Performance of knapsack sprayer: effect of technological parameters on nanoparticles spray distribution

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Abstract

Iraqi farmers are currently used knapsack sprayers in their applications with a low cost to control diseases in vegetables and trees. Laboratory and field tests were carried out to study performance of knapsack sprayer after its modification to determine the optimal spray deposit on the target at different settings to control the flowrate at the time of application. A knapsack sprayer of 16 liters capacity was modified using existing materials in markets and its performance evaluated. Tests were done with conical dual tip nozzle. White papers cards were utilized to measure droplet characteristics. All measurements were made at different nozzle heights of 50, 70, and 90 cm, different operating pressure were without pressure gauge, 15, 25, and 30 psi. The main results showed that droplet distribution was proportional to nozzle heights and operating pressures. Increasing nozzle heights and operating pressure cause an effect in droplet distribution and spray deposit. A high spray deposit was observed at nozzle height of 50 cm and operating pressure of 30 psi. Operating pressure has greater influence on droplet size than nozzle height. Increasing operating pressure from 15psi to 30psi led to decrease in droplet size of 13.62%.

Keywords: *Knapsack sprayer, nozzle height, operating pressure, droplet size diameter, deposit, coverage*

Introduction

Increasing the population numbers are requires increasing in the crop production and quality [1]. Use of pesticides produces at agricultural applications is an important issue in fields to improve both of quantity and quality of agricultural yield. As well as, to protect plants from diseases, weeds which consider unfavorable for agricultural plant [2].From the other hand, the use of pesticides have side-effect on the environment and human health [3,4].

According to ASAE (American Society of Agriculture Engineers) droplet sizes are categories from very fine to extremely coarse. Droplet size diameter is one of the most important factors use to evaluate the performance of any sprayer that affecting on several parameters as VMD (Volume Median Diameter), spray deposits, and spray coverage.

VMD is defined as droplet size diameter which indicates that half of the spray volume is in droplet smaller than this number and half of the spray volume is in droplets larger than this size. In additions, there are two other values important insides VMD. First value is $Dv_{0.1}$ which indicates that 10% of the spray volume is in droplets smaller than this value and may be a major part of the driftable fine sizes. Second value is $Dv_{0.9}$ which indicates that 90% of the spray volume is in droplets smaller than this value and 10% of the spray volume is in droplets larger than this value [5].

The distribution of spray deposits and coverage on the target site are depends on several factors as density of plant, droplet size diameter, droplet velocity, droplet density, physo-chemical properties of spray liquid, surface characteristics of the foliage, and meteorological conditions at time of spraying

application [6,7,8,9,10]. Some of these studies have focused on the complex relationship that exists between spray coverage on the target site, droplet size diameter and the efficacy of agricultural spraying applications.

One of techniques is used for determination of spray characteristics in field is water sensitive cards. These cards are widely utilized in the world by different authors in order to measure droplet size spectrum on the target site [11,12].

The technologies that used in agricultural applications to apply the pesticides in farming are advancing rapidly in the world. While, in small scale farmers, the knapsack sprayers offers several advantages to reduce the face difficulties in choosing a suitable sprayers machine for different types of crops and pesticides application [13].

Most of the Iraqi farmers are currently used knapsack sprayers in their applications to apply pesticides with a low cost to control any disease in vegetables and trees up to 2.5m height.

Several studies were conducted on sprayers using different technological parameters as nozzle height and working pressure separately to show their effect on spray characteristics. Select a proper nozzle height and working pressure at agricultural applications allows uniform coverage of the spray pattern. When the nozzle height is closed to the target site, the overlap might be not achieved. Also, excessive nozzle height leads to increase in spray drift contamination [14,15]. In addition, nozzle height was reported by [16] to be the most significant variable in spray deposit, coverage, and to reduce spray drift. To achieve satisfied spray characteristics could be considered an appropriate nozzle height that causes major differences in deposition on the intended target site.

