INFLUENCE OF NOZZLE TYPE, WORKING PRESSURE, AND THEIR INTERACTION ON DROPLETS QUALITY USING KNAPSACK SPRAYER

M. H. R. Alheidary

Lecturer

Agri. Mach. and Equip. Dept., Coll. Of Agric., University of Basrah, Basrah, Iraq

alheidary.majid@gmail.com

ABSTRACT

The present experiment was carried out at the Dept. of Agricultural Machines and Equipment, College of Agriculture, University of Basrah. The aim of the study is to highlight the effect of the nozzle type, working pressure and their interaction onto droplet quality using knapsack sprayer to improve their performance. Droplet characteristics were sampled on white paper cards at different distances from the nozzle. On the samples spray deposits, spray coverage, droplet size, and volume median diameter was measured using BSF tracer with water after their deposit on the sample. The main studied parameters were: Six nozzle types hollow cone, Flat fan ceramic, flat fan ISO, CFA, AirMix and flat fan air induction nozzle. Two working pressures were 15 and 25 psi. All measurements carried out at the same nozzle height of 50cm by using CRD with three replications. The main results of this study showed the best spray deposition and spray coverage with the highest values 0.06nµl.cm^{-2} and 63% respectively when hollow cone nozzle was compared to other nozzles under the same operating conditions. Whereas, the Flat fan air induction nozzle appeared the most significant droplet size and VMD 377.69 µm and 378 µm respectively when it was compared to the hollow cone and flat fan nozzles.

Keywords: coverage, pressure, deposition, droplet size, VMD, agriculture, parameters

تاثير نوع النافورة وضغط التشغيل والتداخل بينهما على جودة القطرات باستعمال المرشة الظهرية

ماجد حازم رشك الحيدري

مدرس

قسم المكائن والالات الزراعية – كلية الزراعة– جامعة البصرة – البصرة – العراق

المستخلص

أجريت الدراسة في قسم المكائن والآلات الزراعية، كلية الزراعة، جامعة البصرة. تهدف الدراسة لتسليط الضوء على تأثير كل من نوع النافورة وضغط التشغيل والتداخل بينهما على جودة القطرات باستخدام المرشة الظهرية لتحسين أدائها. تم اختبار خصائص القطرات على بطاقات ورقية بيضاء خاصة وعلى مسافات مختلفة من موقع النافورة. قيس ترسيب الرش وتغطية الرش وحجم القطيرات ومتوسط حجم القطرات على النماذج باستخدام الصبغة الملونة BSF بعد مزجها بالماء. المتغيرات الرئيسية التي تم دراستها هي: ستة أنواع من النافورات المخروطي المجوف ، المروحي المصنوع من السيراميك ،المروحي من نوع ISO، المروحية المدمجة بالهواء ، الهوائي الممزوج والمروحي المحقون بالهواء. استخدم نوعين من الضغوط التشغيلية 15 و 25باوند في البوصة المربعة. اجريت جميع القياسات في نفس ارتفاع النافورة 50 سم باستخدام تصميم القطاعات العشوائية الكاملة وبثلاثة مكررات. أظهرت النتائج من هذه الدراسة ان أفضل ترسيب للرش وتغطية الرش بقيم كبيرة 0.06ميكرولتر.سم$^{-2}$ و 63٪ على التوالي عند استخدام النافورة من نوع المخروطي المجوف مقارنة بالنافورات الأخرى تحت نفس الظروف التشغيلية. في حين، اعطت النافورة المروحية المحقونه بالهواء أكبر حجم قطرات ومتوسط حجم القطرة 377.69 ميكرون و 378 ميكرون على التوالي مقارنة مع النافورات المخروطية والمروحية.

الكلمات المفتاحية: نسبة التغطية، ضغط، ترسيب الرش، حجم القطرة، متوسط حجم القطرة، زراعة، متغيرات

