# EFFECT OF THE OPERATING PRESSURE AND NOZZLE HEIGHT ON DROPLETPROPERTIES USING KNAPSACK SPRAYER

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**ABSTRACT**

**A field study was performed in the Agricultural Machines and Equipment Department, Agriculture College, Basrah University, to study the effect of the operating pressure and nozzle height on droplet properties reaching to the target using knapsack sprayer with a maximum capacity of 16l. A nozzle is mounted on the rod of sprayer. Three different operating pressures were tested in this study of 1, 1.7, 2 bar and three different nozzle heights of 50, 70, 90cm. Brilliant Sulpho-Flavinedye was used to measure mean droplet sizes, droplet densities, droplets number, and relative span factor deposited on white card papers. The spray properties were determined after spraying in field and then were analyzed using Image J software. The main results of the study showed asignificant effect of operating pressure and nozzle height on mean of the droplet diameter, droplet volume, droplets number, and relative span factor. Increasing the operating pressure from 1 to 2 bar for the some nozzle height led to decrease droplet diameter by 31.94 % and decrease in mean droplet volume by165.33%. The results also showed that increasing in nozzle height from 50cm to 90cm led to a decrease in the mean of the droplet size of 25.38% and decrease in droplets volume that reaching to the target by155.86%. The effect of the nozzle height on the spray droplet properties was more than that of increasing operating pressure.**

**Keywords: dropletsize, droplets number, relative span factor**



# تاثير الضغط التشغيلي وارتفاع النوزل في خصائص القطرات باستعمال المرشة الظهرية

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**المستخلص**

**اجريت دراسة حقلية في قسم المكائن والالات الزراعية – كلية الزراعة – جامعة البصرة بهدف دراسة تاثير الضغط التشغيلي وارتفاع النوزل في خصائص القطرات الواصلة الى الهدف باستخدام المرشة الظهرية ذات السعة 16 لتر . ثبت النوزل من النوع المخروطي على الذراع الحامل للنوزل. نفذت في هذه الدراسة ثلاثة ضغوط مختلفة 1، 1.7، 2بار وثلاثة ارتفاعات مختلفة 50، 70، 90 سم . كما اضيفت صبغة BSF الى الماء كمؤشرفي قياس خصائص القطرات المترسبة على ورق خاص White Card Papers وحدد كل من متوسط قطر، كثافة القطرة، عدد القطرات لوحدة المساحة، ومعامل التماثل النسبي بعد اجراء الرش حقليا والتي حللت باستخدام برنامج Image J . اظهرت نتائج التجربة الحقلية اختلاف في خصائص القطرات معنويا مع تاثير كل من الضغط التشغيلي وارتفاع النوزل. كما بينت النتائج ان زيادة الضغط التشغيلي من 1 الى 2 بارادى الى صغر في متوسط حجم القطرة بنسبة (31.94%) وزيادة في كثافة القطرات بنسبة (42.57%). كما اوضحت الدراسة ان زيادة ارتفاع النوزل من 50 الى 90 سم ادى الى نقصان في متوسط حجم القطرة بنسبة (25.38%) وزيادة في كثافة القطرات الواصلة الى الهدف بنسبة (73.87%). من جانب اخر الدراسة اكدت ان تاثير ارتفاع النوزل في متوسط قطر وكثافة القطرات كان اكثر من التاثير الحاصل في زيادة الضغط التشغيلي.**

