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Performance of a Field Crop Sprayer Nozzle Used in Bangladesh

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Abstract

This study was carried out during the period from July'97 to May'99 in the department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh. Naboti 910M was tested to evaluate its performances in the laboratory. The discharge increased significantly with the increase in pressure. The relationship between discharge and pressure was $y = 470.58x^{0.377}$. The angle of sprays increased significantly with the increase in pressure from 1 to 4 kg/cm^2 and then the spray angle changed with increasing pressure. They were statistically identical. The relationship between spray angle and pressure was $y = 88.17x^{0.130}$. Curves of spray distribution flattened with increasing nozzle height, pressure and wind speed. Spray liquid distribution uniformity increased significantly with the increasing of nozzle height, pressure and wind speed. The nozzle showed 64.99% distribution efficiency at an interaction effect of pressure 6 kg/cm^2, nozzle height 60 cm and wind speed 2 m/s. Deposition decreased with the increase nozzle height and wind speed. The distribution uniformity of spray increased with increasing pressure and nozzle height. The lowest uniformity was found at 15 cm height and the highest uniformity was found at 60 cm of nozzle height at constant pressure. Distribution uniformity increased with increasing nozzle inclination from o° until it reached at 60° and then distribution uniformity decreased rapidly. The lowest value of distribution uniformity was 15.727% and it was found at combined effect of pressure 1 kg/cm^2 and nozzle height 15 cm and nozzle inclination. The highest value of distribution uniformity was 52.087% and it was found at combined effect of pressure 6 kg/cm^2 and nozzle height 60 cm.

Key Words: Spray nozzle, Discharge, Distribution, Pressure, Spray angle, Nozzle height

1. Introduction

Pesticide application enhances crop production by controlling the pests. Bangladesh needs to provide her teeming millions of people with food and other necessities of life in limited land area. Total land area of Bangladesh is about 14.846 million ha and the total cropped area is 13.80 million ha (BBS, 2004). There is little scope to increase agricultural land through clearing and development but we must have to increase food grain because rapid expansion of population all over the country demands increased rate of production and attention to proper nutrition. A number of technical measures may be taken to ensure the adequate supply of food, fiber and sustainable agricultural production. Chemical control for crop protection have played an important role and it is still the only effective method of controlling most pests, weeds and diseases, despite intensive research into alternative methods. Pesticide is most powerful tool in pest management (Smith 1970). Experimentally, Cook and Jenkins, (1988); Cook and Thomas(1990) found about 10% yield increase attained when a two-spray programme was used. Crop losses caused by insect pests sometimes exceed 3.6 million tons/year and this is 25% of the total production (Hossain and Sarker, 1980). It is possible to increase paddy yield upto 31% by spraying pesticide only (Alam, 1985). A significant portion of affected crop area by insect pest remains untreated, it varied from 35.59% to 21.42% during 1991-92 to 1993-94 (BBS, 1997). So, the facilities for proper application of pesticides must be developed and must be reached to the door of farmers. A guideline for proper use, maintenance of sprayer and application methods of pesticide should be provided. Nozzle atomizes the spray liquid and has played a significant role in efficiency of sprayer for efficient control of insect pest. Sprays contain a large number of droplets (spray spectrum), i.e. very small spheres of liquid, mostly less than 10 μm in diameter. Droplet size is highly important if pesticides are to be applied efficiently with the minimum contamination of the environment. Nozzle height and nozzle orientation has a significant effect on efficiency of pesticide application. The influence on sediment and drift in the field comes from wind speed, boom height (distance to target area), drop size spectrum, evaporation, working width, height of equipment, forward speed, crop height and atmospheric stability (Kaul *et al.*1996). Increased nozzle height improves spray distribution at reduced pressure and/or increased spacing (Chung *et al.* 1995). The methods for testing agricultural spray nozzles cover nozzle flow rate, nozzle spray angle, liquid distribution, spray droplet size and nozzle wear rate

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(ASTM, 1996). Therefore, the present study was conducted on a sprayer nozzle used by the farmers: i) to study the calibration of air speed profile produced from blower and air carried sprayer; ii) to calibrate the nozzle discharge; iii) to study the nozzle spray angle, spray distribution pattern, spray distribution uniformity and losses of spray liquid under experimental conditions.