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INTRODUCTION

Crop protection product (CPP) is a key of an important topic in the farm for pesticide application which plays a sensitive role in the pest management. Several types of nozzles are available in the aspect of agricultural spraying for pesticide application and each nozzle has a function and purpose to use. The primary function of nozzles is breaking the liquid under pressurized spray liquid into droplets with a wide range of droplet sizes. All nozzles used in agricultural spraying produce droplets with different sizes ranging from extremely fine to coarse size depending on operating conditions (ASABE)(4). Nozzle type related to droplet size plays a significant role in CPP for minimizing environmental contamination. Also, droplet size influences on spray deposition and spray coverage. A nozzle type that produces big droplets size is usually selected to control spray drift. Whereas, the type that mainly produces fine size is utilized to increase spray deposition and spray coverage percentage on the zone treated (11,16). Selection of the correct nozzle critical type and nozzle pressure is the most important issue to reach certainly the effective spray deposition and spray coverage thereby improving pest and weed control (6). Many types of nozzles are available with different feathers in their setting as spray pattern, spray coverage and droplet size. These nozzles are designed to use under various operating conditions (19). The best choice of nozzle type depends on the type of the application. The most common nozzle types used in agricultural spraying are flat fan nozzles and hollow cone nozzles. Several studies that performed on knapsack sprayer using Flat fan nozzle mounted on rode which proved the success of these nozzles in CPP (2, 3, 14, 20). These studies indicated their success in CPP depends on the effectiveness of it's under field conditions. Various types of flat fan nozzles are grouped in the flat fan as the flat fan standard and the flat fan air induction nozzles. Flat fan air induction nozzles may be offered in a single or twin jet spray. These nozzles are recently developed to produce a spray pattern that like a standard flat fan nozzle with much coarse droplet sizes to limit spray drift considerably (1, 7, 8, 18, 24). Knapsack sprayers use in Iraqi farms because they are inexpensive tools and available to apply various types of pesticide in small areas. So, they were selected in this study. In the field, nozzle performance is measured by different techniques as white papers cards (WPCs) has advantages including visualization, possibility to measure droplet characteristics after changing the colour paper to yellow due to tracer, calibration of the droplet density and spray impact (Fox et al., (10). White papers cards (WPCs) have been used by different researchers for measuring spray coverage and spray deposit (2, 3, 9, 12, 13, 21, 25). All previous studies in Iraqi farms used knapsack sprayer with a Flat Fan nozzle. There is never information about the possibility to use different types of nozzle on knapsack sprayer. So, the main objective of this present study to investigate the effect of the nozzle type mounted, working pressure and their interaction on droplet quality using knapsack sprayer.

MATERIALS AND METHODS

This study was performed using knapsack sprayer. The reasons that led to use this sprayer in this study was a practical, available in a local market, multi-purpose and useful for spraying a wide range of pesticides as herbicide, insecticide, fungicide, etc. as well as, it is easy to use.

Knapsack sprayer setup

Traditional knapsack sprayers existing in Iraqi markets cannot maintain the pressure; therefore, they lead to spray drift away or lower spray deposition and spray coverage percentage. In this study, the knapsack sprayer was modified as shown in Fig. 1a. It was used after adding a pressure gauge (Fig.1 b) and height-adjustable nozzle (Fig.1 c). A knapsack sprayer description is given in Table 1. Knapsack sprayer was carried on the backpack of the worker with a constant walking speed approximately of 0.73 m/s. Both of the actual distance (m) that measured in the field and average time (sec) represented to calculate the worker speed into the following formula:

$$Worker\ speed = \frac{Distance(m)}{Time\ (\text{sec})} \dots\dots (1)$$

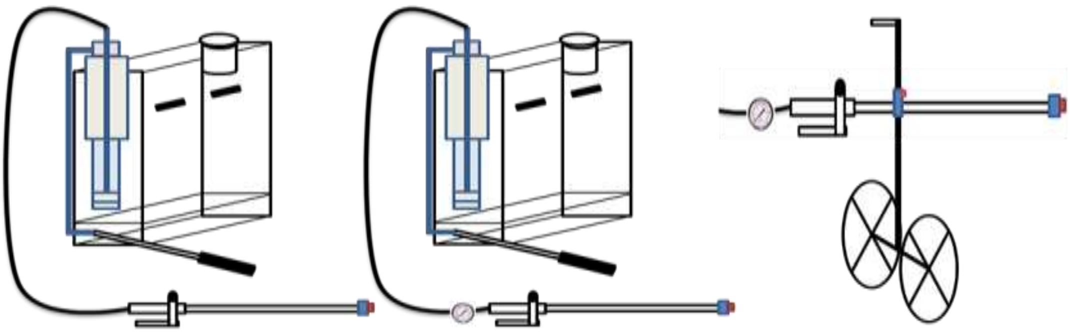

Figure 1. Overview of knapsack sprayer

Table 1. Knapsack sprayer description

Knapsack sprayer model	Total tank capacity (litter)	Number of a nozzle mounted	Power source	Piston pump	Colour
XF-16B	16	1	Manual	Internal	Blue

The experiments were carried out in both of the crop protection laboratory for measuring actual nozzle flowrate at two operating pressures for each nozzle, and in the field experiment for measuring droplet size, spray coverage percentage, and spray deposition.

