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AN APPARATUS FOR TESTING THE PERFORMANCE OF SPRAYERS UNDER EGYPTIAN CONDITIONS

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ABSTRACT

An apparatus for testing the sprayer performance has been designed and manufactured at AEnRI, Rice Mechanization Center (RMC), Meet El-Dyba, Kafr El-Sheikh Govrnorate. The apparatus was used to evaluate the distribution pattern knapsack sprayer through measuring characteristic operating parameters. The apparatus consists of main frame equiped with no:.zle carrier, adujsting. high bar, manometr, electric motor, belts drive and driven pullies, this combination has been accumulated so. as to receive the distribution surface (patternator) which is inclined with an angle of 45^{o} with the harizontal. Consequently the spray fluid collected plastic bottls representing the actual amount of spray fluids for each nozzle. This procedure indicated the spray patterns in terms of symmetry, maximum and minimum point. The apparatus also, automatically control and measure the spray pattern of the fluid at surface area of 1 m2 and also it can measure the movement speed of the fluid.

The rsults of study included the determination of coefficient of variation, percentage of minimum point, percentage of maximum point, coefficient of symmetry, coefficient of uniformity, distribution characteristics, time and arial deposit rate and deposit efficiency. The performance of the sprayer was tested under different variations of : spray height (200, 300, 400 and 500 mm), spray pressure (500, 1000, 1500 and kPa) and nozzle diameter (0.57, 1.0 and 1.5 mm).

A maximum value of deposit rate (3.516 L/min.) was obtained at orifice diameter of 1.5 mm, spray height of 200 mm and spray pressure of 2000 kPa, while having the orifice diameter of 1.0 mm, spray height of 200 mm and pray pressure of 2000 kPa gave the maximum value of deposit efficiency (97.85%).

The best uniformity of the distribution pattern obtained with orifice diameter 1.0 mm, spray height of 500 mm, nozzle space of 500 mm,and spray pressure of 2000 kPa and any skewing about that tends to deteriorate the spray pattern.

INTRODUCTION

Chemical herbicide application offers a quick and effective method in controlling weeds in rice fields. Its use results in increasing yield and, therefore, higher income to the growers. However, the increasing cost of herbicides coupled with the growing public concern to minimize the use of farm chemical calls for efficient application equipment than is currently being used. Also, the increasing concern of the general public about environmental pollution and food health and the rising cost of these pesticides necessitate on improvement of the application process. Proper application of liquid pesticides depends, to a large extent, upon the uniformity of application, droplet size and proper coverage of plant surface. These factors had always a prime importance during designing and developing any spray equipment.

Hall and Reichard (1978) reported that coverage optimum distribution of spray droplets is greater with small droplets than with large droplets. However, the drift potential tends to be greater and the deposition efficiency less with small droplets than with large droplets. Hunt (1982) indicated the factors affecting the eventual spray concentration per acre are pressure and discharge of pump, speed of forward travel, water-spray ratio in tank, height of boom, nozzle spacing and concentration of spray materials.

Azimi et al. (1985) showed that the shape of the pattern profile of an individual nozzle depends party on the type and capacity of the nozzle utilized which in turn is influenced by the pressure at the pressure at the nozzle, height of the nozzle from the spray surface and the angle at which the nozzle is oriented. They also indicated that spray distributions from flooding and cone type nozzle are not strongly influenced by pressure but, till angle and operating height have significant effects upon spray distribution from these nozzles.

Akesson et al. (1989) indicated that droplet size distribution was affected by air speed, nozzle orientation, nozzle type and by physical properties of the oil or spray mixtures tested. Awady and El-Sayed (1989) indicated that the spray distribution along the flow centerline is affected by many factors such as the initial velocity of the air, outlet shape of blower, distance from outlet and physical properties of spray material. They also added that the ratio between the distribution extent on the target end outlet area of the jet increased with the initial velocity of the air, meanwhile it decreased about the jet core as the outlet area increased.

Reichard *et al.* (1992) remembered the effects of several variables on drift distance of spray droplets. Variables were initial droplet size, velocity and height of discharge, wind velocity, turbulence intensity and relative humidity and velocity of the liquid. Ramon and Baerdemaeker (1995) indicated that sprayer performance is measured by the uniformity of spray deposit distribution, which can be affected by pressure variations in hydraulic equipment. Worn nozzle drift due to wind gusts, swath matching, and a varying forward speed of the tractor and, horizontal motions of nozzles relative to the tractor.