2. Materials and Methods

2.1 Instrumentation

A pressure cylinder was constructed to preserve spray liquid with high pressure. An Air compressor was connected with whose pipe to the pressure cylinder to develop pressure. A spray gun was constructed and was connected to the outlet port of pressure cylinder. The spray gun consisted with a sophisticated control valve and a pressure gauge. To study the effect of wind speed on distribution pattern, a blower was used to provide wind speed (Fig.1). A patternator was used on which the liquid was sprayed and collected the sprayed liquid at different channel of patternator and the quantity of liquid of each channel was recorded for further analyses. It had a wooden frame of 2.1 x 1.83 m. The frame was designed at 10° inclined plane. The main frame was covered with galvanized corrugated iron sheet. Two such sheets were placed side by side with 13 cm overlap. The total length and width of the iron sheet was as same as the wooden frame. The iron sheets consisted 28 corrugated channel at an interval of 7 cm.

2.2 Wind profile

A centrifugal axial flow electric blower with 7.62 cm diameter was used. The blower was seated on a stand of 75 cm height. 13 points were marked along the center line of blower at every 50 cm distance from the 0 to 6 m. After starting the blower the air speed was measured at every marked point along the vertical and lateral directions. The vertical height was selected at center-line, above center line and below center line. To record the wind speed a sophisticated digital anemometer was used (*Model: RS 180-7111*).

2.3 Nozzle selection

A nozzle commonly used at farm level named **Naboti 910M** was selected. This nozzle was swirl hollow cone type. It was made of brass. It consisted of two parts, the body and the cap. The swirl grooves were on the body. The orifice diameter, width of swirl grooves and diameter of swirl chamber were 1.588 mm, 0.981 mm and 8.42 mm, respectively. There were three swirl grooves. Four nozzles of the same type were employed in the experiment.

2.4 Discharge calibration

Pressure was taken as a factor for this test as P_1=1 kg/cm^2, P_2=2 kg/cm^2, P_3= 3 kg/cm^2, P_4=4 kg/cm^2, P_5=5 kg/cm^2, P_6=6 kg/cm^2, P_7=7 kg/cm^2 and P_8= 8 kg/cm^2 with five replication. All four selected nozzles were calibrated. Discharges were recorded against pressure ranges from 1 kg/cm^2 to 8 kg/cm^2. The discharges were plotted against pressure and a regression model was fitted for every nozzle. The data were analyzed with one-way ANOVA model and LSD test was done among the mean difference.