Laboratory measurements

Different nozzle types were used in this study are show in Table 2.

Table 2. Nozzle characteristics used in the study

No.	Nozzle type	Manufacture	Nozzle colour	Nozzle code
1	Hollow cone	ALBUZ	Yellow	11002
2	Flat fan ISO	HARDI	Orange	11002
3	Flat Fan ceramic	TEEJET	Yellow	11002
4	Compact Fan Air (CFA)	ASJ spray-Jet	Green	11002
5	AirMix	Agrotop	Yellow	11002
6	Flat fan air induction (CVI) (single jet)	ALBUZ	Yellow	11002

All these nozzles were used at the same angle and size (110 02). Working pressures were selected based on minimum and maximum pressure (15-25) PSI which may be able to work with knapsack sprayer.

Nozzle flowrate measurement

The nozzles flowrate was measured in laboratory conditions by using two working pressures (15 psi and 25 psi). In this case, all nozzle discharges ($l.min^{-1}$) were collected in a cylinder tube using stopwatch; then they were returned to the tank after each measurement. After that, nozzle application rate ($l.ha^{-1}$) was measured according to the nozzle flowrate ($l.min^{-1}$). The replications were made three times for each nozzle type and working pressure combination then the average was calculated separately. Actual flowrate for each nozzle and working pressure combination are listed in Table 3.

Table 3. Average nozzle flowrate for each working pressure combination

No.	Nozzle type	Working pressure (psi)	Nozzle flowrate (L/min)	Nozzle application rate (L/ha)
1	Hollow cone	15	0.46	91.99
		25	0.59	117.99
2	Flat fan orange	15	0.49	97.99
		25	0.63	125.98
3	Flat Fan ceramic	15	0.47	93.99
		25	0.52	103.98
4	CFA	15	0.37	73.99
		25	0.61	121.99
5	AirMix	15	0.41	81.99
		25	0.51	101.99
6	Flat fan air induction (CVI) (single jet)	15	0.44	87.99
		25	0.54	107.98

Field measurements

The field experiment was carried out in October 10, 2017 at Agriculture College in a place without plants at a location 30.561204N, 47.745806E.

Nozzle height

Nozzle-adjustable height was fixed at 50 cm above the WPCs

Tracer concentration

BSF tracer (Brilliant Solpho Flavine) was added to the tank at a concentration of 1 $g.l^{-1}$. The tracer concentration on the WPCs was quantified using DepositScan software®.

Droplet size measurement

Droplet size was measured in this present study using the white paper card (WPCs) in DepositScan ® technique. All droplet sizes deposited on WPCs were taken into account. The average of each test was separately calculated after WPCs scanning with scanner HP 600 dpi. The three replications of WPCs were collected and saved in prelabeled-sealable bag until their analysis completion.

Determination of Spray distribution

Measurements of spray distribution as droplet size, spray deposition and spray coverage were carried out using WPCs. The nozzle was positioned in a frontal position (perpendicular to wind direction). The direct spray of each nozzle was positioned on the WPCs. WPCs were placed at different locations as shown in Fig. 2.