**الكلمات المفتاحية: حجم القطرة، عدد القطرات، معامل التماثل النسبي**

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## INTRODUCTION

The intended target to be sprayed forpest control is determined by the droplet size produced from nozzle mounted on the sprayer machines. Droplet size is one of the most important variables that have received attention in recent decades from many researchersespecially, when it is dealing with agricultural sprayers and their relationship with pesticides. The process of liquid defragmentation from the nozzle orifice results variable particles size from one nozzle to another. Droplet sizesdependent on nozzletype is an important factor for obtaining the best spray efficacy to eradicate the pest.Different agricultural spraying equipment, methods, andnozzletypes were used to measure droplet size in agricultural applications, therefore the American Society of Agricultural and Biological Engineers (ASABE) (2) classified droplet sizes into different categories ranges from the extremely fine < 60 µm to the Ultra-coarse in size > 650 µm.There arenumber of variables related to droplet size such as droplet volume, and droplets number per unit area. Droplet volume was studied by a few researchers that were evaluated using laser-induced breakdown technique (19). Diagnosis of droplet volume by usingthistechnique in laboratory experimentsistoo cost test and cannot measure absolute droplet volume in the field directly.Droplet number per $cm^2$ is one of the most important properties to be observed for controlling a disease in the field. According to the type of infection, it will help in the selection of the nozzle type to be used on the sprayer to treat a specific infection caused by fungi, insect, bacteria or herbs.However, droplets number were studiedby few researchers (18)studied the correlation between spray droplet number per $cm^2$ and droplet size in banana field using two contact fungicides. The main result of this study found that the changes of the droplets number result from the change in droplet size at the time of application.Droplet properties represented by droplet size, droplet volume, and droplets number are strongly related tonozzle size, operating pressure, nozzle height, type of sprayer, and the physio-chemical properties of spray liquid. As well as meteorological conditions during the spraying process. The study of Wang et al.(17) reported a significant effect of the nozzle type used in meanof the droplet size reaching to the target.The results showed an increase in mean of the droplet size with decrease in forward speed and decrease it with increase in the nozzlewidth and height.The nozzle size also has an evident effect on the spray pattern (Flat Fan nozzle, and hollow cone) which effectson the droplet size.Whereas the effect of the nozzle height on the droplet size was confirmed by the study (8). Increasing the nozzle height from the target leads to reduce droplet sizes, which allowstayingthe droplets longer and drift away with prevailing wind and directionbefore reaching the target. Also, the meteorological conditions directly effecton the diameters of the droplets and carrying them from the zone of spraying to off-target depending on their size. There are many techniques used to study the droplet size, droplets number, and droplet volume during spraying as water sensitive papers which are placed on the target. Many researchers have used this technique as(4, 5, 6, 10, 14, and 20)to measure the droplet properties deposited on the target. The main results of these studies showed a strong relationship among the droplet size, nozzle type, nozzle height and the meteorological conditions.The large variation in the droplet properties during spraying made the researchers to shed light on the nozzles to limitingthe variability in droplets properties.The most important parameters affecting the selection of nozzles are the operating pressure and nozzle height to obtain recommended range of droplet properties. All previous studies were discussed droplet properties separately. So, the main objective of this present study is to investigate the effect of the operating pressure and nozzle height on the dropletproperties reaching the target by using knapsack sprayer.

## MATERIALS AND METHODS

A field experiment was carried out at the site of Basrah University - Agriculture College in a land without plants to study the effect of operating pressure and nozzle heighton the dropletproperties reaching the target. Three operating pressureswerestudies of 1, 1.7, and 2bar and three different nozzle heights were

50, 70, and 90cm. knapsack sprayer 16L was used in this experimental study.

**Nozzle characteristics**

Hollow cone nozzle was mounted on the knapsack sprayer and the properties of nozzle were given in Table 1

**Table1. characteristics of nozzle used in this study**

| Operating pressure (bar) | Nozzle flowrate ($L.min^{-1}$) |
|---|---|
| 1 | 0.52 |
| 1.7 | 0.64 |
| 2 | 0.83 |

**instrumentations**

**Measurement of the droplet size**: Mean droplet size was calculated using the water paper card technique by the following formula,

$$\textbf{Droplet diameter} = \frac{\textbf{Stain diameter}}{\textbf{Spread Factor}} \ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

Spread factor was calculated according to the following formulaCunha et al.(12):

$$\boldsymbol{feD_m = 0.74057 + 0.0001010399 * D_m + 0.02024884 * In(D_m)} \ldots\ldots\ldots\ldots\ldots(2)$$

The spray droplets that fall down on the paper leave yellow spots resulting from the use of BSF (Brilliant Sulpho-Flavine) added to water by 1 $g.l^{-1}$. These spots were measured after spraying in the laboratory using Image J software® after scanning its. The main advantage of this method is easy to measure the efficiency of spraying after placing the paper at different locations.

