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Improvement of spray distribution pattern for a knapsack sprayer using boom spray nozzles

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ABSTRACT

Knapsack sprayers of various types are commonly used in Egypt, especially in small farms, but; performance of most of these sprayers and their ability to be used pesticides accurately and efficiently is poor. Therefore, this research was carried out to overcome some problems of knapsack sprayers, uneven spraying and low field capacity. The research aims to develop and evaluate performance of a boom for a knapsack sprayer to improve spray quality and distribution pattern and increasing the field capacity. The developed boom was tested at different spray pressures, nozzles spacing and height of spray boom. The results showed that; The average values of spray liquid discharge rates for the developed sprayer were 1.29, 1.56 and 1.86 L/min at spray pressures 1.5, 2.0 and 2.5 bar, respectively. For the uniformity of spray volume distribution, the ratio of nozzle spacing to spray height 1:1 was the best for all tested cases of spray pressure due to the values of variation coefficient was less than 10 %, and it's preferable to be nozzles spacing and spray height at 50 cm to increase the performance rate of spraying under all tested pressures. The developed sprayer can be used for spray volume rates from 60 - 80 L/fed. The maximum values of the theoretical field capacity were 1.86 and 1.40 fed/h for spray volume rates of 60 and 80 L/fed, respectively at spray pressure of 2.5 bar, whereas; The maximum values of the effective field capacity were 1.44 and 1.12 fed/h for spray volume rates 60 and 80 L/fed, respectively at spray pressure of 2.5 bar and spraying width of 3.0 m. Also, the average values of field efficiency were 82.20, 80.53 and 78.81 % at spray pressures 1.5, 2.0 and 2.5 bar, respectively. the average values of continuous operating time of the developed sprayer using the battery were 8.27, 5.55 and 3.85 h at operating pressures 1.5, 2.0 and 2.5 bar, respectively.

1. Introduction

There are different pest control methods like biological pest control, trap cropping, pesticides, fumigation, sterilization, etc. Among them, pesticide application is the most widespread and oldest method worldwide. Pesticides are being used till now for protecting crops and increasing the yield of crops. These pesticides are mostly being applied using sprayers, Bhanagare (2015) and Rabbani et al. (2020). Knapsack sprayers are indispensable agricultural equipment for small farmers to pest control because of affordability and ease of operation, knapsack sprayers commercially available are manual, petrol engine operated and battery operated, Sinha et al. (2018). The quality of a number of these sprayers and their ability to be used to apply pesticides accurately and efficiently is of great concern due to their design and operation. In addition to that, most of the sprayers performed poorly, indicating that they are poorly designed with poor

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materials and mishandled by the farmers, Mamat and Omar (1992). It was estimated that around 50 to 80 % of applied pesticides are wasted due to poor spray machinery and inappropriate application methods, Khan et al. (1997).

Rabbani et al. (2020) designed and developed a boom for lever operated sprayer; the boom contained four plastic nozzles at a distance interval of 20.75 cm, then tested performance of this boom, they found that; the effective field capacity of the boom sprayer was 0.35 fed/h at walking speed of 2.015 km/h whereas the field efficiency was 71.86 %. Rahman (2010) reported that the effective field capacity of the boom sprayer and spraying by lance swing were 0.48 and 0.46 fed/h, respectively by considering the field efficiency of 75% and the coefficient of uniformity of spray distributions was improved by 28% due to using the boom and concluded that the boom might be used with a lever operated knapsack sprayer to increase the uniformity of deposition. Wang et al. (1995) carried out a laboratory experiment on uniformity of spray volume distribution for agricultural nozzles and showed that nozzle height had a strong effect on spray distribution uniformity, but spray pressure had no significant effect on the uniformity. Alaa et al. (2017) mentioned that the value of coefficient of variation (CV) is an indicator for the uniformity of spray liquid. The determined CV value from the field deposit must be 15% or less at applying pesticide on soil, grass, or weed surfaces, according to ISO 5681(1992), while the laboratory CV value is usually smaller than this value (15%) which was measured under the field condition, (Smith, 1992). ISO 16122-2 (2015) set a threshold for the uniformity of the spray distribution within the total overlapped range; the CV according to this standard must be 10% or less under laboratory scale.

Elsanusi et al. (2020) tested three types of spray equipment were; ULVA sprayer (centrifugal atomization technique), electric battery sprayer (pressure or hydraulic atomization) with flat fan Ss83 nozzle and conventional motor sprayer (pressure or hydraulic atomization). For electric battery sprayer the obtained data were as follow; the values of spray liquid flow rate, application rate, spray height, spray width and productivity were 0.85 L/min, 89.3 L/fed, 50 cm, 100 cm and 0.57 fed/h at working speed of 2.4 km/h.

The overlap or unsprayed areas can be occurred during swing operation of lever operated knapsack lance and the nozzle height was changed by 10% in each swing of lance and it is quite impossible to maintain a constant nozzle height during swing of the lance. Also; the operator of sprayer will suffer from health hazards by swing of lance in front of his body, Alam et al. (2000) and Rahman (2010). In addition to irregular walking speed during spraying process and indeterminate nozzle height from plant tops resulting uneven distribution of spray liquid. So, this study was carried out to overcome these problems, uneven spraying and low field capacity.

