice on experiments in Iraq (1, 3, 22, 27). It requires an attention from the operator to direct the spray on the target. This study was aimed to reduce the cost of losing quantities of the sprayed solution during the process of spraying trees. In addition this study investigates the way that ensure the concentration of the sprayed solution on the target.

MATERIALS AND METHODS

The experiment was conducted using a locally manufactured orchards sprayer (Figure 1) that operates with a micro-spray system. Two types of sensors with a solenoid electric valve were used to control the spray flow from the nozzles at different speeds. The sprayer consisted of a tank with 100 liters. A single-piston engine running on gasoline with a horsepower of 6.5 horses, and a piston pump was used. Three nozzles were fixed at a distance of 50 cm on the vertical boom.

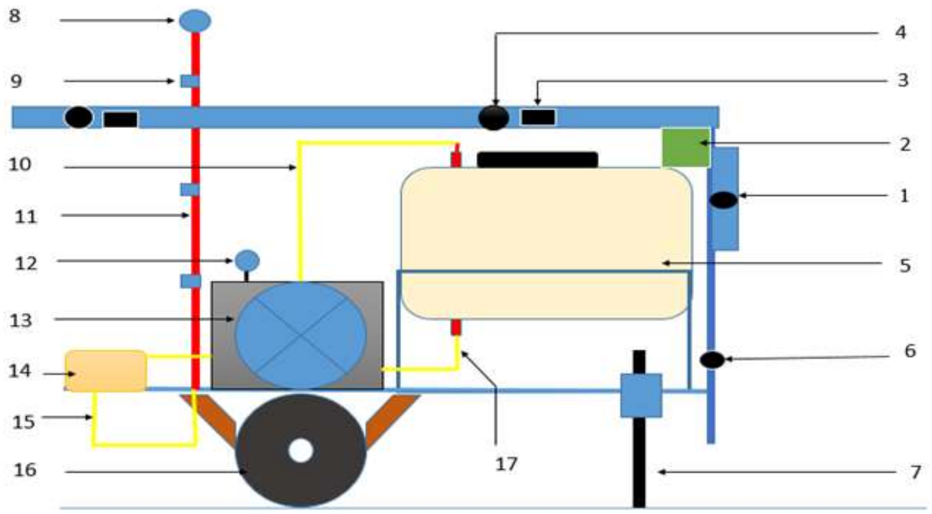

Figure 1. Profile diagram of the sprayer body

1. Upper connection point; 2. Control panel; 3. LiDAR sensor; 4. Ultrasonic sensor; 5. Tank; 6. Bottom connection point; 7. Sprayer bracket on the floor; 8. Pressure gauge; 9. Nozzle; 10. Return tube; 11. Nozzle holder tube; 12. Pressure gauge; 13. Motor with piston pump; 14. Control valve; 15. Transmission tube from the control valve to the nozzle holder tube; 16. Rubber tire; 17. Transmission tube from the tank to the pump

Sensors : Two sets of sensors were used in this study. These sensors can detect objects passing in front of them at different distances. This distance (between the target and the sprayer) is up to 3 meters for the Ultrasonic sensor and 12 meters for the LiDAR sensor. These distances can be controlled through an electronic distance regulator (resistance). The location of this regulator is in the main control panel of the sprayer. When these sensors pass in front of the target (tree), they work to incite an electric signal to the electric control valve.The solenoid valve allows the spray to flow through it. Two types of sensors were used in the study:

1. Ultrasonic Sensors JSN-SR04T is an easy-to-use, water-resistant ultrasonic resistance sensor with a sensing range of 25 to 450 cm, accuracy (2 mm), operating at a voltage of 3-5 V. It is connected with the micro-electronic controller (Arduino) within a code (for a specific case). The ultrasonic distance sensor works by sending ultrasound waves to be recovered by an object. The ultrasonic sensor detects them by calculating how much time spent during the sending and receiving of the sound waves. Distance between sensor and object can be calculated as following:

$$\boldsymbol{d = \frac{s * t}{2}} \ldots\ldots\ldots\ldots\ldots\ldots. \boldsymbol{(4)}$$

Whereas:

d: distance, cm

s: the speed of sound, cm/microseconds

t: time is the time between sending and receiving sound waves and is measured, microseconds.