**Measurement of the droplets number and droplets volume:** Number of droplets deposited per $cm^2$ was determined by measuring the number of droplets on the white paper resulting from the nozzle. The experimental tests repeated three times and the average for each test was calculated. The droplets number reaching to the paper (target) was calculated by the following equation: (16)

$$\boldsymbol{N_d = 60\pi^{-1}(100d^{-1})^3 Q} \ldots\ldots\ldots\ldots\ldots(3)$$

Where $N_d$: is the dropletsnumber per $cm^2$, d: is a droplet diameter (µm), Q: is the size to be applied ($L.ha^{-1}$)

The droplet volume $\mu m^3$ was calculated by:

$$\boldsymbol{V_g = \frac{\pi d^3}{6}} \ldots\ldots\ldots\ldots\ldots.(4)$$

Where Vg: is the droplet volume$\mu m^3$, d is the droplet diameter µm

**Measuring Relative Span Factor**

Relative span factor was calculated in this study using the following equation (11):

$$\boldsymbol{RSF = \frac{Dv0.9 - Dv0.1}{Dv0.5}} \ldots\ldots\ldots\ldots\ldots\ldots \textbf{(5)}$$

Where: RSF: Relative Span Factor, $Dv_{0.9}$: 90% of total volume is contained in droplets of a greater diameter, which indicate for coarse droplets to avoid the waste of chemical; $Dv_{0.1}$: 10% of total volume is contained in droplets of a smaller diameter, which indicate for fine droplets that are more drift away; $Dv_{0.5}$: 50% of total volume of the liquid sprayed is made up of droplets with diameters larger than the stated value and 50% is made up of droplets with diameters smaller than the stated value. Dv0.5 is most commonly used value for describing droplet size distribution.===The relative span factor refers to uniformity of droplets when spraying. The lower RSF, Indicate to the best uniform of the droplet spectrum.

**Meteorological conditions**

Temperature, Relative Humidity, and Wind Speed at the time of the experiment were measured by using an anemometer model(MS 6252B) with an accuracy of ±2.0. The results aregiven in the following Table 2

**Table 2. Meteorological conditions during the spray test**

| Maximum Temperature ºC | Minimum Temperature ºC | Average Relative Humidity % | Average wind speed $m.sec^{-1}$ |
|---|---|---|---|
| 16 | 14 | 52.4 | 2 |

**Statistical analysis**

The results of the experiment study were statistically analyzed using ANOVA table based on the factors studied (operating pressure and nozzle height). The least significant difference L.S.D at a probability level of 0.05was calculated to show differences between the treatments (12).

**RESULTS AND DISCUSSION**

**Effect of operating pressure and nozzle height on mean of the droplet size :** Figure 1 shows the relationship between nozzle height and operating pressure on the meanof the droplet size deposited on the white paper cards. Astrong relationship between nozzle height and operating pressure onthe droplet meansize.When the operating pressure was fixed and increasingof the nozzle height from

50 to 90cm,the average of droplet diameter decreasedvisibly by percentage of 25.38%. This decrease may due to increase of the effect of the weather conditions on the droplet sizes result of increasing in the nozzle height, which lead to the evaporation some of droplets, especially small sizes ones, and their distribution and transfer to un intended target depending on droplet sizes.The result of this point isagreed with the results of the studiesAlheidary (1) andMiller et al.(7)which confirmed a decrease in the droplet size with an increase in the nozzle height at time of spraying. As the same figure shows when the nozzle height was fixed, increasing operating pressure from 1 to 2 bar showed clearly gradually decrease in the mean of the droplet size by more than 31.94%. This resultagreed with the results Alheidary (1), Miller et al. (7), and Nuyttens et al. (9) which showed that the decrease occurs in the average droplet size with increased in operating pressure during the spraying process. The results of the droplet size according to nozzle height and operating pressure are indicative of the difference in this measured quality and its impact on these two main factors during field spraying experiments. With a nozzle height of 50 cm and an operating pressure of 1 bar higher achieved maximum droplet size which reached of 176.8 µm, and with an increase ratio of 52.41% than meandroplet size of other operating pressures and nozzle heights. This is due to the increasein the discharge of the solution perunit time withconstant of nozzle size, which reflected negatively on the droplet sizes produced. While the treatment of 2 bar and nozzle height of 90 cm was gave the lowest mean in droplet size of 84.13 µm.