Other parameter is operating pressure that can be controlled using pressure gauge. Pressure gauge on the knapsack sprayer is an important issue that affecting on the variable in each of flowrate of nozzles, spray pattern, spray width, droplet size in spray, spray coverage and chemical performance in field to control the disease intended. Also, inconsistent pressure has influence on the spray drift. One of the main problems that face using of knapsack sprayers in agriculture applications is cannot maintain of operating pressure at all time of pesticides application which effect on each other explained above.

Several types of sprayers as knapsack sprayers are requires on specific information as maximum amount of spray deposit on the intended site, droplet size diameter, number of droplet density, spray coverage area.

The main goal of this present study is to evaluate the performance of knapsack sprayer after its modification for the following reasons:

Use different nozzle heights of knapsack sprayer existing after check it at different operating pressures to Study the suitable height of nozzle vs. target.

Study the variable in the operating pressure occurs at the time of application.

Evaluate and compare the droplet diameter, spray coverage, spray deposit and uniformity of droplets with standard type of knapsack sprayer existing in market without pressure gauge.

To get more details accurately at the time of spraying to guaranty reach the acceptable amount of pesticides on target and

To improve the deposition volume on the intended target site using both of a suitable nozzle height and working pressure.

Materials and Methods

The knapsack sprayer was used in this study as shown in Figure 1.

Figure 1: View of knapsack sprayer used

(a) Before modification   (b) After modification

This type of sprayer was modified at Department of Agriculture Mechines and Equipments, Agriculture College, Basrah University. The main part that modified in this study was added pressure gauge to the pipe before the nozzle mounted Fig.1 (b) for controlling the pressure at time of Agricultural applications. Tank capacity of knapsack sprayers was 16 liters. Knapsack sprayer is carried on the back by two adjustable shoulder straps. An operating level, positioned either over the shoulder. Drives a piston or diaphragm pump. The pump is most commonly fitted on the inside of the tank in order to prevent damage. The piston pump is preferred for applying insecticides and fungicides which considered working with a maximum pressure of 30 PSI. The level of pressure in chamber size is not stable at the time of sprayer applications; however, these variations in pressure level are considerably worsened if pressure chamber capacity is inadequate.

Considerations taken in modified of knapsack sprayer

Modification of knapsack sprayer in this study was considered in the development of crop protection as following:

1. The materials selected are easy, found in

the markets, and

 2. Materials parts are used resistance to chemical products.

Flowrate setup

A cylinder tube was used in laboratory tests for measuring the volume of liquid discharged into it in ml per minute unit to fix the flowrate nozzle using a tap water.

Nozzle setup

Dual conical tip nozzle used in this study as shown in Table 1

Table 1: Nozzle characteristics

Flowrate (L.min^{-1})			
With pressure gauge (PSI)			Without pressure gauge
15	25	30	
0.52	0.64	0.83	0.59

Meteorological conditions

Meteorological conditions including air temperature, Relative humidity and wind speed were recorded during each field test at site (Fig. 2) using anemometer model MS 6252B.

Figure 2: Picture of the test measuring setup.

A summary of meteorological conditions during of spray test is shown in

Table2.

Table 2: Weather conditions during the spray test

Average temperature °C	Average relative Humidity %	Average wind Speed m.s^{-1}	Wind direction
16.1	52.46	2.1	North

Modalities setup

The field test was carried out with an operator at field measuring 10m length * 10m width. The worker walked with average speed 0.9 m/sec. The discharged volume in liters per minute was recorded at time of test for the nozzle that used in this study as shown in table 1. 36 modalities were conducted in this study by using different nozzle height (50, 70, and 90cm), different operating pressures (without pressure gauge, 15, 25, and 30 PSI). All modalities carried at the same nozzle type dual conical tip and average wind speed of   2.1 m.s^{-1}. The test of procedure was repeated 3 times and the mean value determined.