2. LiDAR sensors (TFmini): is a sensor that defines ranges (various distances) by targeting an object with a laser and measuring the time to reflect light back to the receiver. LiDAR might also make 3D digital representations of the areas on the earth's surface and the ocean’s floor. Due to the differences in the laser return times, and the different laser wavelengths, it is sensed with a range of (0.3 - 12 m) and a voltage of (5v). Working principle: Lidar sensor: TFmini depends on Time of Flight Principle (TOF). The device transmits an

infrared modulation wave it reflects the wave after contact with the target object. The phase between the waves round trip then calculates the relative range between device and target.

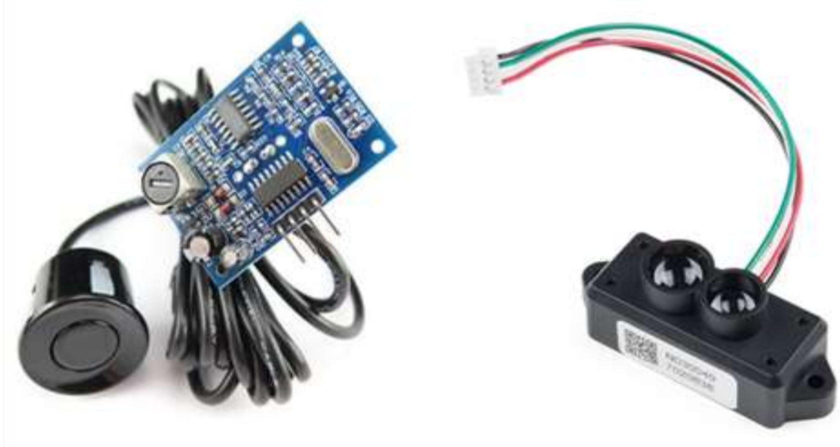

Figure 2. A. Ultrasonic Sensors and B. LiDAR Sensors

The sensors instructed the electric solenoid control valve to deliver the liquid to the nozzle. It shuts off or opens down by programming it to do this procedure once the sensor passes in front of the target (tree or bush). It gives notification to the valve through an electronic system (the Arduino electronic controller, (Figure 3) to execute the required command or close the valve. The same thing happens when the sensor leaves the target. This means that the function of this system is to control the amount of material flowing towards the target. A control panel that contains a screen to indicate the type of sensor used in the required process manages the system. It is supplied with electric power through lithium batteries. The batteries are constantly charged by a charger attached to the puller's main battery (12 volts).

Nozzles and kromekote papers

The nozzles used in the test were APS80R 03C type (hollow conical nozzle), which operates at an 80° spray angle with 5 bar pressure. The cone nozzle produces very fine droplets that meet ISO requirements for agriculture and horticultural spraying systems. The pressure range from (3-20) bar is ideal for fungicides and insecticides. Kromekote paper has been placed to measure the quantities of spray reaching the target by means of the (DepositScan) program. The dimensions of these papers were 7 cm x 2.5cm