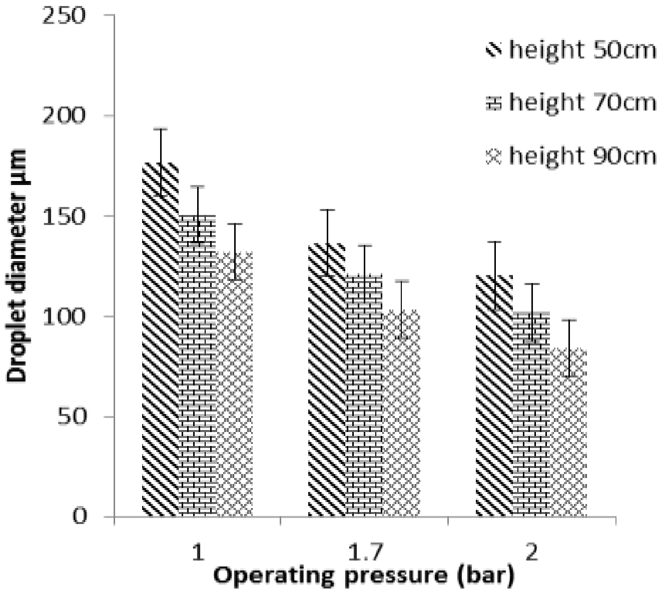


**Figure 1: effect of operating pressure and nozzle height on droplet mean size**

**Effect of operating pressure and nozzle height on mean of the droplet volume:** Figure 2 introduced the relationship between operating pressure and nozzle height on mean of the droplet volume, which was measured in field on white paper cards. The results showeda significant effect of both operating pressure and nozzleheight on droplet volume. Increasingof operating pressure from 1 to 2 bar at a constant nozzle height showed a visible reduction in the meanof the droplet volume by percentage of 165.33%. This decreasing in droplet volumemay be to decrease in mean of the dropletssize with increasing in operating pressure. This result agreed with the studiesAlheidary (1) andNuyttens et al.(9).On the other hand, increase of the nozzle height from 50 to 90 cm, at a constant operating pressure led to decrease in mean droplet volume by percentage of 155.86%. This decrease may due to a decrease in mean droplet size. This result agreed with the studies Taylor et al.(15)and Yashiro and Kakehata (19). The highest mean droplet volumefor the treatment of 50 cm of nozzle height and operating pressure of 1 bar was 3144561 $\mu m^3$. While the lowest mean droplet volume was recorded of 311624.1 $\mu m^3$at 90 cm of nozzle height and 2 bar of operating pressure.

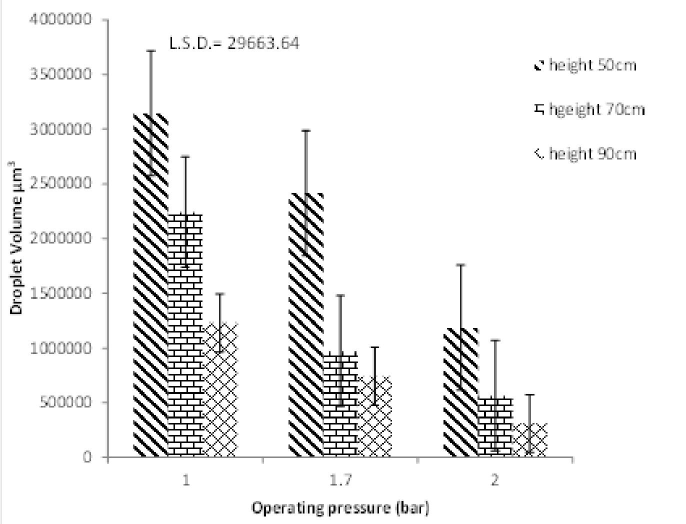


**Figure 2. Effect of operating pressure and nozzle height on mean droplet volume**

**Effect of operating pressure and nozzle height on mean of the droplets number per cm$^{2}$:** Figure 3 showsa significanteffect of the operating pressure and nozzleheight on mean of the droplets number per cm$^2$. Aconstant nozzle height and increasingof the operating pressure from 1 to 2 bar, the resultsillustrated a significant increase in the droplets number reaching the target site between percentage of 27.09% and 35.34%. The reason of the increasing in droplet number may due to a decrease in the mean of the droplet sizes. This decreaseled to an increase in the droplets number reaching the target per unit area that related to an increase in operating pressure. This result agreed with the results of the studiesRachadi (13) and Washington(18) which confirmed that an increase in the number of droplets per unit area due to decrease in droplet sizes. Anincreasein nozzle height from 50 to 90 cm with aconstantof the operating pressure resulted in a significant effect of theincreasein the droplets number deposited cm$^{-2}$. The percentage of increasing ranged from58.45% to 65.81%. This increase in droplets number is to a decrease in droplet size as a result of an increasein the nozzle height.