Procedure the work

The experiments were performed at Department of Agriculture Mechines and Equipments, Agriculture College, Basrah University. The experiments were conducted in soil virgin (without plants). Spray deposits were collected for measuring and analysis using both horizontal and vertical collectors. A spray deposit with vertical collectors were 0.5m width* 2m length, whereas the horizontal collectors were placed at each 1m until 10m. A total of 12 vertical white cards were collected for each test, the collector layout is shown in Fig. 3.
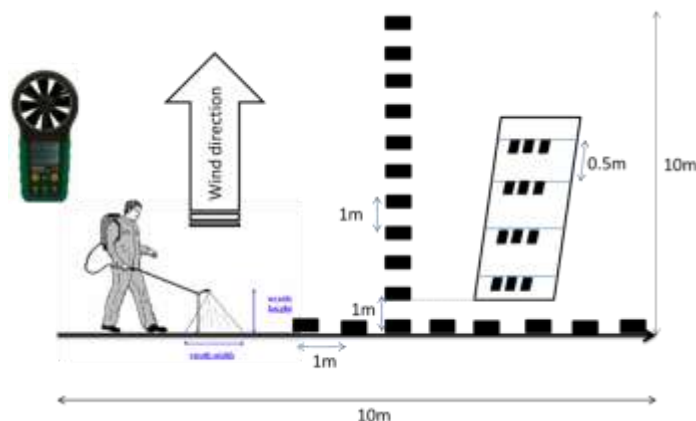

Figure 3: Schematic view of the test site and collection spray locations.

All tests were applied in a crosswind (perpendicular to wind direction). The average of wind speed for all tests was 2.1 m.s^{-1}.

Determination of spray distribution

Spray distribution with nozzle test was conducted using white papers. A liter of water was mixed with a tracer florescent which poured into the tank of sprayer. The position of spray nozzle was located at lateral position (parallel to wind direction). The total deposition onto horizontal surface that covered with droplets of liquid on the white cards (42 cm^2) above the ground was measured Figure 4. Testing was conducted when the average wind speed was 2 m/s. So, wind drift was minimal. The white cards were scanned using DropletScan® software.

The white papers are positioned at the safe distance, safe wind speed to avoid walking and to crush it by the worker.
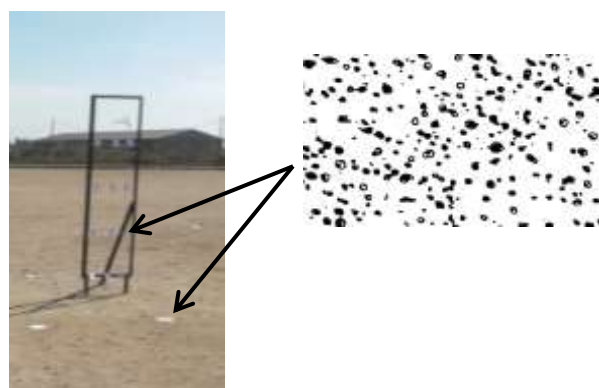

Figure 4: sampling of white cards after demonstration

After each replication, the white cards were remained in their origin place for 15 min after spraying until dry it then placed in prelabeled-sealable bags for preservation. Data envelopes were used to organize and store the white cards until analysis was complete.

This present work, it presents just only the samples in horizontal collectors because of the values in vertical locations were small at a low wind speed of 2.1 m.s^{-1}.

Measurement distribution of the spray characteristics

Droplet size was measured on the white cards paper after spraying. The papers were collected and scanned by a scanner (HP Scanjet 2400) with a resolution of 600 dpi none interpolated and analyzed by means of the computer DropletScan® (WRK of Arkansas, Lonoke, AR; and WRK of Oklahoma, Stillwater, Ok; Devore Systems, Inc., Manhattan, KS) was used to analyze the white cards. Each white card was 5 cm width*8.5 cm length. The total area of the pieces of white card was analyzed by the program. For the analysis, were evaluated the volume median diameter, Dv0.1, Dv0.9, and droplet median diameter, droplet size.