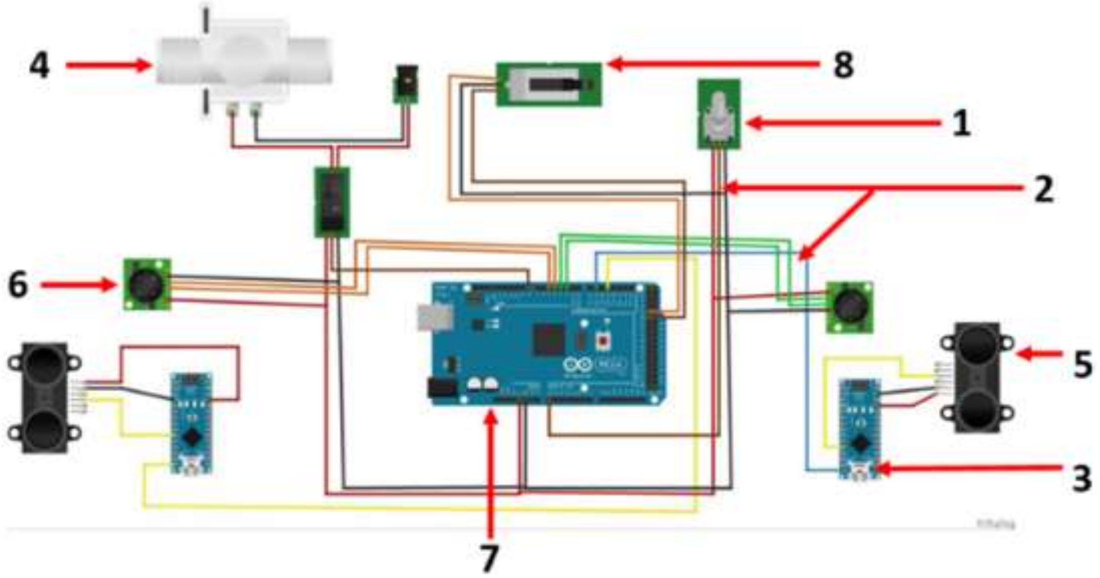

Figure 3. Electronic diagram of the sensor operating system

1 . Distance control resistor; 2. Connecting wires; 3. Electronic controller to operate the Lidar sensor; 4. Solenoid control valve; 5. Lidar sensor; 6. Ultrasonic sensor; 7. Arduino; 8. Variable direction switch to operate the sensors

The sprayed substance was (Brilliant Blue Sivi Karisimi dye), a blue food dye (a bright blue liquid mixture) in a liquid form used to color food products

Conducting the experiment

The experiment was conducted on Monday, 13/12/2021, when the wind speed was at the range of (0.75-1.61 km/h) and the minimum temperature was 12-21 Celsius degrees, and the weather was sunny to partly cloudy. The pear orchard trees were planted on square heads measuring (2m) between one tree and another on the same line and adjacent lines (Figure 4). The spraying process was carried out using New Holland (35 hp) tractor. The Randomized Complete Block Design (RCBD) was used. The effect of the two factors mentioned earlier, namely the forward speed of the sprayer (three levels: 1.2 km/h, 2.4 km/h, 3.6 km/h), and the type of sensor (two levels) was recorded. The pressure used was 3 bar and it was constant in all treatments. According to the design followed, the field was divided into 18 experimental units and three replicates. The distance between the sensor and the trees was determined by (1.5 m).

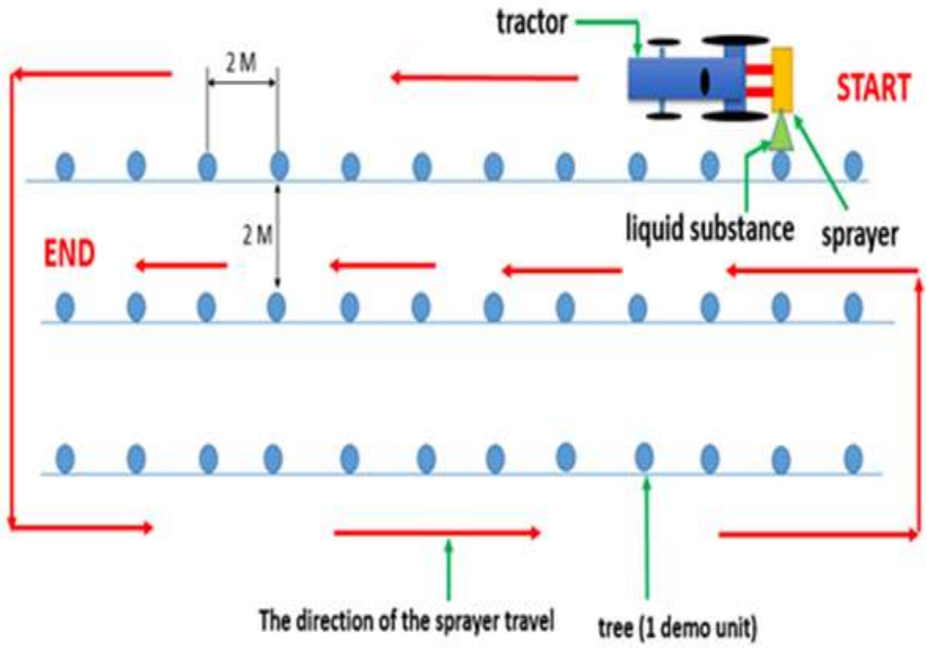

Figure 4. Diagram showing the implementation of experiment

The speed of the spraying was determined according to the following (2):

$$V_P = \frac{d}{t} * 3.6 \ldots\ldots\ldots (2)$$

Whereas:

Vp: the theoretical speed of the tractor (Km/h).

d: distance, m

t: theoretical time, s

3.6: conversion factor

The sprayer tank was filled with 35 liters of water with the addition of (280 ml) of Brilliant Blue Sivi Karisimi blue dye. Then, Kromekote paper was fixed on the trees in a cross shape (Figure 5), with an equal distance of 20 cm for each end of the tree. This is for the vertical and transverse symmetry. As for the leaves placed in the heart and face of the tree, they were at a distance of 20 cm between them in order to measure the penetration. Papers were also placed on the ground between the trees within the same row to measure the losses.

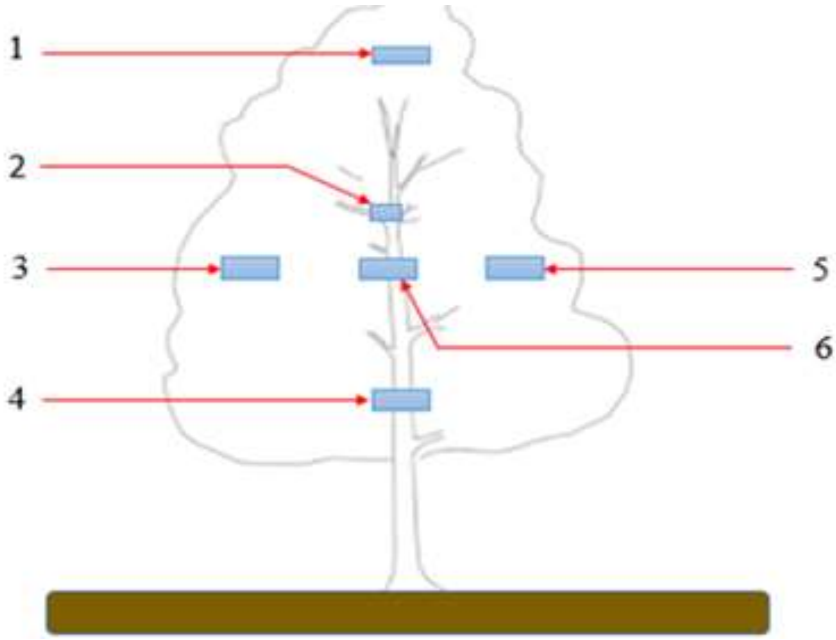

Figure 5. Picture of a tree showing the location of the Kromekote paper

1.Kromekote paper on top of the tree; 2.Kromekote paper in the heart of the tree; 3. Kromekote paper on the left side of the tree; 4 Kromekote paper at the bottom of the tree; 5. Kromekote paper on the right side of the tree; 6. Kromekote paper in the face of the tree

When the spraying process was conducted, the papers were collected after they were left for a certain time on the trees to dry. Later, they were placed in special conditions prepared for that, with the name of the treatment and its position on the trees. As a result, DepositScan image processing programs were used to analyze the quality of spraying on the papers after they were scanned and converted to photos.

Studied characteristics

1- Calculation of the percentage of losses: it means calculating the amount of spray falling on the ground. It represents the percentage of spray that falls within the space between the trees. The spray percentage was expressed by calculating the percentage of coverage inside the Kromekote paper. Three leaves were placed before, after and behind the tree and at a distance of one meter.

2. Calculation of the amount of coverage for spraying %: This represents the percentage between the areas covered with blue spots to the white background area of the paper.

3. Calculation of the spray density (number of drops/cm^2): it represents the number of droplets per square centimeter. It was calculated using the "DepositScan" program by computing the spray density (spot density) (number of smears/cm^2).