This research aims to develop and evaluate performance of a boom for a knapsack sprayer to improve spray quality and distribution pattern, the specific objectives were as follow:

1. To develop a boom for a knapsack pesticide for uniform distribution of spray liquid and increasing the field capacity
2. To study some spray characteristics; spray liquid discharge rate and spray distribution pattern.
3. To determine of the field performance; speed of spraying, theoretical field capacity, effective field capacity, field efficiency and daily operating time for the developed sprayer by using a battery.

2. Materials and methods

All experiments were carried out at the Laboratory of Agricultural Machinery and Power Engineering Department, Faculty of Agricultural Engineering, Al-Azhar University, Cairo, Egypt, in the year of 2020.

2.1. Materials

2.1.1. Magnetization treatment device

The materials used in this research consisted of the developed knapsack sprayer, measuring tools and devices.

2.1.2. Developed knapsack sprayer

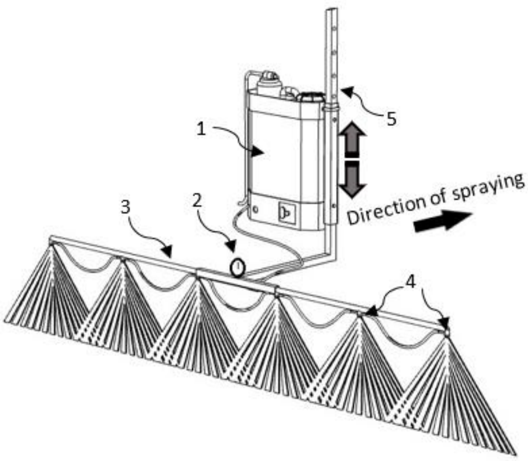
The developed sprayer consisted of electric knapsack pesticide sprayer and spray boom. The knapsack pesticide sprayer before development is shown in Figure 1. This sprayer was used in this study for many reasons: more common and used by Egyptian farmers (especially in small areas), can be powered manually or electrically, easily operation, maintenance, transportation, small storage area, low consumed energy, therefore; low operating cost and uniformity of liquid flow rate due to constant pressure. In addition to that the sprayer is modifiability and development.

(1) Sprayer tank, (2) Filler cap, (3) Hand pump, (4) Hand pump arm and 5) Spray lance

Figure 1. Knapsack sprayer used before development.

The specifications of the knapsack sprayer are as follow; the sprayer brand is Lamsin, model number is HX-D18F and place of origin is China. This sprayer is works with liquid pressure (hydraulic atomization) from 2.5 to 4.5 bar. Dimensions of sprayer are 40 cm for length, 17 cm for width and 47 cm for height. Tank of sprayer is made of high-density polyethylene and its capacity of 20 liters. The sprayer has a 12V DC diaphragm pump, consumed current range from 1.4 to 2 A and its speed ranged from 2800 to 3200 rpm. The sprayer has a 12 V (DC) battery with capacity of 9 Ah. The total weight of sprayer at full tank with water is 26 kg. The sprayer has regulator to control in operating pressure or flow rate of spray liquid.

The spray boom consists of six nozzles from type of flat fan spray pattern. The specifications of used nozzle were as follow; No: PL D-5, diameter of nozzle hole is 0.5 mm, operating pressure range from 1.4 - 7.0 bar and liquid discharge rate range from 0.21 -0.5 L/min. The nozzles were connected by using a hosepipe to control the nozzles spacing on the boom. In order to measure the spray liquid pressure during running; a pressure gauge was placed in the midpoint of the spray boom. The developed boom was mounted at the back of the sprayer to protect the sprayer operator from contaminating his body with pesticide spray. The developed knapsack sprayer and equipped with spray boom is shown in Figure 2.



(1) Sprayer tank, 2) Pressure gauge, 3) Boom, 4) Nozzles and 5) Control lever in spray height.

Figure 2. 3D drawing of the developed knapsack sprayer.

2.1.3. Measuring tools and devices

The measuring devices used in this study were as follows; Pressure Gauge: the pressure gauge used was connected in the midpoint of spry boom to measure the spray pressure, the device brand is SOLO, its accuracy of 0.1 bar and range of measuring ranged from 0.1 up to 4 bar, Stopwatch: a digital stopwatch was used to measure the time discharge of individual nozzle of spray boom and sprayer tank discharge as a batch volume in addition to measure a daily spraying time by using a battery at different operating pressures, Steel Measuring Tape: it was used to measure the nozzles spacing and height of spray boom, its accuracy of 1 mm and its range is from 0 to 3 m and Graduated Cylinder with capacity of 100 ml was used to measure the amount of discharged liquid of each of channels of patternator during testing of spray distribution pattern.

Performance evaluation methodology of the developed sprayer was carried out to achieve the following objectives:

- Developing a spray boom for a knapsack sprayer for uniform distribution of spray liquid and increasing the field capacity.
- Study of some spray characteristics; spray liquid discharge rate and spray volume distribution pattern.
- Determine of the field performance; speed of spraying, theoretical field capacity, effective field capacity and field efficiency at spray volume rates (20, 40, 60 and 80 L/fed) and different ratios of length to width of feddan (1:1, 2:1 and 3:1). In addition to determine the daily operating time by using the sprayer battery.