Dropletscan software converts each individual image spot area to the actual droplet diameter by using the equation

$D_d = 1.06 \text{ As}^{0.455}$ ------------------ (1)

Where D_d is actual droplet diameter µm; As is spot area cm^2

Collection spray deposition measurements

After spraying, the droplets deposit on the collector. Fluorescent dye Brilliant Sulpho-Flavine (BSF) was selected in this study with a concentration of 1g.l^{-1}. One of the main reasons to use BSF tracer in this article are due to the results of [17] when compared the performance of different fluorescent dyes and selected this type of tracer as the best type of tracer

to reproduce the atmospheric transport of pesticides. As well as, BSF tracer was with a low degradation after it exposure to sunlight. All experimental measurements are repeated three times then calculated the average after.

Statistical analysis

All experiments were statistically analysed of data using graph pad software® to enable the comparison between repetition and normalize the data.

Results and discussion

Effect of nozzle height and operating pressure on volume median diameter

As shown in Table 3 increasing the operating pressure and nozzle height led to significant differences in droplet diameter. The minimum of VMD value was observed 214.55 µm at unknown pressure (without pressure gauge mounted on the rod of sprayer) and nozzle height of 90cm, and the maximum of VMD value was 278.5µm at 15 PSI and nozzle height of 50 cm.

Table 3: Spray characteristics at different nozzle heights and operating pressure

Nozzle height (cm)	Operating pressure			
	15psi	25psi	30psi	Without pressure guage
50	278.5	250.8	247.94	267.42
70	264.22	245.02	259.92	246.76
90	262.02	247.48	238.94	214.55

The percentage of droplets diameter less than 100 mm on the white card were 69 % at nozzle height 90cm and operating pressure of 30psi.

Increasing operating pressure led to reduce in the mean of droplet sizes in all modalities conducted in this study and increased in the percentage of spray volume in droplet size less than 100µm.

Effect of operating pressure and nozzle height on spray distribution (droplet size)

Increasing both of the operating pressure and nozzle height led to significant differences in droplet size diameter. As shown in Figures 5, 6, 7, 8, represents the effect of working parameters as operating pressure and nozzle height on spray distribution (droplet size). Increasing in operating pressure and nozzle heights results in generating spray droplets with smaller size in diameter. Consequently, the results showed increasing in the percentage of spray coverage with increase in operating pressure. Also, it could be seen that any change in operating pressure lead to influence on the spray distribution. The portion of small droplet size on the collectors was small in low operating pressure and nozzle height. The effect of operating pressure on droplet size was greater than nozzle height. Increasing operating pressure from 15psi to 30psi led to decrease in droplet size of 13.62%.
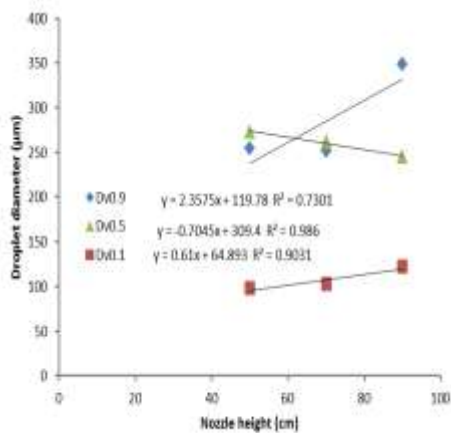