The objectives of the present study were to develop an apparatus for evaluating the distribution pattern of the sprayers, test its performance under field conditions and study the effect of some operating variables on the spray pattern of knapsack sprayer under Egyptian conditions.

MATERIALS AND METHODS

The present study was carried out at Rice Mechanization Center, Meet El-Deeba, Kafr El-Sheikh Governorate with the aim to manufacture an apparatus for evaluating the spray pattern and testing the performance of knapsack sprayer under Egyptians conditions.

The apparatus consists of a carrier unit, nozzles, magnetic clutch and elect circuit shown in Fig. 1. It was designed and constructed in the laboratory having the facility several specifications. The theory of this combinetion is to receive the spray fluid over the distribution surface (patternator) which incline with angle of 45o with the horizontal. Consequently the spray fluid collected in plastic bottles representing the actual amount of spray fluid for each nozzle. This procedure indicates the spray patterns in terms of summitry, maximum and minimun point. The apparatus also, can automatically control and measure the spray pattern of the flied at surface area of 1m2 and also it can measure the movement speed of the fluid.

General specifications

Overall dimensions	100 x 100 x 300 cm
Number of nozzles	4
Nozzles spacing	variable 15 to 70 cm
Size of nozzles	changeable 0.57 to 1.50 mm
Spray height	variable 10 to 100 cm
Spray pressure	adjustable 0 to 25 k Pa.
Discharge of nozzle	depending on size and ranging from 3 to 12 L/min.

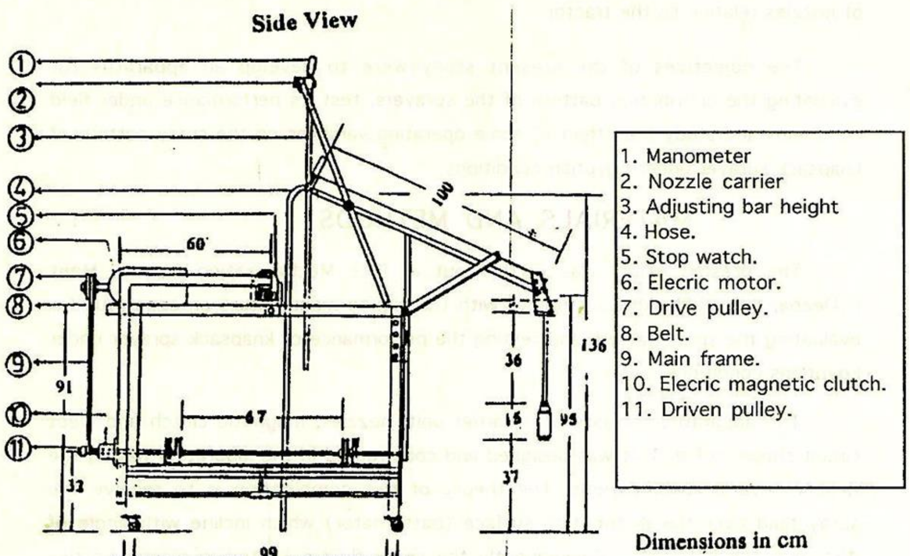

Fig. 1 Side view of the apparatus for testing the sprayers.

The tests have been operated under following conditions:

a. Spray height of 200, 300, 400, and 500 mm.

b. Nozzle space of 300, 400, 500 and 600 mm.

c- Spray pressure were 500, 1000, 1500 and 2000 kpa.

d- Orific diameter used were 0.57, 1.0 and 1.5 mm.

Spraying operations were carried out using tap water under room temperature (25oC) and under approximately a constant relative air humidity (60%). The laboratory calibration tests included determination of discharge rate, distribution pattern and spray deposition.

-Tests carried out on the spray pattern were

1. Coefficient of variation:

The coefficient of variation indicates the uniformity of spray distribution. It was calculated according to ASAE. Standards (1992) from the following equation:

$$C.V = \sqrt{\frac{\frac{(xi-\overline{x})^2}{n-1}}{x}} \times 100$$

Where :

C.V = Coefficient of variation, %.

xi = Amount of spray deposited in cylinder (i) in spray swath;

$\overline{x}$ = Mean of spray of distribution across the spray swath;

n = Number of collector location used.