The following factors were studied:

- Spray pressure (1.5, 2.0 and 2.5 bar),
- Nozzles spacing (30, 40 and 50 cm) and
- Spray heights as follow:
  - 20 and 30 cm at nozzles spacing 30 cm,
  - 20, 30 and 40 cm at nozzles spacing 40 cm and
  - 20, 30, 40 and 50 cm at nozzles spacing 50 cm.

All experiments were replicated three times and the average value was taken as the value of the experiment.

2.1.4. Spray characteristics

2.1.4.1. Spray liquid discharge rate

The spray liquid discharge rate (Q L/min) for spray boom supplied with six nozzles was determined by using the tap water, the values of spray discharge rates at tested operating pressures were calculated by using the following equation:

$$Q = \frac{V_T}{t} \quad ... [1]$$

where V_T: is the total volume of the collected spray liquid (liters) form all nozzles and

t : discharge time (min).

2.1.4.2. Spray volume distribution pattern

The spray volume distribution pattern was tested by using a patternator according to Bhanagare (2015). The patternator was made of asbestos-cement and its dimensions are 300 cm for length and 100 cm for width. The patternator (Figure 3) consists of 37 curved grooves at equal spacing each of 8 cm and depth of 2.5 cm. The patternator was installed above wooden base and its inclination angle was 5° to easy collect the tested liquid (tap water) in the plastic cups. The spray boom was placed horizontal above the patternator at height of 20, 30, 40 and 50 cm to determine spray volume distribution pattern by using two nozzles. The distance between the two nozzles was changed as previously mentioned. The sprayer was operated for three minutes for each experiment at the following pressures values; 1.5, 2.0 and 2.5 bar. The coefficient of variation (CV, %) was used to evaluate the uniformity of the spray transverse distribution according to the following equations:

$$CV = \left(\frac{S}{\bar{x}}\right) \times 100 \quad \ldots [2]$$

where S: is the standard deviation of spray distribution (cm^3) and can be calculated from the following equation:

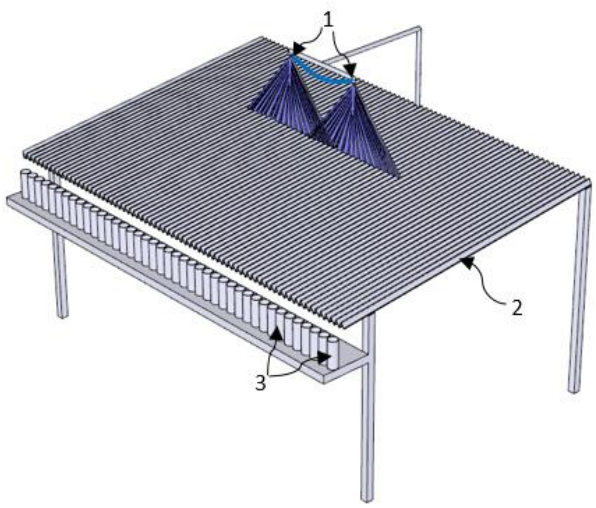
$$S = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}} \quad \ldots [3]$$

$\bar{x}$: mean volume of collected spray in all beakers (cm^3) and can be calculated from the following equation:

$$\bar{x} = \frac{\sum x_i}{n} \quad \ldots [4]$$

x_i: volume of collected spray (cm^3) and

i: 1, 2, 3, … n (number of beakers used).



1) Nozzles, 2) Patternator and 3) Plastic cups

Figure 3. 3D drawing of the patternator.

2.1.5. Field performance

2.1.5.1. Speed of spraying

The speed of spraying was calculating by using the following equation:

$$S = \left(\frac{L}{1000}\right) \times \left(\frac{60}{t_{SV}}\right) \quad \ldots [5]$$

where S: is the spraying speed, (km/h),

L: length of the field, (m) and can be calculated from the following equation:

$$L = \frac{A}{W_S} \quad \ldots [6]$$

A: area of one feddan (4200 m^2).

W_S: effective width of spraying, (m) and can be calculated as follow:

$$W_S = \text{nozzles spacing} \times \text{number of nozzles} \ldots [7]$$

t_{SV}: discharge time of required spray volume per feddan (min).

2.1.5.2. Theoretical field capacity

The theoretical field capacity (TFC, fed/h) was calculated using the following equation according to Rabbani et al. (2020):

$$TFC = \frac{S \times W_S \times 1000}{4200} \quad \ldots [8]$$

2.1.5.3. Effective field capacity

The effective field capacity (EFC, fed/h) was calculated by using the following equation:

$$EFC = \frac{60}{(T_{Th} + T_{Ref} + T_U + T_{RM})} \quad \ldots [9]$$

where T_{Th}: is the time of theoretical spraying per feddan, (min/fed) and can be calculated from the following equation:

$$T_{Th} = \frac{60}{TFC} \quad \ldots [10]$$

T_{Ref}: lost time in sprayer tank refilling per feddan, (min/fed) assumed (5 min per one time) and can be calculated from the following equation:

$$T_{Ref} = N_{TRT} \times 5 \quad \ldots [11]$$

N_{TRT}: number of tank refilling times per feddan,

T_U: lost time in turning per feddan, (min/fed) assumed (3 sec per turn) and can be calculated from the following equation:

$$T_U = N_R \times (3/60) \ldots [12]$$

N_R: number of turns per feddan and can be calculated from the following equation:

$$N_R = \left[\left(\frac{W_F}{W_S}\right) - 1\right] \ldots [13]$$

W_F: width of field, (m)

W_S: effective width of spraying, (m)

T_{RM}: lost time in maintenance and repair per feddan, (min/fed) assumed (10 % from theoretical time of spraying).