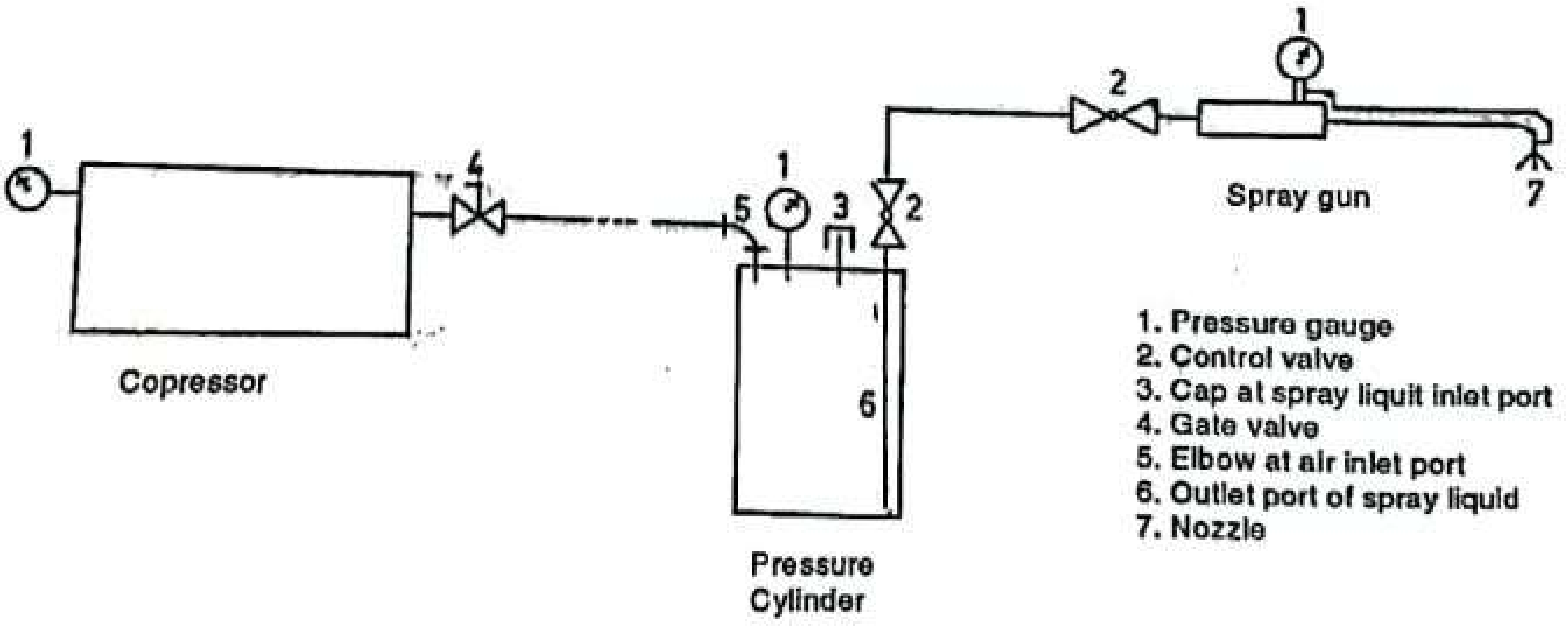

Fig.1. Line diagram of experimental setup

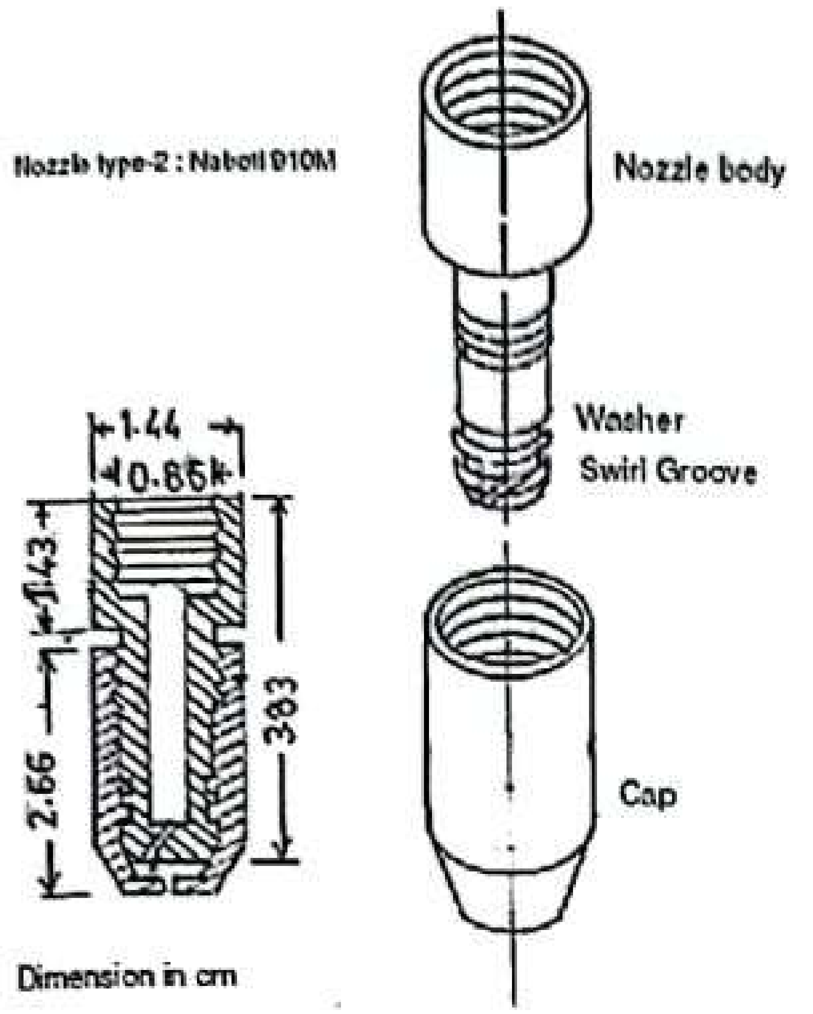

Fig.2. Sectional view and schematic diagram of nozzle Nobati 910M

2.5 Spray Angle Calibration

Pressure was taken as a factor for this test as P_1=1 kg/cm^2, P_2=2 kg/cm^2, P_3= 3 kg/cm^2, P_4=4 kg/cm^2, P_5=5 kg/cm^2, P_6=6 kg/cm^2, P_7=7 kg/cm^2 and P_8= 8 kg/cm^2 with three replication. This test was conducted to calibrate the spray angle of nozzle against pressure. Nozzle was fixed at 10 cm height. A constant pressure was maintained with control valve of spray gun. A graduated scale was set at 10 cm below the nozzle tip and the maximum width of spray was recorded. This was repeated for different nozzles and different pressure mentioned above.

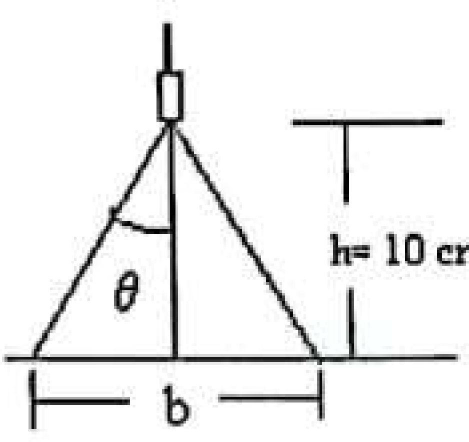

Fig. 3. Spray angle calculation

The angle of spray was calculated using the following relation.

$$\tan\theta = \frac{b/2}{h}$$

$$\theta = \tan^{-1}(b/2h)$$

Where, θ = spray half angle, deg; b = width of spray, cm; h = nozzle height, cm

Spray angles were calculated against pressure ranges from 1 kg/cm^2 to 8 kg/cm^2. The spray angles were plotted against pressure and a regression model was fitted for every nozzle. The data were analyzed with one-way ANOVA model and LSD test was done among the mean difference.

3. Performance study of nozzle

3.1 Selection of factors

Pressure, nozzle height, wind speed and nozzle orientation were taken as factors for this test as shown in table 1.

3.2 Distribution Pattern

All possible combination of pressure, height and wind speed levels were used for nozzle orientation 0°.

But pressure levels of 2, 4 and 6 kg/cm^2; nozzle height 60 cm were used for nozzle orientation 30°, 60° and 90°.

Spray distribution pattern tests were done placing the nozzle above the patternator for different treatment combination and after spraying for 1 min. the collected spray volume in the plastic pots through the corrugated channels were measured using measuring cylinder and were recorded for further analyses.

3.3 Distribution Uniformity

The distribution uniformity was calculated from the collected data of spray distribution pattern for the different combination of treatments as mentioned as before. The distribution uniformity was studied to know the spray distribution pattern more accurately. The distribution uniformity was calculated using the following formula:

Table 1. Performance study parameters

Pressure	Nozzle Height	Wind Speed	Nozzle Orientation
1 kg/cm^2	15 cm	No wind	0°
2 kg/cm^2	30 cm	2 m/s	30°
4 kg/cm^2	45 cm		60°
6 kg/cm^2	60 cm		90°