2. Minimum and maximum points in the spray pattern

The minimum and maximum points in the spray pattern were determined as a percentage of the mean point in the spray pattern by using the following equations (Sayedahmed, 1989):

$$\text{Minimum point} = \frac{\text{Minimum point in spray pattern}}{\text{Mean point}} \times 100 \quad \_\_\_\_\_\_\_\_ (2)$$

$$\text{Maximum point} = \frac{\text{Maximum point in spray pattern}}{\text{Mean point}} \times 100 \quad \_\_\_\_\_\_\_\_ (3)$$

3. Coefficient of symmetry (Csy)

The Coefficient of symmetry of the distribution pattern was calculated according to the following equation (Syedahmed, 1989).

$$Csy = [1-(ZR-ZL) / ZT)] \qquad (4)$$

Where : ZR, ZL = Volume of spray collected from the right and left sides of the nozzle center center line respectively; L

Zt = Total volume of spray collected from bottles; L.

4. Uniformity coefficient of solution (CU):

The Coefficient of uniformity (CU) was determined by using the following equation (ASAE, 1992 and Dragos, 1975).

$$CU = (100-CV), \% \qquad (5)$$

5. Spray deposit efficiency (ηsp.) It was calculated from the following equation:

$$\eta sp. \% = (SPD/Q) \times 100 \qquad (6)$$

where :

SPD = Amount of spray deposits in cylinders in spray swath, L/m2.

Q = The applied amount of spray, L/m2.

Q was calculated by using the following equation:

$$Q = Cq/(bv) \qquad (7)$$

where :

q = Pump output discharge, L/min.;

= Number of nozzles x nozzle through put (L/min.).,

b = Swath width, m. and

V = Forward speed, km/h.

C = Converting constant (6x10-2)

6. Distribution characteristics (DC)

$$DC = \frac{\text{(Area receiving more than average depth)}}{\text{(Total wetted area)}} \times 100$$

RESULTS AND DISCUSSIONS

The performance of designed apparatus was tested through evaluating the spray pattern of the knapack sprayer. It has been evaluated in terms of the following parameters:

1. Coefficient of variation (C.V.):

The optimum uniformity of the distribution pattern was obtained at the minimum values of coefficient of variation. Figs. 2 and 3 indicate the effect of orifice diameter, spray pressure, spray height and nozzle spacing on the coefficient of variation in distribution pattern. It is clear that increasing both spray height, spray pressure and nozzle space tends to decrease coefficient of variation. The minimum value of (C.V.) the best uniformity of spray pattern was 13.25% with spray height of 500 mm, spray pressure of 2000 kPa and nozzle spacing of 500 mm. The results also showed that increasing or decreasing the orifice diameter than 10 mm tends to increase the coefficient of variation for all other parameters. Where the small and big droplets as a resulted from orifice diameters of 0.57 and 1.5 mm tends to give improper spray pattern.

2. Percentage of minimum point:

Minimum point in the distribution pattern is expressed as a percentage of the mean point. The best uniformity of distribution pattern was obtained at the maximum values of percentage of minimum point of the mean point in the spray pattern. Figs. 2 and 3 illustrate the effect of spray height and pressure, nozzle spacing and orifice diameter on value of mean point of the spray pattern. It can be noticed that the maximum point in the spray pattern (45.05) was obtained with spray height and nozzzle spacing of 500 mm and spray pressure of 2000 kPa.

According to the obtained results the maximum values of minimum point was obtained at 1.0 mm. This result corresponded to the results obtained previously.

Similar curves were obtained at d = 1.00, 1.50 mm orifice diameter also at S = 400, 500, 600 mm nozzle spacing.

3. Prcentage of maximum point

Similarly, the minimum point in the distribution pattern may be expressed as a percentage of the mean. The best uniformity of distribution pattern was obtained at the minimum values of percentage of maximum point of the mean in the spray pattern. Figs. 4 and 5 demonstrate the effect of spray height and pressure, nozzle spacing and orifice the effect of spray height and pressure, nozzle spacing and orifice diameter on percentage of maximum point of the mean. It is evident that, by increasing both the orifice diameter, nozzle space, spray height and pressure, percentage of maximum point of the mean tends to decrease.

The minimum value of percentage of maximum point of the mean was 86.85% which was obtained at spray height and nozzle spacing of 500 mm and spray pressure of 2000 kPa.