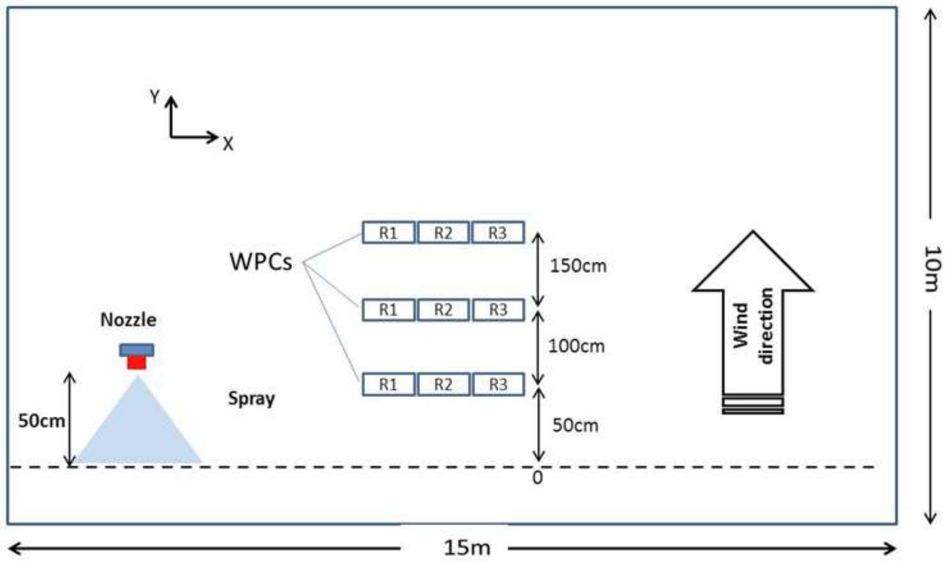

Figure 2. WPCs locations at time of spraying

Metrological conditions

As shown in Table 4 the average of wind speed, air temperature, and relative humidity during field experiments were recorded using Digital anemometer model MS 6252B with an accuracy ± 0.02.

Table 4. Data of metrological conditions measured in this study

Air temperature ºC	Relative Humidity %	Wind Speed $m.s^{-1}$	Wind direction
16.1	52.46	2.1	North

Statistical analysis

Based on the results from this study, analysis statistical was performed using Microsoft Excel software®. ANOVA table was calculated, and the test of $L.S.D_{0.05}$ was used to compare the differences between nozzle types and working pressure.

RESULTS AND DISCUSSION

Effect of nozzle type, working pressure and their interaction on droplet quality

The variable of the spray droplet sizes was evaluated as $Dv_{0.1}$, $Dv_{0.9}$, and $Dv_{0.5}$. The $Dv_{0.1}$ is the droplet diameter consists of 10% of the volume of spray. This diameter represents droplets size smaller than the value (10%), and that may lead to a significant portion of the drift amount. $Dv_{0.9}$ represents the droplet diameter of 90% of the volume of spray and it is smaller than the value. A significant number of $Dv_{0.9}$ indicates bad spray coverage and spray deposition. Another spray parameter is volume median diameter VMD, and it is often indicated by $Dv_{0.5}$. This $Dv_{0.5}$ represents the droplet diameter of 50% of the volume of spray liquid and made up of droplets size smaller than 50%. The results of this study as show in Fig. 3, 4, and 5 statistically indicated variable droplet sizes are significantly influenced by nozzle types, working pressures and their interaction. Higher $Dv_{0.1}$ value 255µm was observed at a combination of Hollow cone nozzle and working pressure of 25psi. The results related to $Dv_{0.9}$ revealed significant differences between nozzle type, working pressure, and their interaction. Higher $Dv_{0.9}$ (426µm) was recorded at the interaction of flat fan air induction nozzle and working pressure of 25psi. The most common parameter that uses to evaluate the droplet size is volume median diameter ($Dv_{0.5}$ or VMD). The results with this parameter showed significant differences between nozzle type and working pressure interaction. Higher $Dv_{0.5}$ (378µm) was observed with flat fan air induction (CVI nozzle) at 15psi compared to other nozzles at 25psi. The results also showed there were no significant differences between FF ceramic and FF ISO (orange nozzle) in droplet size. A conclusion of the previous works showed an effect of variability of working pressure in the $Dv_{0.5}$ at a constant nozzle type (Alheidary, (2); Alheidary, (3). The results of this point are agreed with the results of (15, 17, 18, 23) which confirmed effect of the droplet sizes by changing in working pressure. All tests investigated decrease of the droplet size with target distance download increase. When working pressure was a constant, the air induction nozzle had most significant influence on droplet size compared to Hollow cone and flat fan nozzles. The flat fan air induction nozzle, the higher droplet size was recorded at the time of experiment with 15 psi. For the nozzle Flat fan ceramic and flat fan orange nozzles, there were no significant differences in droplet sizes. Also, the results of $Dv_{0.1}$, $Dv_{0.5}$, and $Dv_{0.9}$ showed no significant differences in droplet sizes between AirMix and CFA nozzles. The result of this point is agreed with Douzals and Alheidary, 2014(8) which approved effect of nozzle type on droplet size.