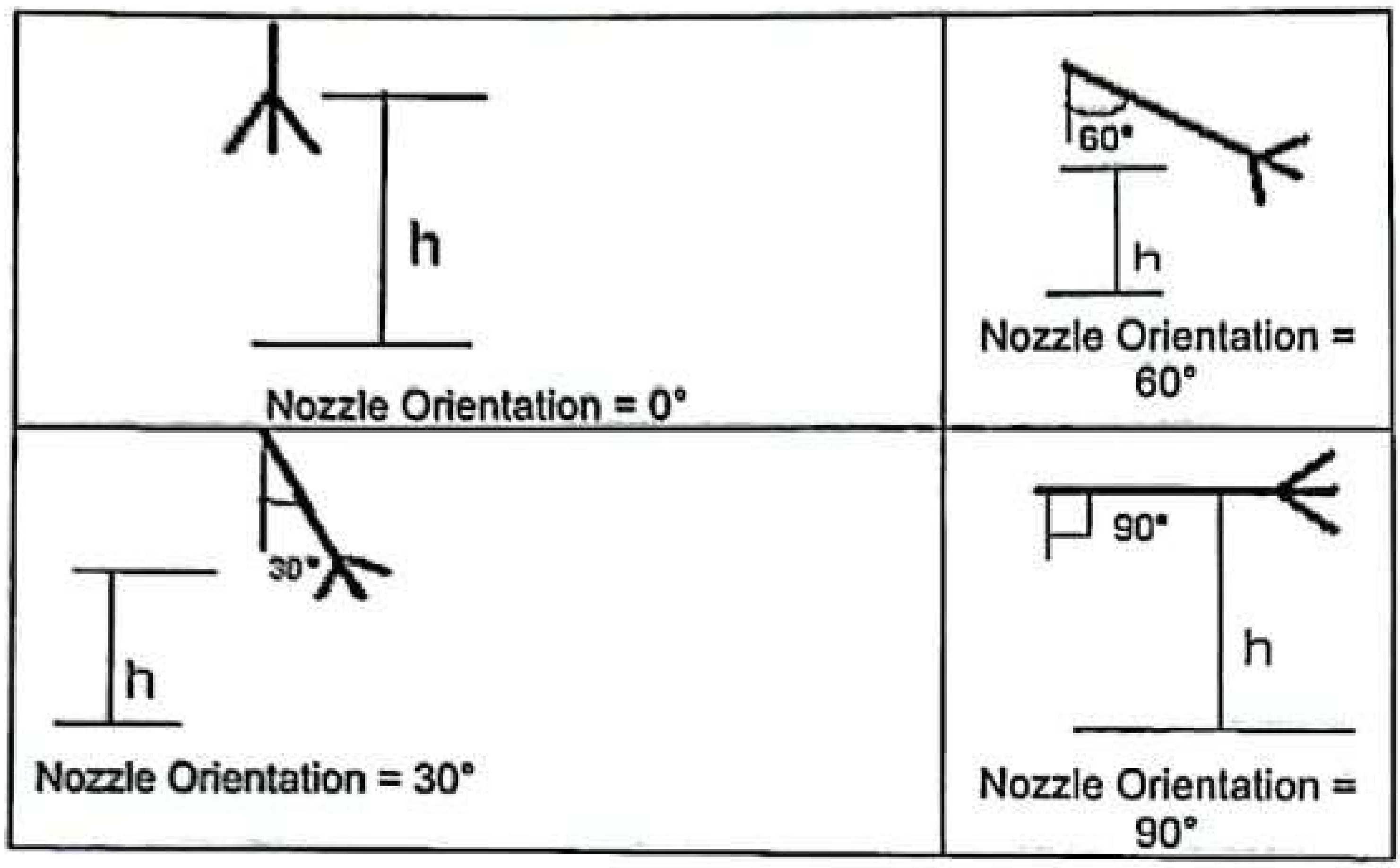

Fig. 4 Different Nozzle Orientation

$D_u = 100(1 - d/x)$ %

where, D_u = Distribution uniformity, %
$x = \Sigma x_i / n$
x_i = Collection volume from ith channel
n = total no. of pots which were filled for a particular combination
$d = (\Sigma|x - x_i|)/n$

The distribution uniformity was plotted against height for different pressure level and nozzle orientation level.

The data were analyzed with complete randomize design (CRD) and the means were ranked using least significant difference (LSD) test. The MSTAT-C and Excel-97 packages were used for the data analyses.

4. Results and Discussion

4.1 Wind profile

The rpm of the blower was 2850 and the blower outlet diameter was 7.62 cm. The blower delivered air at the rate of 0.09 m^3/s. The wind speed at the exit of the blower was 19.74 m/s and was 0.38 m/s at 6 m apart along horizontal axis of blower. Fig. 4 expresses non-linear regression between wind speed and horizontal distance. The regression coefficient $R^2 = 0.95$ and the regression equation is $y = 2.996e^{-0.35x}$.