Figure 5: Effect of nozzle height on spray droplets distribution at 15PSI- horizontal location samples
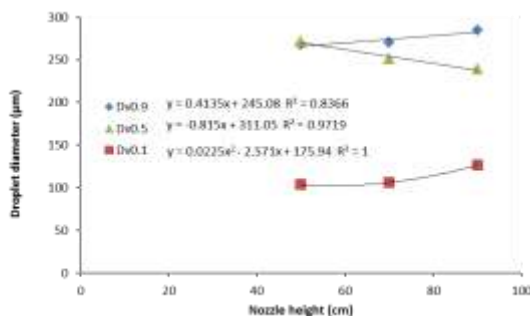
Figure 6: Effect of nozzle height on spray droplets distribution at 25PSI- horizontal location samples
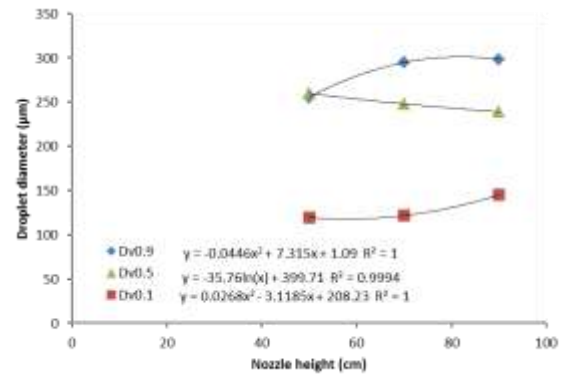

Figure 7: Effect of nozzle height on spray droplets distribution at 30PSI- horizontal location samples
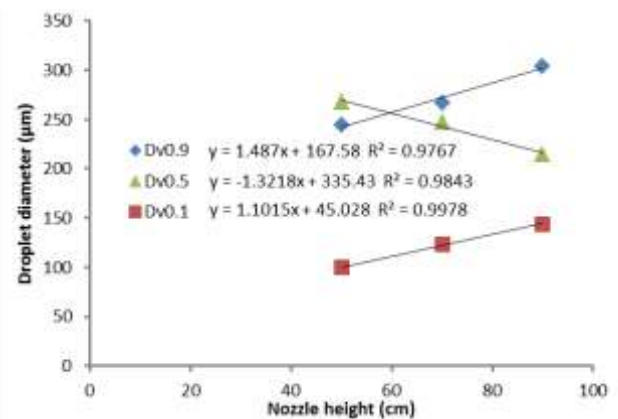

Figure 8: Effect of nozzle height on spray droplets distribution at horizontal location samples- without pressure gauge

Effect of operating pressure on nozzle flowrate

Table 4 induced the nozzle flowrate of water liquid at different operating pressures. The discharge volume of liquid in L.min^{-1} increased from 0.52 to 0.83 l/m when increased operating pressure from 15 to 30 psi.

Table 4: Results of nozzle flowrate

Operating pressure (bar)	Replications	Time taken (sec)	Discharge capacity rate (ml)	Flowrate (L.min⁻¹)	Average flowrate (L.min⁻¹)
without pressure gauge	1	3.53	39	0.66	0.59
	2	3.94	41	0.62	
	3	3.88	31	0.48	
15	1	6.24	57	0.54	0.52
	2	5.46	47	0.51	
	3	6.66	58	0.52	
25	1	3.53	39	0.66	0.64
	2	3.94	41	0.62	
	3	4.78	50	0.63	
30	1	2.4	33	0.83	0.83
	2	2.9	41	0.85	
	3	2.65	36	0.82	

Table 4 revealed that the average discharge volume is change depending on operating pressure and mean time taken to spray in sec. Nozzle flowrate has affected by operating pressure. There was variation in the nozzle flowrate recorded due to working pressure with a constant walking operator speed at the time of field test. Higher flowrate observed at 30 psi and lower nozzle flowrate at 15 psi.

Effect of operating pressure and nozzle height on spray distribution (area coverage %)

Results showed in Tables 5 induced increasing the operating pressure and nozzle height led to significant differences in spray coverage. Spray coverage was increased when increase both of operating pressure and nozzle height. High coverage observed at the highest operating pressure of 30 PSI and nozzle height of 90 cm. The lowest spray coverage in this study was showed at unknown pressure. The results showed that when median droplet size is decreased, spray coverage on the white paper collectors is increased.