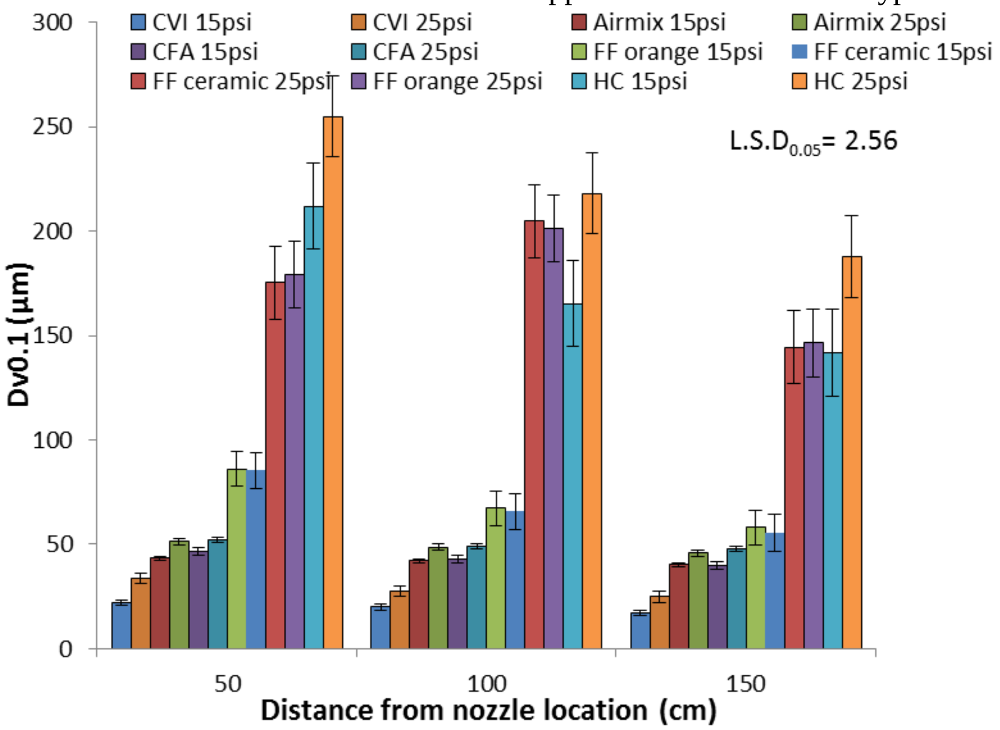

Figure 3. Effect of nozzle type and working pressure on $Dv_{0.1}$

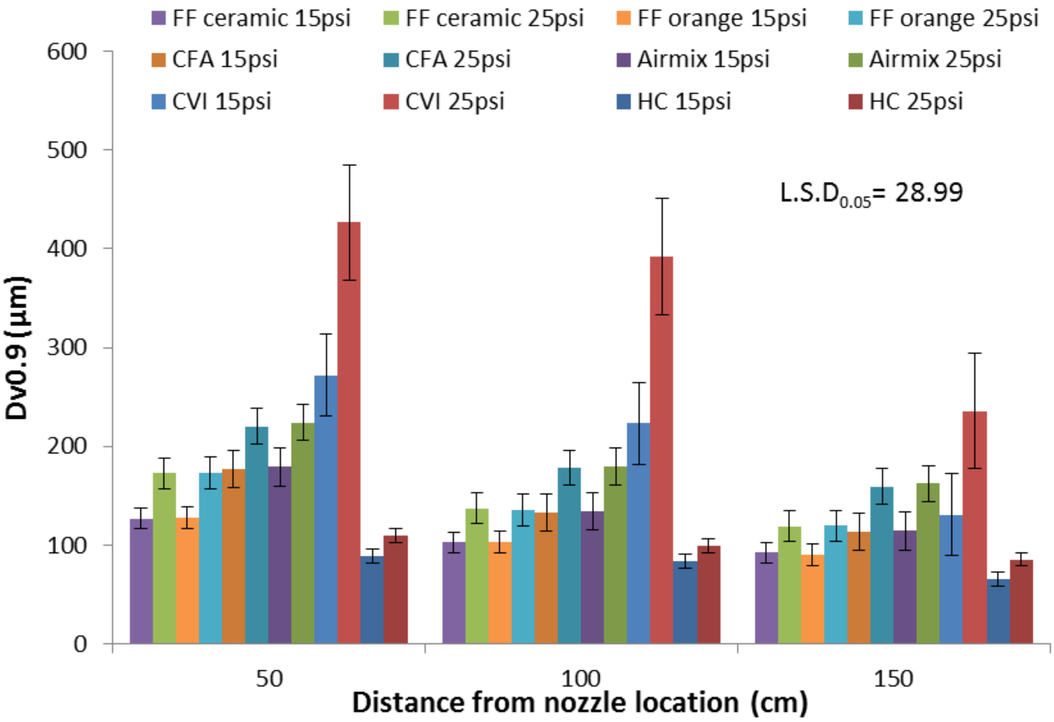

Figure 4. Effect of nozzle type and working pressure on $Dv_{0.9}$

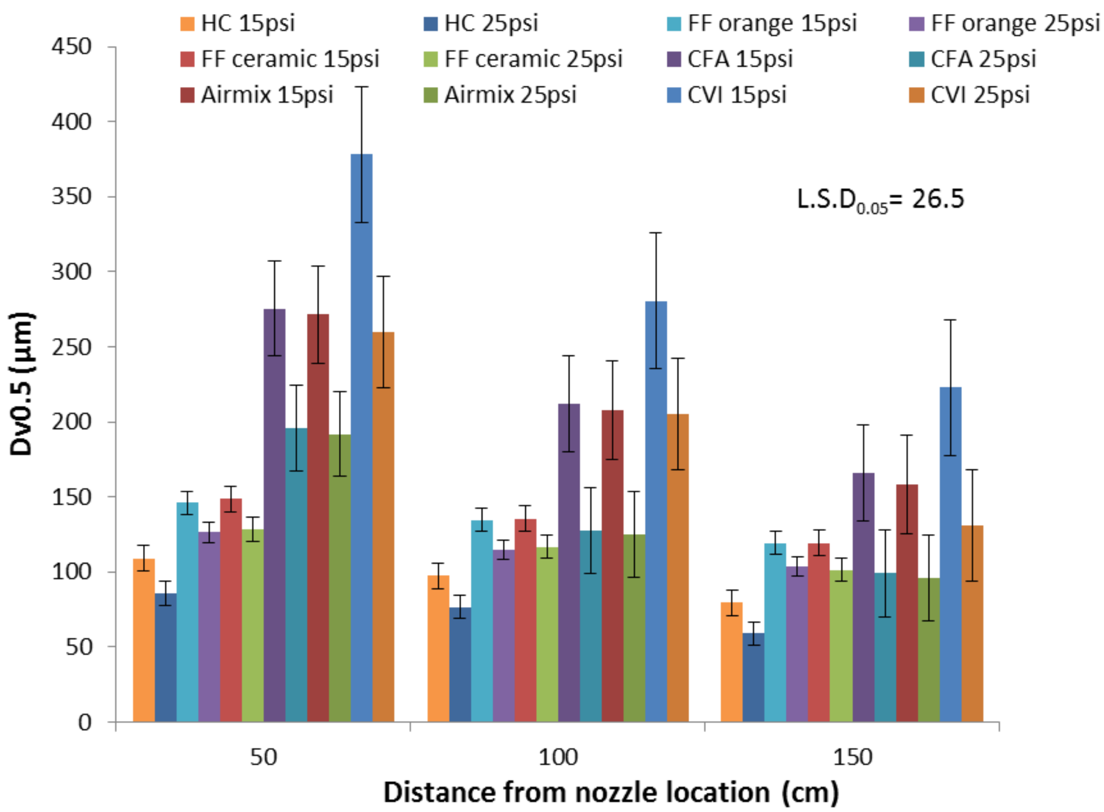

Figure 5. Effect of nozzle type and working pressure on volume median diameter $Dv_{0.5}$

Flat fan air induction nozzle (CVI nozzle) produced droplet size less than 31% with a diameter less than 130 µm. So, the big droplet sizes and VMD merged from CVI nozzle. While the small droplet size and VMD values were observed with Hollow cone nozzle. Fine droplets sizes (lower than 59 µm in diameter size) deposited on the WPCs appeared with Hollow cone nozzle at 25psi. When the nozzle type and working pressure are variables, fine droplets size increase with increasing of the working pressure for all nozzle types. Noticeability, the fine droplet size percentage (71.32%) was observed with Hollow cone nozzle at 25psi compared to fine droplet size percentage (3.17%) with air induction nozzles. The result of this point is agreed with (3).