4.2 Discharge calibration

The flow rates of nozzle were 459.00, 635.00, 711.00, 804.00, 860.00, 914.00, 945.00 and 1056.00 ml/min at pressures 1, 2, 3, 4, 5, 6, 7, and

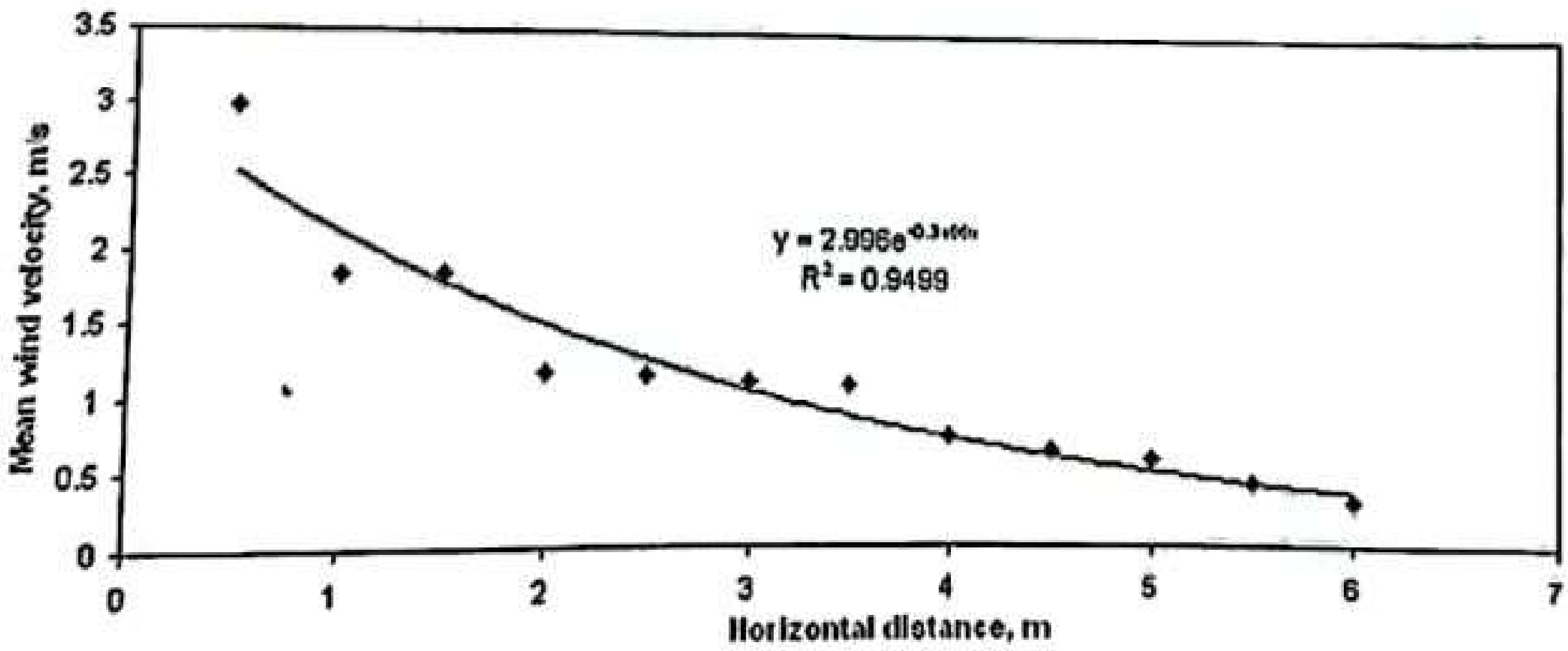

Fig.5. Wind Velocity as a function of horizontal distance for a particular blower