2.1.5.4. Field efficiency

The field efficiency of spraying process is the ratio of the effective field capacity to the theoretical field capacity or the ratio of theoretical spraying time to effective spraying time according to El-gendy (1994) and Rahman (2010). The field efficiency (η, %) was calculated using the following equation:

$$\eta = \frac{EFC}{TFC} \times 100 \qquad \text{... [14]}$$

2.1.5.5. Daily operating time

The sprayer battery was fully charged by Alternating current using a charger (12 V) then, the daily operating time of the sprayer battery was determined at the tested operating pressures.

3. Results and discussions

This chapter contains the obtained results from this study, these results were presented, discussed, and evaluated under the following items: spray characteristics (spray liquid discharge rate and spray volume distribution pattern) and field performance of the developed knapsack sprayer (speed of spraying, theoretical field capacity, effective field capacity, field efficiency and daily operating time).

3.1. Spray characteristics

3.1.1. Spray liquid discharge rate

The results revealed that the average values of spray discharge rates were 1.29, 1.56 and 1.86 L/min at operating pressures 1.5, 2.0 and 2.5 bar, respectively for all tested cases under the range of nozzles spacing from 30 to 50 cm at using 6 nozzles on the spray boom.

3.1.2. Spray volume distribution pattern

The spray volume distribution pattern was investigated using patternator for two nozzles, the experiments were carried out under three operating pressures; 1.5, 2.0 and 2.5 bar. For each pressure, three distances between two nozzles were tested at different heights of spray boom as follow; 30 (at height of 20 and 30 cm), 40 (at height of 20, 30, and 40 cm) and 50 cm (at height 20, 30, 40 and 50 cm). Figures 4, 5 and 6 show the spray volume distribution pattern for two nozzles. Generally, it's found that the breadth of spray increased with increasing the distance between two nozzles, boom height and spray pressure. As expected, it's noted that the overlap increased with decreasing the distance between two nozzles from 50 to 30 cm and increasing the spray pressure from 1.5 to 2.5 bar. Also, the results showed that; the maximum values of spray liquid deposition were recorded at the center of patternator whereas the minimum values were recorded at the extreme ends of the patternator.

The average values of variation coefficient of spray volume distribution were calculated for amounts of deposited liquid in curved grooves of patternator which parallel to distance between two tested nozzles at different spray pressures, boom heights and nozzles spacing as presented in Table 1. For nozzles spacing of 30 cm; the results showed that, the lowest value of variation coefficient was 4.4 % at height of 30 cm and pressure of 1.5 bar while, the highest value of variation coefficient was 10.7 % at height of 30 cm and pressure of 2.5 bar. For nozzles spacing of 40 cm; the results revealed that, the lowest value of variation coefficient was 5.6 % at height of 40 cm and pressure of 2.0 bar while, the highest value of variation coefficient was 17.1 % at height of 20 cm and pressure of 1.5 bar. For nozzles spacing of 50 cm; the results showed that, the lowest value of variation coefficient was 5.5 % at height of 50 cm and pressure of 1.5 bar while, the highest value of variation coefficient was 20.5 % at height of 20 cm and pressure of 2.0 bar.

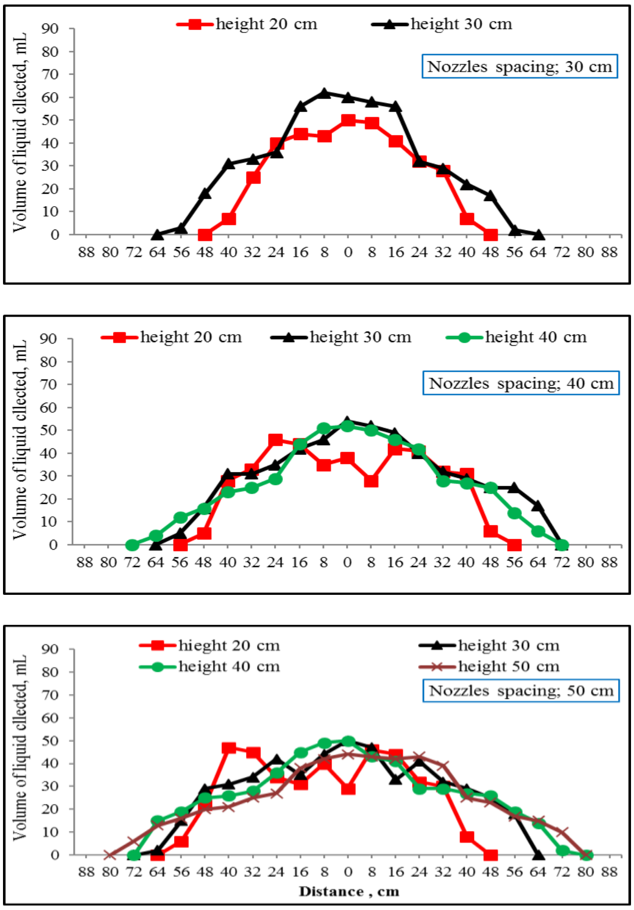


Figure 4. Spray volume distribution pattern for two nozzles at different nozzles spacing and boom heights under operating pressure of 1.5 bar.