4. Coefficient of symmetry (Csy)

The spray pattern tends to be more uniform by increasing the coefficient of symmetry. Figs. 4 and 5 show that the spray height of 500 mm, spray pressure of 2000 kPa. Orifice diameter of 1.0 mm and nozzle spacing of 500 mm gave the maximum values of coefficient of symmetry (99.75%). The results also indicated that the coefficient of symmetry decreased by 2.65 and 1.91% as the orifice diameter decreased from 1.0 to 0.57 mm or increased from 1.0 to 1.5 mm, respectively.

Similar curves were obtained at d = 1.00, 1.50 mm orifice diameter also at S 400, 500, 600 mm nozzle spacing.

5. Coefficient of uniformity:

The best uniformity of the distribution pattern was obtained at the maximum values of coefficient of uniformity. The effect of spray height and pressure, nozzle spacing and orifice diameter was indicated in Figs. 6 and 7. It is apparent that the coefficient of uniformity decreased by increasing or decreasing the orifice diameter than 1.0 and nozzle space than 500 mm for all the other variables. The maximum value of coefficient of uniformity was 86.75%, which was obtained with spray height of 500 mm, spray pressure of 2000 kPa and nozzle spacing of 500 mm. The coefficient of uniformity increased by 10.97% when the spray pressure increased from 500 to 2000 kPa at spray height of 500 mm and orifice diameter of 0.57 mm.

6. Spray distribution characteristics (DC):

The best uniformity of the distribution pattern was obtained at the maximum values of solution distribution characteristics. Figs. 6 and 7 demonstrate the effect of spray height and pressure, nozzle spacing and orifice diameter on the distribution characteristics. It is clear that the increase of the spray height and pressure tends to increase the values of distribution characteristics for all orifice diameters and nozzle spacing. On the other hand, the orifice diameter of 1.0 mm and nozzle pacing of 500 mm gave the maximum values of distribution characteristics compared with the other levels. The maximum value of distribution characteristics was 98.90% which obtained at spray height and nozzle space of 500 mm and spray pressure of 2000 kPa.

7. Deposit rate:

Figs. 8 and 9 illustrate the effect of spray height and pressure, nozzle diameter and orifice diameter on the time deposit rate. It is concluded that the increase of both orifice diameter and pressure tends to increase the deposit rate for all the spray heights and nozzle spacing. The results also showed that, the deposite rate tends to increase by increasing or decreasing the nozzle spacing than 500 mm for all orifice diameters, spray heights and pressures. However, the orifice diameter of 1.5 mm, spray height of 200 and spray pressure of 2000 kPa gave the maximum value of deposit rate which was 3.516 L/min.

8. Deposit eefficiency:

Figs. 8 indicates the effect of spray height and pressure, nozzle space and orifice diameter on the deposit efficiency. It is clear that the orifice diameter of 1.0 mm gave the maximum values of deposit efficiency compared with the other diameters for all nozzle spaces, spray height and pressures. According to the obtained results, it is apparent that the increase of spray height tends to decrease the deposit efficiency for all spray pressures, nozzle spaces and orifice diameters. On the other hand, the deposit efficiency tends to increase by increasing the spray pressure for all orifice diameters, spray heights and nozzle spaces. The maximum value of deposit efficiency was 97.85%, which obtained at orifice diameter of 1.0 mm, spray height of 200 mm and spray pressure of 2000 KP_a.

Similar curves were obtained at s = 400, 500 and 600.

Generally, the distribution pattern of knapsack sprayer is indicated in Fig. 10. It is noticed that the increase of spray pressure tends to increase the pattern width and decrease the pattern peaks for all the other factors. It is also clear that the orifice diameter of 1.0 mm gave the maximum width of pattern and the minimum peaks compared with the other diameters of 0.57 and 1.5 mm for all the spray pressures and while the pattern peaks decreased when the spray height increased from 200 to 500 mm for all spray pressures and orifice diameters.

CONCLUSIONS

The following conclusions can be drawn as follow:

1- The manufactured apparatus proved high efficiency for testing and evaluating the spray pattern of sprayers.

2-The increase of spray height and pressure tends to decrease the coefficient of variation then, uniformity of spray pattern. The minimum value of coefficient of variation (13.25 %) was obtained with spray height and nozzle space of 500 mm and spray pressure of 2000 kPa.

3-The maximum value of minimum point of 45.05% and the minimum value of maximum point of 86.85% were obtained at spray height of 500 mm, nozzle space of 500 mm and spray pressure of 2000 kPa.