Spray coverage percentage

According to the results of spray coverage percentage as shown in Fig. 6, the nozzle type, working pressure, and their interaction significantly affected spray coverage percentage at different distances from the nozzle location. When working pressure was constant, there was a good relationship between nozzle types and spray coverage percentage. High spray coverage percentage (63.33%) was obtained with Hollow cone nozzle at working pressure of 25psi. The results also indicated no significant differences in spray coverage percentage among CFA, AirMix, and Flat fan air induction nozzles. Similarity, there were no significant differences between Flat Fan ceramic and Flat fan orange nozzle. This result agreed with resulted of Salyani et al.,2013 (21) On the other hand, when the working pressure was variable, it had an effect on spray coverage percentage for all nozzles tested. Increasing of working pressure led to a significant increase in the spray coverage percentage for all nozzle types. Noticeability, the high working pressure of 25psi produced the highest spray coverage percentage using Hollow cone nozzle compared to other nozzle types tested in this study. The result of this point is agreed with (2, 3) which mentioned effect of spray coverage at the time of the variable in working pressure. The effect of WPCs location on spray coverage percentage was also studied. Spray coverage percentage decreased with WPCs distance increasing for different nozzle types and working pressures interaction. High spray coverage percentage was observed at 50cm distance for all nozzle types and working pressures interaction.

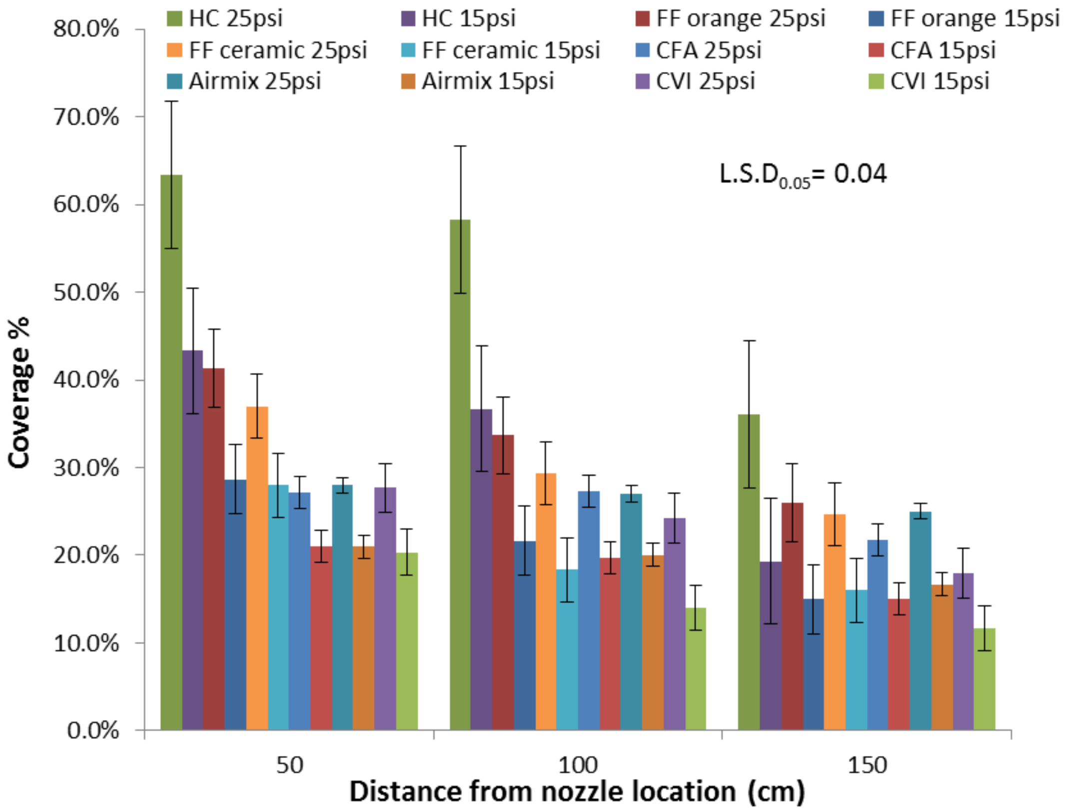

Figure 6. Effect of nozzle type and working pressure on spray coverage percentage at different distances