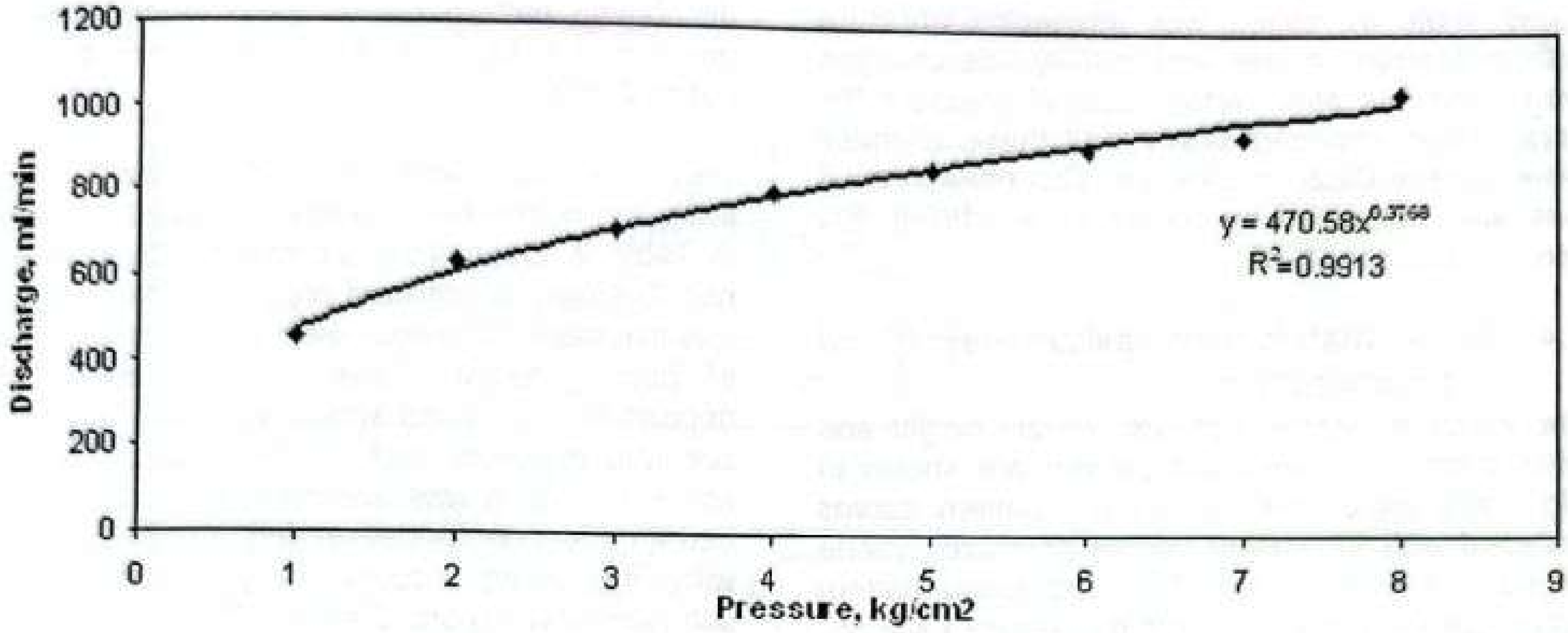

Fig.6. Discharge of nozzle against nozzle pressure

8 kg/cm^2, respectively. The flow rate increased with increasing pressure and the mean difference of discharges were statistically significant ($P \leq 0.01$) at LSD value of 25.98. The regression between pressure and discharge followed a power equation ($y = 470.58x^{0.377}$, where, y = discharge, and x = pressure) with correlation coefficient $R^2 = 0.9854$ (Fig. 5). The curve revealed that the flow rate increased with increasing pressure with decreasing rate.

4.3 Angle calibration

The spray angles for nozzle were recorded as 90.59°, 93.68°, 100.90°, 104.85°, 107.60°, 111.42°, 115.63° and 116.70° at pressure 1, 2, 3, 4, 5, 6, 7 and 8 kg/cm^2, respectively. The lowest spray angle was 90.59° at 1 kg/cm^2 and the highest spray angle was 116.70° at 8 kg/cm^2. The spray angle at 3 kg/cm^2 was significantly higher than 1 and 2 kg/cm^2, and the spray angle at 4 and 5 kg/cm^2 were statistically identical but they were statistically higher than 1, 2, and 3 kg/cm^2. Angle at 6 kg/cm^2 was statistically higher than 1 to 5 kg/cm^2 but it was statistically lower than that of 7 and 8 kg/cm^2. The spray angles at 7 and 8 kg/cm2 were statistically identical. The LSD value was 3.60 and significant level $P \leq 0.01$. The spray angle against pressure followed a power regression line ($y = 88.17x^{0.1302}$; where, y = angle, x = pressure) and the correlation coefficient was $R^2 = 0.943$ (Fig. 6).