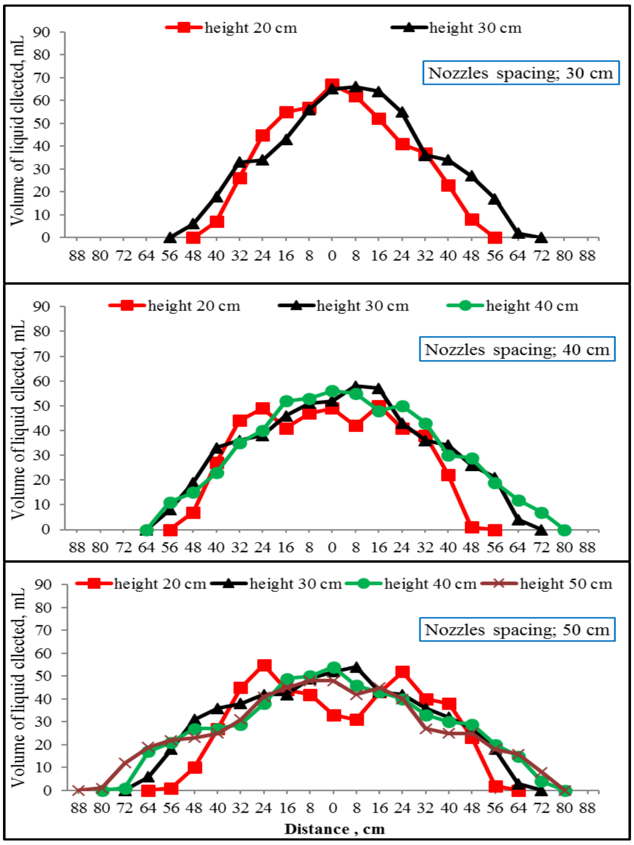


Figure. 5. Spray volume distribution pattern for two nozzles at different nozzles spacing and boom heights under operating pressure of 2.0 bar

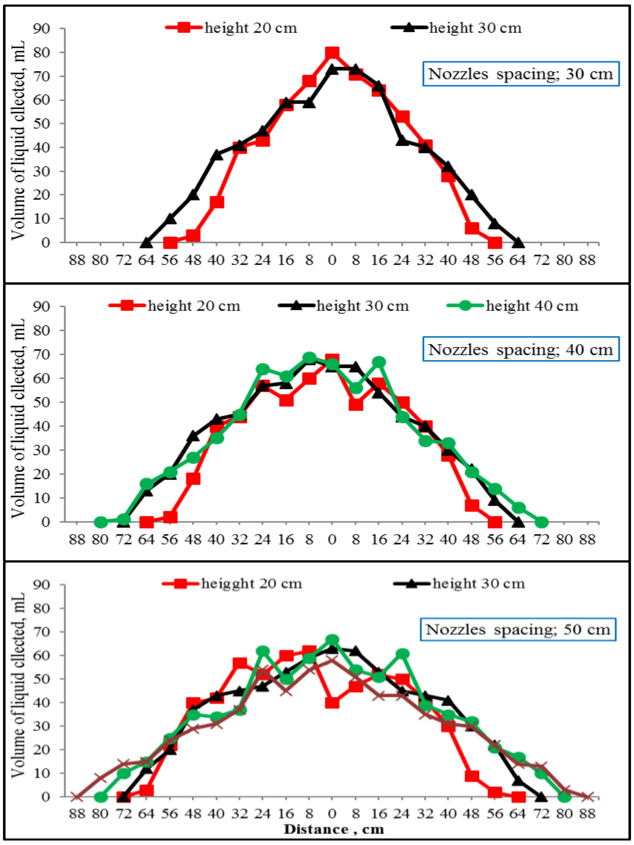


Figure 6. Spray volume distribution pattern for two nozzles at different nozzles spacing and boom heights under operating pressure of 2.5 bar.

Table 1

Variation coefficient values of spray distribution pattern at different spray pressures, boom heights and nozzles spacing.

Nozzles spacing, (cm)	spray heigh, (cm)	Values of CV, (%) at operating pressure, (bar)			Average (± SD)
		1.5	2.0	2.5	
30	20	8.6	10.3	12	10.30 (1.70)
	30	4.4	8.7	10.7	7.93 (3.22)
40	20	17.1	8.2	11.8	12.37 (4.48)
	30	11.7	11.6	9.3	10.87 (1.36)
	40	8.6	5.6	7.5	7.23 (1.52)
50	20	18.2	20.5	14.4	17.70 (3.08)
	30	14.4	11.5	13	12.97 (1.45)
	40	17.3	12.3	10.7	13.43 (3.44)
	50	5.5	7.6	11.6	8.23 (3.10)