Spray deposition on WPCs

Based on the WPCs scanning, the results as shown in Fig. 7 revealed an effect of nozzle types, working pressures, and their interaction on the spray deposition. Increasing of working pressure from 15 psi to 25 psi led to increase spray deposition of 60.31%, 40.35%, 62.5%, 86.63%, 81.63%, and 41.73% for AirMix, CFA, CVI, FF ceramic, FF Orange, and Hollow cone nozzles respectively at 50cm distance from nozzle location. The results of this point are agreed with (15, 19). The spray deposition on the WPCs reduced by an average 2.15 times with increasing the distance from nozzle location for all nozzles tested. The results also indicated no significant differences in spray deposition between AirMix and CFA nozzles. Similarity, there were no significant differences between Flat Fan ceramic and Flat Fan orange nozzles on spray deposition. The highest spray deposition was observed with a hollow cone nozzle at 25psi compared to other nozzle types and working pressures. This results of this point are agreed with (21, 22)

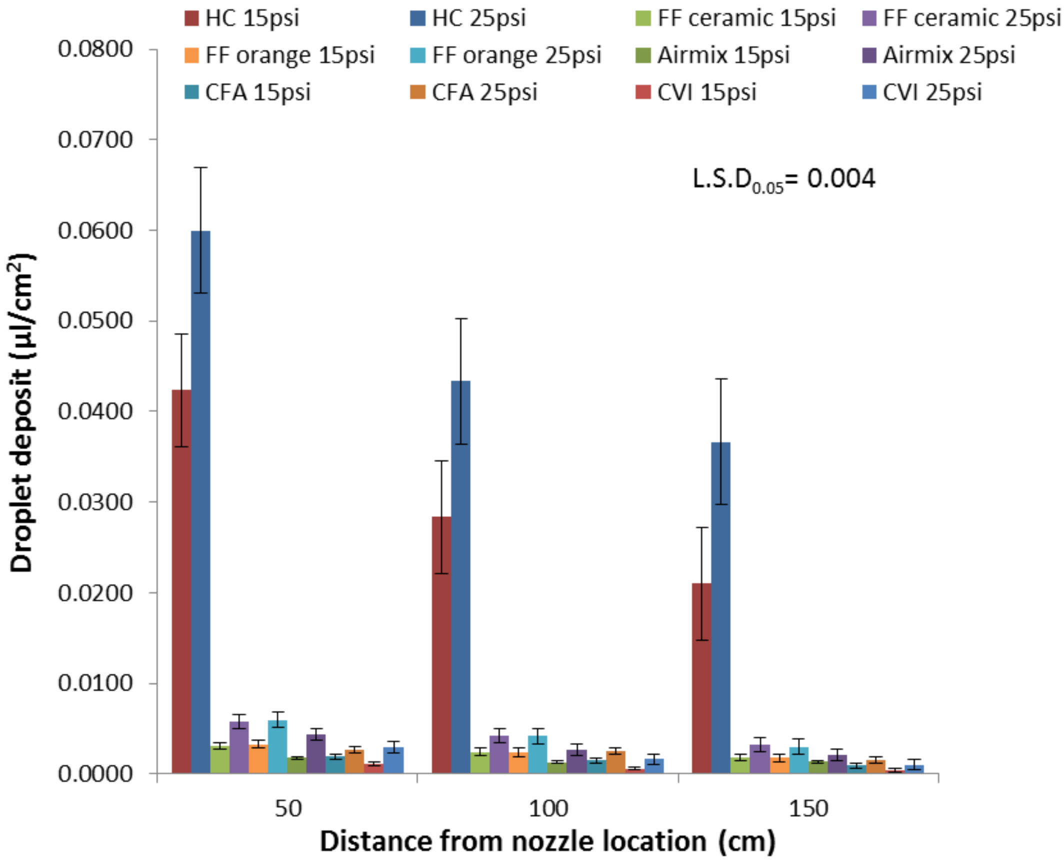

Figure 7. Deposition rate for different nozzle types and working pressures at different distances

The main results of this study demonstrated a clear visible effect of the nozzle types, working pressures and their interactions on droplet characteristics. The conclusions of this study showed increasing of working pressure led to an increasing of the spray coverage percentage, spray deposition, and nozzle flowrate for all nozzles types. Also, increasing working pressure produced an increase in the number of small droplet diameter. Results illustrated there was a good correlation between droplet quality and the interaction of nozzle type and working pressure. The results demonstrated the quality of the Hollow cone nozzle was the best compared to other nozzles in respect to droplet size, spray coverage percentage, and spray deposition and Hollow cone nozzle had the best spray deposition and spray coverage percentage. As well as, results mentioned the selection a proper nozzle type and working pressure interaction are essential to obtain the best spray coverage and spray deposition on the target. So, the perspective work will focus on spray contamination (off-target) occurred by using Hollow cone nozzle in the field.

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