4- By increasing both the spray height and pressure the distribution characteristics, coefficient of symmetry and uniformity tends to increase for all the other parameters. On the other hand, increasing or decreasing the orifice diameter than 1.0 mm and nozzle space than 500 mm tends to decrease the obtained values of distribution characteristics, coefficient of symmetry and uniformity.

5- The maximum values of coefficient of symmetry, coefficient of uniformity and distribution characteristics were 99.75, 86.85 and 98.90%, respectively, at spray height of 500 mm, nozzle space of 500 mm and spray pressure of 2000 kPa.

6- The deposit rate tends to increase by increasing both orifice diameter and spray pressure but, it decreases by increasing the spray height., However, the diameter of 1.5 mm, spray height of 200 mm and spray pressure of 2000 kPa gave the maximum value of time deposit rate which was 3.51% l/min.

7- By increasing the spray pressure or decreasing the spray height, the deposit efficiency tends to increase but the orifice diameter of 1.0 mm and nozzle space of 500 mm gave the maximum values of deposit efficiency compared with the other levels of diameters and spaces. The maximum value of deposit efficiency was 97.85% which was given with orifice diameter of 1.0 mm, spray height of 200 mm and spray pressure of 2000 kpa.

8- The increase of spray pressure and height tends to increase the swath width and decrease the pattern peaks but, the orifice diameter of 1.0 mm gave the maximum width of the pattern and the minimum peaks compared with the diameters of 0.57 and 1.5 mm.

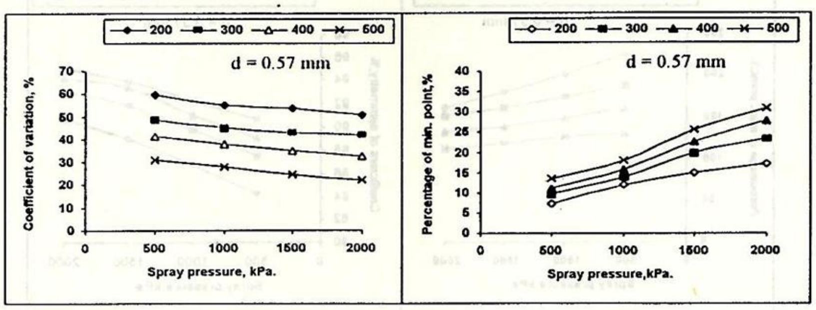

Fig. 2. A typical effect of spray height (H) spray pressure (P) and orifice diameter (d) on the Coefficient variation,% and percentage of min. point,% in distribution pattern. Similar curves were obtained at=1.0, 1.5 mm diameter.

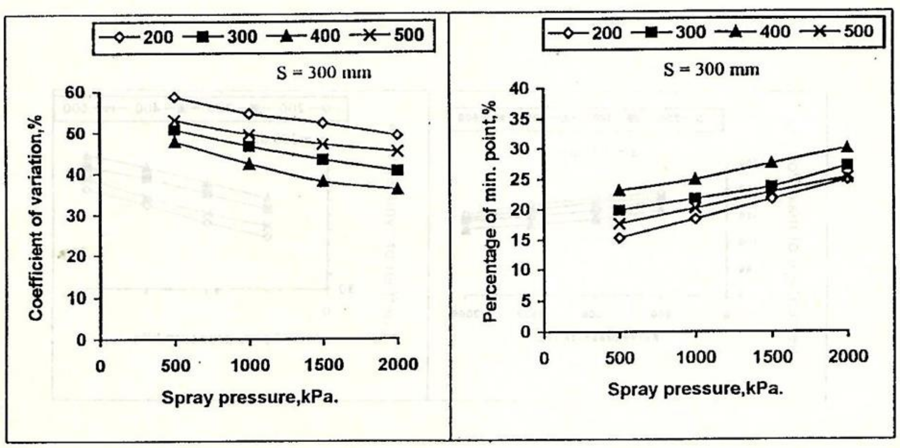

Fig. 3. A typical effect of spray height (H) spray pressure (P) and nozzle spacing (S) on the Coefficient variation,% and percentage of min. point,% in distribution pattern.