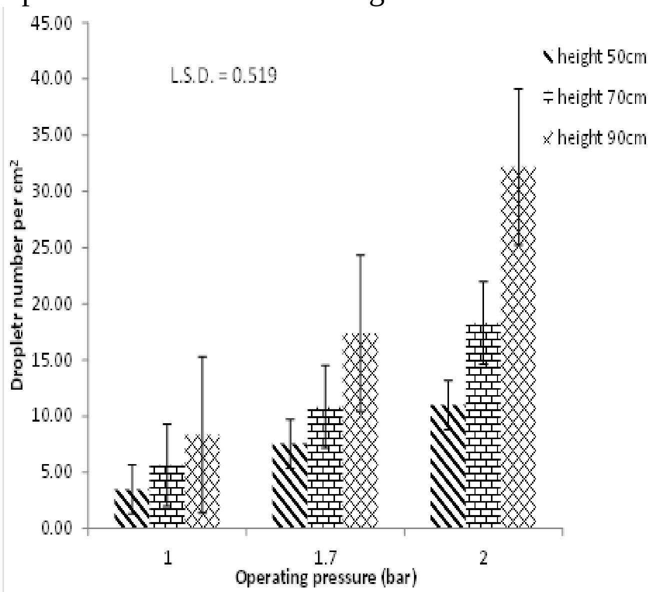


**Figure 3. Effect of operating pressure and nozzle height on droplets number**

**Effect of operating pressure and nozzle height on relative span factor:** The effect of both operating pressure and nozzle height on calculatedrelative span factor that was based on the field experimental data that was explainedin the equation 5as shown in Fig. 4. Relative span factor is significantly affected by the increase in either or both of the operating pressure and nozzle height during spraying process. An increase in operating pressure from 1 to 2 bar ata constant nozzle height led to an increase in RSF of 26.24%. Also,an increase in the nozzle height from 50 to 90 cm at a constant operating pressure led to a clear increase in RSFfrom 18.44% to 40.19%.

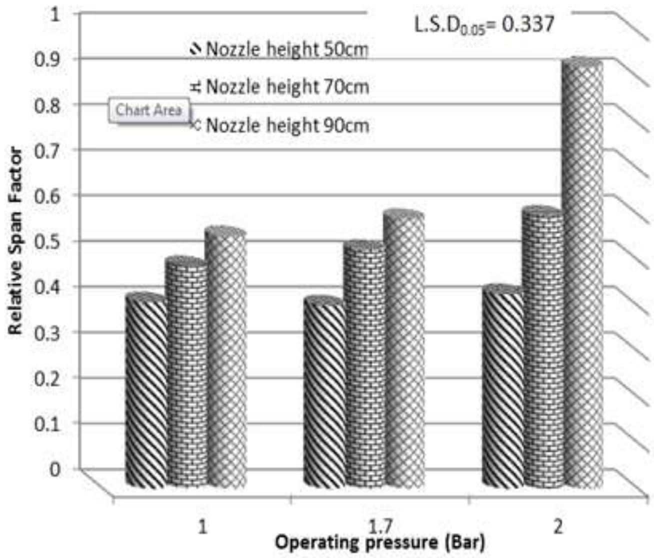


**Figure 4. Effect of operating pressure and nozzle height on relative span factor**

Based on field experiments, the results of this work showeda significant effect of the operating pressure and nozzle heighton droplet properties as droplet size, droplet volume, droplet numbers, and relative span factorat time of spray applications. Increasingofthe operating pressure and nozzle height resulted in a decrease in of the droplet meandiameter,droplet volume.On the contrary, increase in the droplets number per unit area and an increase in relative span factor with increase of the nozzle pressure and height. The results also showed that the best configuration of the nozzle height and the optimum operating pressure in terms of droplet size,droplet volume and number of droplets per unit area was 50 cm and 2 bar, respectively.As well as, this study illustrated that the increasing of nozzle height was more influence on spray properties than the increase of operating pressure.

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