The results also indicated that the mean values of variation coefficient under the tested range of spray pressure decreased with increasing the height of spray boom for all tested nozzles distances. From Table 1 the mean values of variation coefficient under the tested range of spray pressure decreased from 10.30 to 7.93 % when increased the height of spray boom from 20 to 30 cm at nozzles spacing of 30 cm. Whereas the mean values of variation coefficient under the tested range of spray pressure decreased from 12.37 to 7.23 % when increased the height of spray boom from 20 to 40 cm at nozzles spacing of 40 cm. Also, it's observed that the mean values of variation coefficient under the tested range of spray pressure decreased from 17.70 to 8.23 % when increased the height of spray boom from 20 to 50 cm at nozzles spacing of 50 cm. Therefore, we can concluded that the variation coefficient values of spray volume distribution pattern of the developed knapsack sprayer are acceptable when the ratio between nozzles spacing to boom height equal 1:1 [(30:30), (40:40) and (50 cm: 50 cm)] because these values are within or less than 10%, according to Siebe and Luck (2016). Whereas the tested range of spray pressures (1.5 to 2.5 bar) have no detectable effect on the variation coefficient values of spray distribution pattern. Consequently, it is preferable to be nozzles spacing and spray height at 50 cm to increase the performance rate of spraying for all tested pressures.

3.2. Field performance

3.2.1. Speed of spraying

Table 2 shows the calculated values of spraying speed at operating pressure (1.5, 2.0 and 2.5 bar) of the developed sprayer and spraying width 3.0 m corresponding to the nozzles spacing 50 cm at using 6 nozzles on spray boom under different spray volumes (Application rate); 20, 40, 60 and 80 L/fed. The results showed that the values of spraying speed gradually decreased with increasing the spray volume rate from 20 to 80 L/fed for all parameters of tested spray pressures. Under the range of operating pressures (from 1.5 to 2.5 bar) corresponding to the range of spray discharge rates (from 1.29 to 1.86 L/min) required applying for field crops in scale of low volume (20 to 80 L/fed) and spraying width 3.0 m it's found that the speed of spraying ranged from 1.35 to 5.42, 1.64 to 6.56 and 1.95 to 7.78 km/h at spray pressures 1.5, 2.0 and 2.5 bar respectively, but; the values of speeds under spray volume from 20 to 40 L/fed were high and not suitable for sprayer operator, whereas; the values of spray speeds under the spray volume rates from 60 to 80 L/fed can be applied according to required spray volume rate. Matthews (2008) mentioned that the required spray volume should be increase with increasing the age of plant because increasing of plant surface area. So, shouldn't never only dependence on the ground area occupied with a crop, therefore; we can choose the suitable operating conditions from Table 2 for applying the required spray volume from 60 to 80 L/fed, these conditions include spray pressure and suitable spraying speed which achieve the required spray volume according to plant type, planting method and its age which related to size (area of plant surface).

Table 2

Effect of spray pressure and spray volume rate on speed of spraying at nozzles spacing 50 cm.

Spray pressure, (bar)	Speed of spraying, (km/h) at different spray volumes, (L/fed)			
	20	40	60	80
1.5	5.42	2.71	1.81	1.35
2.0	6.56	3.28	2.18	1.64
2.5	7.78	3.91	2.60	1.95

3.2.2. Theoretical field capacity

The theoretical field capacity was determined at parameters of operating pressures (1.5, 2.0 and 2.5 bar), spraying width (3.0 m) and spray volume rate (60 and 80 L/fed) as shown in Table 3. The results showed that the average values of theoretical field capacity decreased with increasing the spray volume rate from 60 to 80 L/fed for all cases of tested spray pressures, also; it was found that the values of theoretical field capacity increased with increasing the spray pressure from 1.5 to 2.5 bar for all tested cases of spray volume rates. Under the range of spray volume from 60 to 80 L/fed, the values of theoretical field capacity ranged 1.29 to 0.97 with mean 1.13 ± 0.16, 1.56 to 1.17 with mean 1.37 ± 0.20 and 1.86 to 1.40 with mean 1.63 ± 0.23 fed/h for spray pressures 1.5, 2.0 and 2.5 respectively.

Table 3

Effect of spray pressure on theoretical field capacity at different spray volume rate

Spray pressure, (bar)	Theoretical field capacity (fed/h) at different spray volumes, (L/fed)		Average (±SD)
	60	80	
1.5	1.29	0.97	1.13 (0.16)
2.0	1.56	1.17	1.37 (0.20)
2.5	1.86	1.40	1.63 (0.23)

3.2.3. Effective field capacity

The results indicated that the values of the effective field capacity decreased with increasing the spray volume rate from 60 to 80 L/fed for all cases. Also, it was found that the values of the effective field capacity increased with increasing spray liquid discharge rate from 1.29 to 1.86 L/min and ratio of length to width of feddan from 1:1 to 3:1.

From Table 4, under the range of ratio of length to width of feddan area from 1:1 to 3:1 and spray volume rate from 60 to 80 L/fed, it was found that the values of effective field capacity ranged from 0.80 to 1.05 with mean 0.93 ± 0.12 fed/h, 0.95 to 1.24 with mean 1.10 ± 0.14 fed/h and 1.11 to 1.45 with mean 1.28 ± 0.16 fed/h at spray liquid discharge rates 1.29, 1.56 and 1.86 and spray pressure 1,5, 2.0 and 2.5 bar respectively.

Table 4

Effect of spray discharge rate and ratio of length to width for feddan area on effective field capacity at nozzles spacing of 50 cm.