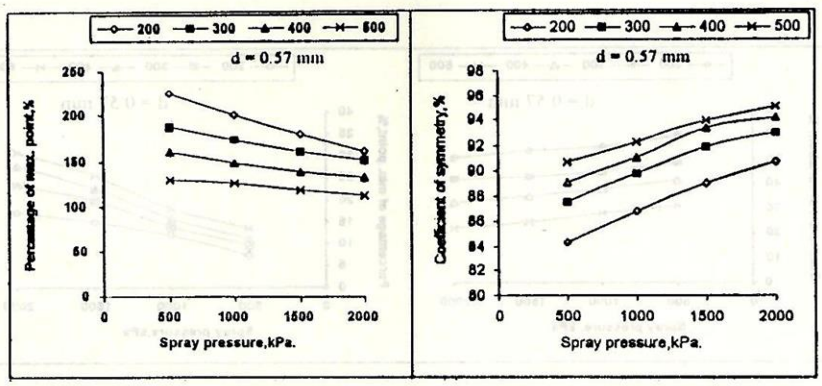

Fig. 4. A typical effect of spray height (H) spray pressure (P) and orifice diameter (d) on the percentage of max point, % and coellicient of symmetry, % in distribution pattern.

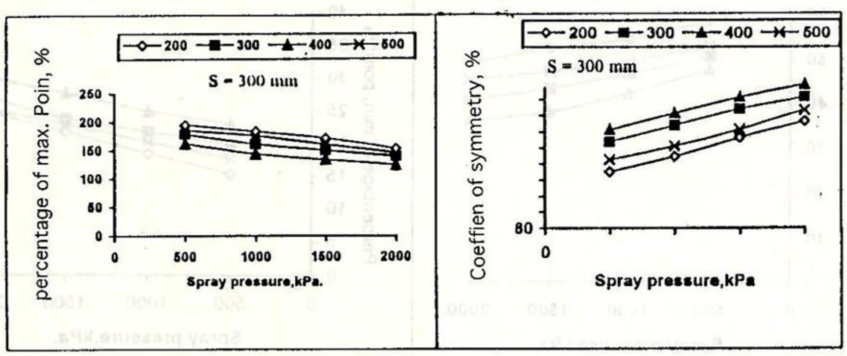

Fig. 5. A typical effect of spray height (H) spray pressure (P) and nozzle spacing (S) on the of percentage of max. point, %and coefficient of symmetry, % in distribution pattern.

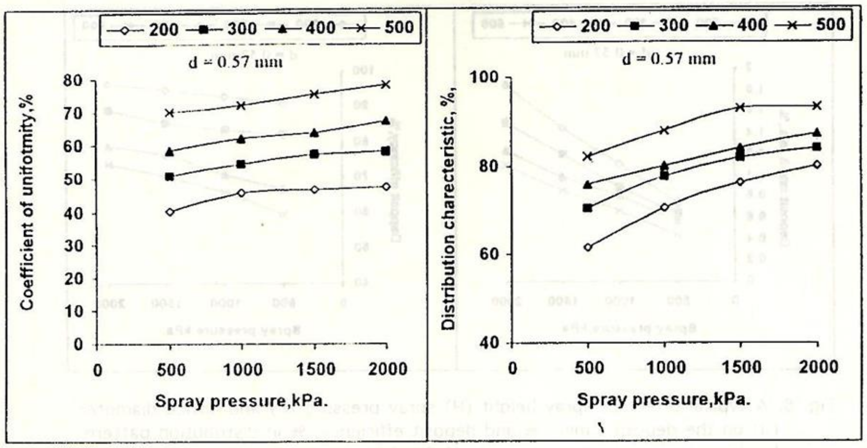

Fig. 6. A typical effect of spray height (H) spray pressure (P) and orifice diameter (d) on the coefficient of uniformity, % and distribution characteristic, % in distribution pattern.

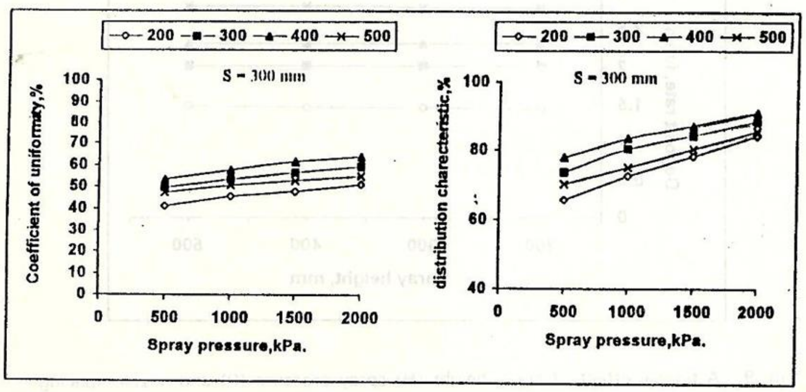

Fig. 7: A typical effect of spray height (H) spray pressure (P) and nozzle spacing (S) on the coefficient of uniformity, % and distribution characteristic, % in distribution pattern.