Table 5: effect of operating pressure and nozzle height on area coverage %

Operating pressure (bar)	Nozzle height (cm)		
	50	70	90
Without pressure gauge	10.1	13.6	18.2
15	12.4	13.6	14.8
25	12.8	14.2	15.4
30	14.5	15.5	17.2

The decreased in droplet size observed at the highest operating pressure of 30psi and highest nozzle height of 90 cm , but the spray coverage increased to the highest value 17.2%.

Effect of operating pressure and nozzle height on droplet deposition

Increasing the operating pressure and nozzle height led to significant differences in droplet deposition. As shown in Fig. 6 droplet deposit has affected by operating pressure and nozzle height.

Table 6: effect of operating pressure and nozzle height on spray deposit ($\mu L/cm^2$)

Operating pressure (bar)	Nozzle height (cm)		
	50	70	90
Without pressure gauge	0.06	0.041	0.030
15	0.042	0.039	0.037
25	0.048	0.044	0.039
30	0.058	0.050	0.047

The deposits on the white papers are between 0.03 and 0.06 $\mu l/cm^2$. Results from this study showed that the application without a constant pressure has a greater effect on droplet size and coverage which related directly to droplet deposit.

Smaller droplets size gives better uniformity in droplet deposit distribution than larger droplets size. They are also higher deposits on the white papers when the nozzle height is the lowest and the operating pressure is the highest. These results are important because it would support to select of a suitable droplet size and coverage at each parameter used. Also, it would to support the management of spray drift. Also, the results from this study showed higher droplets deposit in the first line of sample and

low drift deposits on the ground after 2m downwind due to low wind speed at the time of test.

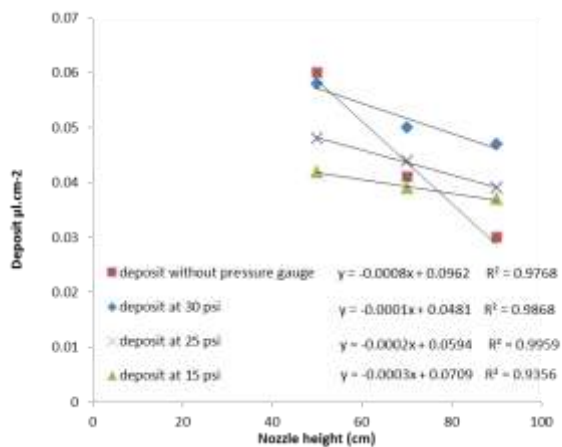The results in Table 6 was represented in Fig. 9

Figure 9: Effect of operating on deposit at different nozzle heights

As shown from the experimental results in Figure 8 a linear correlation between spray deposit and operating pressure at different nozzle heights. It is also observed when the sprayer without pressure gauge the deposit decreased rapidly with nozzle heights compared to with pressure gauge.

Conclusions

The paper presents the effect of technological parameters as nozzle height and operating pressure on spray characteristics as droplet size diameter, spray coverage, and spray deposit. The main results showed technological parameters have significant impact on spray characteristics. The impact are varies with both of nozzle height and operating pressure. Spray deposit and coverage influenced by changing of droplet size diameters. The main factor has effected on droplet size was operating pressure. Any change in the mean of droplet diameter as a function of changes in the operating pressure will be changed in spray deposit and coverage. It would be recommended to alternate these parameters to increase coverage at increase operating pressure and decrease nozzle height as possible.

Other recommendations of the study to use pressure gauge with knapsack sprayer for limiting the differences in spray impact. As well as inconsistent pressure influence on the spray deposit and coverage by controlling the flowrate and nozzle height at the time of application when applied at an acceptable meteorological conditions. To achieve a constant volume application rate at the time of application, the pressure level must be maintained.

Acknowledgements

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