Discharge rate, (L/min)	Ratio of length to width	Effective field capacity, (fed/h) at different spray volumes, (L/fed)	
		60	80
1.29 at 1.5 bar	01:01	1.04	0.80
	02:01	1.05	0.81
	03:01	1.05	0.81
	Average	1.05	0.81
1.56 at 2.0 bar	01:01	1.22	0.95
	02:01	1.24	0.96
	03:01	1.24	0.96
	Average	1.23	0.96
1.86 at 2.5 bar	01:01	1.42	1.11
	02:01	1.44	1.12
	03:01	1.45	1.13
	Average	1.44	1.12

3.2.4. Field efficiency

Table 5 shows the effect of different parameters of spray pressure and spray volume rate under the range of length to width ratio of feddan area. The results showed that the values of field efficiency increased with increasing the spray volume rate from 60 to 80 L/fed for all tested cases of the spray pressures, also; it was found that the values of the field efficiency decreased with increasing the spray pressure from 1.5 to 2.5 bar for all tested cases under spray volume rate. From Table 5, under the range of spray volume rate from 60 to 80 L/fed it was found that the values of the field efficiency ranged from 81.01 to 83.28 with mean 82.20 ± 1.19, 79.22 to 81.84 with mean 80.53 ± 1.31 and 77.31 to 80.30 with mean 78.81 ± 1.49 % at operating pressures 1.5, 2.0 and 2.5 bar corresponding to the liquid discharge rates 1.29, 1.56 and 1.86 L/min, respectively.

Table 5

Effect of spray pressure and spray volume rate on the field efficiency of spraying.

Spray pressure, (bar)	Field efficiency of spraying, (%) at different spray volumes, (L/fed)	
	60	80
1.5	81.01	83.28
2.0	79.22	81.84
2.5	77.31	80.30

3.2.5. Daily operating time

The daily operating time of the developed sprayer was carried out to determine the discharge time of sprayer battery at tested operating pressures. The results showed that the continuous operating time of the developed sprayer by using the battery were 8.27, 5.55 and 3.85 h at operating pressures of 1.5, 2.0 and 2.5 bar with constant spraying rates were 1.29, 1.56 and 1.86 lit/min, respectively.

4. Conclusions and recommendations

Conclusions

- The average values of spray liquid discharge rates for the developed sprayer were 1.29, 1.56 and 1.86 L/min at spray pressures 1.5, 2.0 and 2.5 bar, respectively.
- For the uniformity of spray volume distribution, the ratio of nozzle spacing to spray height 1:1 was the best for all tested cases of spray pressure due to the values of variation coefficient was less than 10 %, and it's preferable to be nozzles spacing and spray height at 50 cm to increase the performance rate of spraying under all tested pressures.
- Under the range of spray pressure from 1.5 to 2.5 bar, the developed knapsack sprayer can be used for spray volume rates from 60 to 80 L/fed.
- The maximum values of the theoretical field capacity was 1.86 and 1.40 fed/h for spray volume rates of 60 and 80 L/fed, respectively at spray pressure of 2.5 bar.
- The maximum values of the effective field capacity were 1.44 and 1.12 fed/h for spray volume rates 60 and 80 L/fed, respectively at spray pressure of 2.5 bar and spraying width of 3.0 m.
- The average values of field efficiency were 82.20, 80.53 and 78.81 % at spray pressures 1.5, 2.0 and 2.5 bar, respectively.
- the average values of continuous operating time of the developed sprayer using the battery were 8.27, 5.55 and 3.85 h at operating pressures 1.5, 2.0 and 2.5 bar, respectively.

Recommendations

- The developed knapsack sprayer equipped with spray boom (6 nozzles) and spray width of 3.0 m, can be used in pest control for field crops at spray pressure 2.5 bar and boom height of 50 cm from plant tops for spray volume rate from 60 to 80 L/fed.
- Development of the sprayer to power by solar energy (photovoltaic cell system) due to reducing the daily operating time at spray pressure of 2.5 bar.
- Periodic inspection and calibration of spray nozzles should be carried out before pest control process. In addition to periodic cleaning of tank and spray nozzles from pesticide residues after spraying.

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تحسين نمط توزيع الرش لرشاشة ظهرية باستخدام حامل بشابير

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الملخص العربي

توجد طرق متعددة لمكافحة الآفات منها: المكافحة البيولوجية، المصائد، مبيدات الآفات، التبخير، التعقيم، ... الخ. ومن أكثر هذه الطرق انتشار و أقدمها في جميع أنحاء العالم هي استخدام مبيدات الآفات، حيث تستخدم المبيدات بغرض حماية المحاصيل وزيادة إنتاجيتها ويتم توزيع محاليل المبيدات باستخدام آلات الرش - وتعتبر الرشاشات الظهرية أحد أهم الآلات الزراعية التي لا غنى عنها لمكافحة الآفات خصوصاً في المساحات الصغيرة لما تتمتع به من مميزات أهمها: رخص سعرها وسهولة تشغيلها وصيانتها ومنها ما يعمل يدوياً، أو بمحرك بنزين أو بالبطاريات – إلا أن معظم أداء هذه الرشاشات وقدرتها على رش المبيدات بدقة وكفاءة يكون ضعيفاً – وتشير التقديرات إلى أن حوالي ٥٠ - ٨٠٪ من مبيدات الآفات المطبقة تُهدر بسبب سوء اختيار آلات الرش وطرق التطبيق غير المناسبة – وأثناء عملية الرش يتم تأرجح رمح الرش يمينا ويسارا مسببا تداخل غير منتظم وقد تترك مساحات غير مرشوشة وبالتالي سوء توزيع سائل الرش بالإضافة إلى أن عملية تأرجح رمح الرش تسبب إجهاداً للعامل – بالإضافة إلى عدم التحكم في ارتفاع فوهة الرش من أسطح النباتات والتي تؤدي إلى توزيع غير متساوٍ لسائل الرش. لذلك أجريت هذه الدراسة للتغلب على مشكلتي الرش غير المتكافئ والسعة الحقلية المنخفضة.