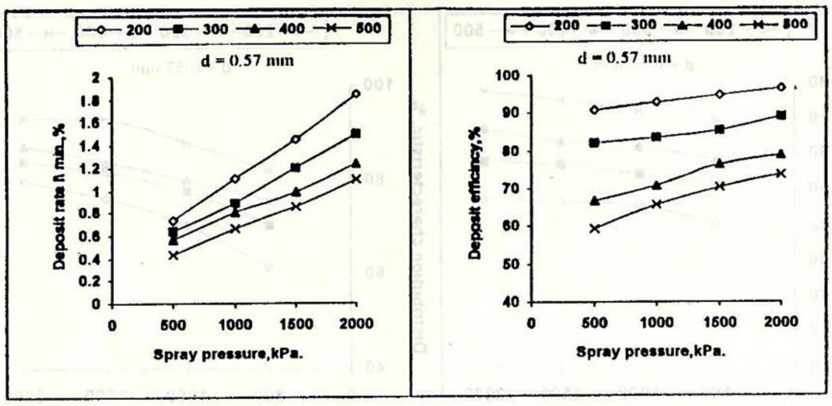

Fig. 8. A typical effect of spray height (H) spray pressure (P) and orifice diameter (d) on the deposit l/min., % and deposit efficiency, % in distribution pattern. Similar curves were obtained at d = 1.00, 1.5 mm diameter.

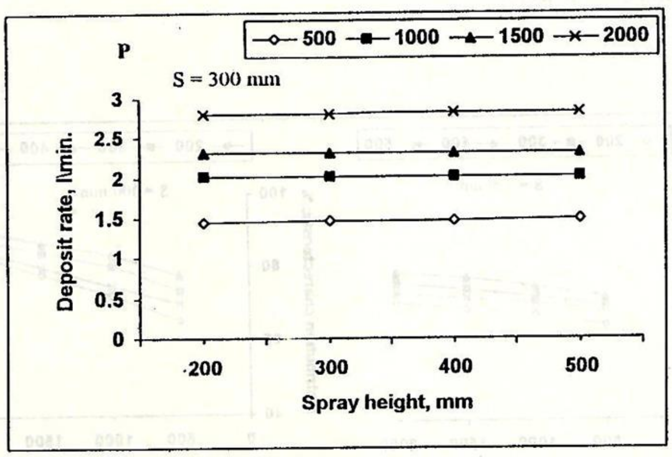

Fig. 9. A typical effect of spray height (H) spray pressure (P) and nozzle spacing (S) on the Deposit rate, l/min. in distribution patten.

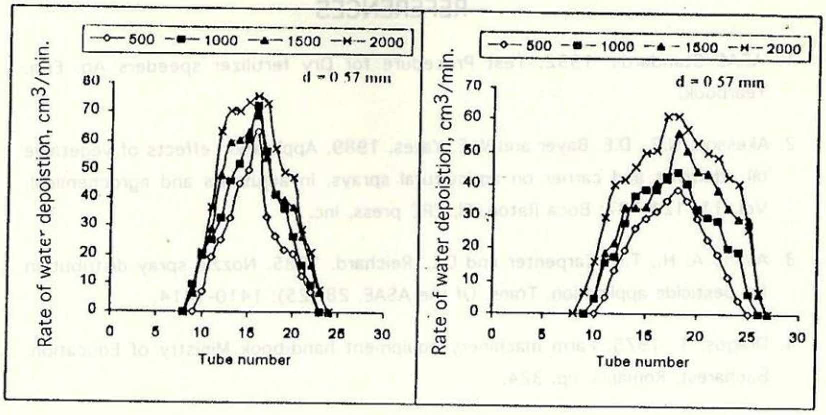

Fig. 10. Distribution pattern of flat nozzle for different pressure (P), spray height (H), at orifice diameter (d) 0.57 mm.