RESULTS AND DISCUSSION

Losses percentage: Table 1 elaborates the impact of speed on the percentage of losses. Increasing the sprayer speed from 1.2 km/h to 2.4 km/h and then to 3.6 km/h significantly decreased the percentage of losses. It was decreased from 6.05% to 5.39 %, and then to 2.05% respectively. This result can be attributed to the higher speed that lowered the losses amounts. Sensor type has no major impact of the loss amounts percentage. However, the Ultrasonic sensor is preferred because it is cheaper than the Lidar sensor. Moreover, there are time differences in the speed of response to the electrical signal emanating from them to the solenoid electric control valve, this result is consistent with (16, 26, 31). The interaction between the speed and the type of sensor resulted in a significant effect. Interaction between the speed of 3.6 km/h and the type of Ultrasonic sensor led to a significant decrement in the percentage of losses reaching 1.69%. In comparison, the highest percentage of losses reached 8.22% when the interaction between the speed of 1.2 km/h and the same type of Ultrasonic sensor was used.

Table 1. Effect of speed, and sensor type on the percentage of losses %

Sprayer speed km/h	Interaction between speed and sensor type Ultrasonic	Lidar	Speed average
1.2	8.22	3.88	6.05
2.4	3.37	7.41	5.39
3.6	1.69	2.42	2.05
LSD=0.05	4.398*		3.110*
Sensor average	4.43	4.57	
LSD=0.05	2.539		

Spray density

Table 2 shows that the type of sensor affects the spray density values. It showed that the use of the Lidar sensor resulted in a decrease in the spray density per square centimeter from 60.6 stains/cm^2 to 49.3 stains/cm^2. The same table shows that the speed significantly affects the spray density. It is clear from the table that increasing the speed from 1.2 to 2.4 led to a decreases in spray density from 62.3 cm^2 to 37.6 cm^2 Moreover, by increasing the speed to 3.6 km/h, the spray density can reach 65.1 drops/cm^2. Nonetheless, decreasing the speed may lead to an increase in the spray density, this is consistent with results published in reference (24). Besides, the interaction between the type of sensor and the speed has a remarkable impact on the spray density. For instance, if the speed set to be 3.6 km/h and the type of sensor used is the Ultrasonic sensor, the highest spray density of 83.2 drops/cm^2 that represent the highest among other interactions While The lowest spray density was recorded when the Lidar sensor at a speed of 2.4 km/h was used with the Ultrasonic sensor leading to a spray density that reach to 33.1 drops/cm^2.

Table 2. Effect of speed and sensor type on spray density

Sprayer speed km/h	Interaction between speed and sensor type Ultrasonic	Lidar	Speed average
1.2	56.5	68.0	62.3
2.4	42.0	33.1	37.6
3.6	83.2	46.9	65.1
LSD=0.05	21.61*		15.28*
Sensor average	60.6	49.3	
LSD=0.05	12.47		

Coverage: Table 3 shows the effect of speed on the percentage of coverage %. The increase in the speed from 1.2 km/h to 2.4 km/h and then to 3.6 km/h led to a significant decrease in the percentage of coverage and amounted to 17.73% to 13.14%, to 11.12%, respectively. According to this experiment, the higher speed led to a lower coverage percentage. The type of sensor, did not affect the percentage of coverage However, it showed a relative decrease in the Lidar sensor, as the coverage percentage decreased from 14.06% to 13.93%. In addition, the interaction between speed and sensor type did not show any significant impact. Still, the test results showed the highest coverage rate at 1.2 km/h, the Ultrasonic sensor type amounting to 18.27%, and the lowest value at 3.6 km/h, and the Lidar sensor type.

Table 3. Effect of speed and sensor type on percentage coverage, %

Sprayer speed, km/h	Interaction between speed and sensor type Ultrasonic	Lidar	Speed average
1.2	18.27	17.19	17.73
2.4	12.61	13.66	13.14
3.6	11.30	10.94	11.12
LSD=0.05	5.482		3.876*
Sensor average	14.06	13.93	
LSD=0.05	3.165		

CONCLUSIONS

There was a significant decrease in losses, which amounted to 6.05%, 5.39%, and 2.05% at speeds 1.2 km/h, 2.4 km/h, and 3.6 km/h, respectively.

1. The interaction between the speed and sensor type resulted in the highest coverage percentage at 1.2 km/h speed and Ultrasonic sensor type, which amounted to 18.27%.
2. The interaction between the sensor type and speed improved significantly the spray density. The speed of 3.6 km/h and Ultrasonic sensor type was superior to obtaining the highest spray density of 83.2 drops/cm^2.

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