تهدف هذه الدراسة إلى تطوير وتقييم أداء حامل بشابير لرشاشة ظهرية كمحاولة لتحسين جودة ونمط الرش - وكانت الأهداف التفصيلية لهذه الدراسة على النحو التالي:

- لتطوير حامل بشابير لرشاشة مبيدات ظهرية للحصول على توزيع متماثل لسائل الرش وزيادة السعة الحقلية.
- لدراسة بعض خصائص الرش (معدل تصرف سائل الرش ونمط توزيع حجم الرش) باستخدام حامل البشابير المطور عند دراسة العوامل التالية: ضغط الرش، تباعد الفوهات وارتفاع الرش
- لتحديد الأداء الحقلي (سرعة الرش، السعة الحقلية النظرية، السعة الحقلية الفعلية، الكفاءة الحقلية وزمن التشغيل اليومي للرشاشة المطورة باستخدام البطارية) تحت معدلات مختلفة لحجم الرش ونسب مختلفة لمساحة الفدان (نسبة الطول إلى العرض).

تم استخدام رشاشة ظهرية تعمل كهربائيا (باستخدام بطارية الرصاص الحامضية، ١٢ فولت - ٩ أمبير ساعة) وتقوم هذه الرشاشة بتجزئة سائل الرش بالضغط وتم تركيب حامل بشابير يحتوي على ستة بشابير - جميع تجارب هذه الدراسة تم إجراؤها بكلية الهندسة الزراعية بالقاهرة – جامعة الأزهر.

وكانت أهم النتائج المتحصل عليها كالتالي:

- أظهرت النتائج أن متوسط معدل تصرف سائل الرش كان ١,٢٩، ١,٥٦ و ١,٨٦ لتر/ دقيقة عند ضغوط الرش ١,٥، ٢,٠ و٢,٥ بار على التوالي.
- تم الحصول على أفضل انتظامية لتوزيع سائل الرش عندما كانت نسبة تباعد الفوهات لارتفاع الرش ١:١ لكل الضغوط المختبرة وذلك بسبب انخفاض قيم معامل الاختلاف لأقل من ١٠٪ - إلا أنه يفضل أن تكون المسافة بين الفوهات وارتفاع الرش ٥٠ سم وذلك لزيادة معدل آداء الرش عند الضغوط المختبرة.
- أوضحت النتائج أنه يمكن استخدام الرشاشة المطورة لمعدلات رش تتراوح من ٦٠ - ٨٠ لتر/فدان.

- القيم القصوى للسعة الحقلية النظرية للرش كانت (١,٨٦ و ١,٤٠ فدان/س عند معدلات رش ٦٠ و ٨٠ لتر/فدان) عند ضغط تشغيل ٢,٥ بار.
- القيم القصوى للسعة الحقلية الفعلية للرش كانت (١,٤٤ و ١,١٢ فدان/س عند معدلات رش٦٠ و٨٠ لتر/فدان) عند ضغط تشغيل ٢,٥ بار وعرض رش مقداره ٣,٠م (تباعد الفوهات ٥٠ سم).
- بينت النتائج أن القيم المتوسطة للكفاءة الحقلية كانت ٨٢,٢٠ ، ٨٠,٥٣ و٧٨,٨١ % عند ضغوط التشغيل ١,٥، ٢,٠ و ٢,٥ بار على التوالي.
- أظهرت النتائج أن القيم المتوسطة لزمن التشغيل اليومي للرشاشة المطورة (بدون توقف) باستخدام البطارية كان ٨,٢٧، ٥,٥٥ و٣,٨٥ ساعة عند ضغوط التشغيل ١,٥، ٢,٠ و٢,٥ بار على التوالي.

التوصيات:

- توصي الدراسة باستخدام الرشاشة الظهرية المطورة ذات حامل البشابير (ستة بشابير) بعرض ٣,٠م في عملية رش مبيدات الآفات للمحاصيل الحقلية عند ضغط تشغيل ٢,٥ بار وعلى ارتفاع ٥٠ سم من قمم النباتات لمعدلات رش تتراوح من ٦٠ إلى ٨٠ لتر/فدان.
- تطوير الرشاشة كي تعمل بالطاقة الشمسية (نظام الخلايا الفوتو فولطية) نظراً لانخفاض زمن التشغيل عند ضغط رش (٢,٥ بار).
- يجب إجراء الفحص الدوري والمعايرة لفوهات (بشابير) الرش قبل إجراء عملية مكافحة الآفات - بالإضافة لتنظيف خزان الرش والفوهات من متبقيات مبيدات الآفات بعد إجراء الرش.