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جهاز لتقييم أداء الرشاشات تحت الظروف المصرية

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٣ باحث ومدير مركز ميكنة الأرز بمت الديبة -كفر الشيخ.
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تعتبر عملية الرش من العمليات الزراعية الهامة في مراحل إنتاج المحاصيل الحقلية المختلفة، لما لها من تأثير مباشر علي إنتاحية المحصول فضلا علي تأثيرها السلبي في تلوث البيئة وصحة الإنسان والحيوان إذا ما وزعت المبيدات بطريقة غير منتظمة.

ومن هنا فقد تمت محاولة للمساهمة في التغلب علي المشكلة المشار إليها بإجراء هذا البحث بغرض تصميم جهاز لاختبار أداء الرشاشات تحت الظروف المصرية للوصول لانسب انتظام لتوزيع (شكل) الرش ولتحقيق هذا الغرض فقد استخدمت آلة رش ظهرية (Knapsack sprayer) تم تقييمها باستخدام الجهاز الذي تم تصميمة خصيصا لذلك وتتلخص نظرية عمل الجهاز في استقبال سائل الرش علي سطح التوزيع والذي يميل بزواية ٤٥ درجة على الافقى لتجميع سائل الرش فى أوعية بلاستيكية . بحيث يستقبل كل وعاء السائل الساقط خلال خلال مجرى (٥X٥سم) وقد تمت الدراسةعند مستويات مختلفة من ارتفاع الرش وقطر البشبورى والمسافة بين البشابير وضغوط تشغيل مختلفة مع بيان تاثيرها على شكل التوزيع. وكانت مؤشرات الدراسة هى معامل الاختلاف ، النقط الصغرى والكبرى عن المتوسط، معامل التماثل معامل الانتظام ، خصائص التوزيع، معدل الترسيب الزمنى وكفاءة الترسيب .

وكانت أهم النتائج المتحصل عليها هى:-

١ - أدت زيادة كل من أرتفاع وضغط الرش إلى نقص معامل الاختلاف ومن ثم انتظام شكل الرش بينما أعطى قطر البشبورى ١ مم والمسافة بين البشابير والتى قدرها ٥٠٠ مم احسن انتظام لشكل التوزيع مقارنة بالاقطار والمسافات الاخرى

٢ - بلغت أقصي قيمة لاقل نقطة عن المتوسط ٤٥,٠٥ ٪ واقل قيمة لاعلى نقطة عن المتوسط ٨٦,٨٥ ٪ وذلك عند استخدام ضغط تشغيل ٢٠٠ كيلو بسكال على مسافة ٥٠٠ مم بين البشابير وارتفاع قدرة ٥٠٠ مم لحامل البشابير، بينما أعطى قطر البشبورى ١ مم احسن انتظام فى شكل الرش ومقارنة بالاقطار ٠,٥٧ ، ١,٥ مم.

٣ - أدت زيادة كل من ضغط وارتفاع الرش الى زيادة قيم كل من خصائص التوزيع ومعامل التماثل ومعامل الانتظام فى شكل الرش وكانت أعلى قيمة هى ٩٩,٧٥ ، ٨٦,٧٥ ، ٩٨,٩٠ ٪ على الترتيب

٤ - أدت زيادة كل من قطر البشبورى وضغط الرش الى زيادة معدل الترسيب الزمنى، بينما قل بزيادة ارتفاع الرش. وأعطى قطر البشبورى ١,٥ مم وارتفاع الرش ٢٠٠ مم وضغط تشغيل ٢٠٠٠ كيلو بسكال أعلى قيمة بمعدل الترسيب الزمنى وهى ٣,٥١٦ لتر /دقيقة.

٥ - زياده ضغط اتشغيل ونقص ارتفاع الرش يؤديان إلى زياده كفاءة الترسيب كذلك أعطى قطر البشبورى ١ مم والمسافة بين البشابير ٥٠٠ مم على قيم لكفاءة الترسيب وهى ٩٧,٨٥ ٪

٦ - أدت زيادة كل من ضغط وارتفاع الرش الى زياده عرض الرش ونقص قمم شكل التوزيع. وقطر البشبورى ١ مم أعطى نفس النتيجة .

٧ - أحسن انتظام فى شكل التوزيع تم الحصول علية مع قطر البشبورى ١ مم وارتفاع الرش ٥٠٠ مم ، والمسافه بين البشابير ٥٠٠ مم ، وضغط التشغيل ٢٠٠٠ كيلو بسكال واى انحراف عن هذه القيم يؤدى الى سوء شكل الرش.

٨ - اثبت الجهاز المصنع كفاءة عالية فى تقييم شكل الرش.