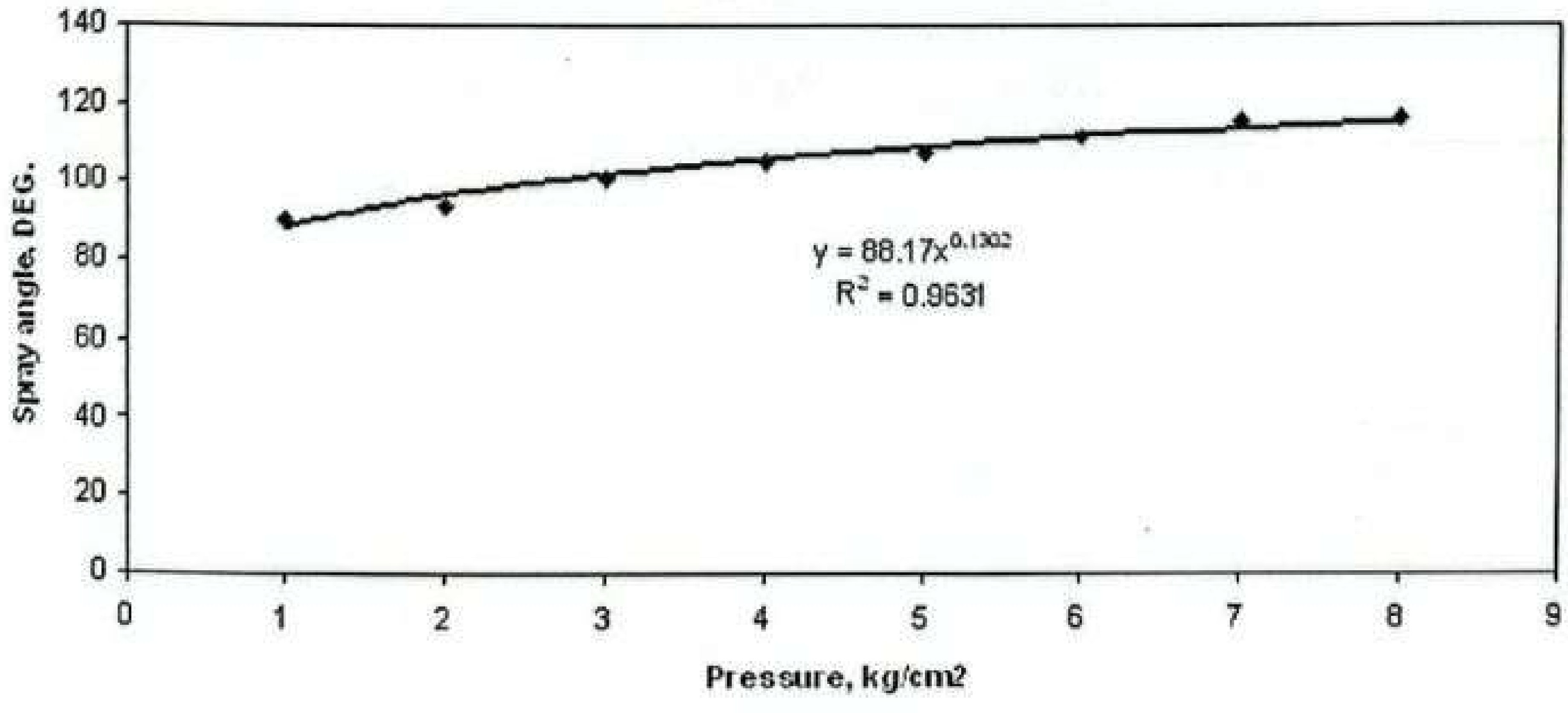

Fig.7. Spray angle against nozzle pressure

From the above discussion it is noted that the spray angle increased with increasing pressure with a decreasing rate and initially this changes were rapid but after certain level of pressure the spray angle changed slowly and these changes were not statistically significant. This phenomenon was also respected by Bainer *et al.* (1960) and Hindy and Zidan (1993).

4.4 Spray distribution pattern at 0° of nozzle orientation

The effect of nozzle pressure, nozzle height and wind speed on distribution pattern are shown in Fig.7 and Fig.8. The distribution pattern curves flattened with increasing nozzle pressure, nozzle height and wind speed. The distribution pattern curve was more steep at nozzle pressure 1 kg/cm^2, nozzle height 15 cm and no wind. The more flat distribution pattern curves were found at nozzle pressure 6 kg/cm^2, nozzle height 60 cm and wind speed 2 m/s.

Deposition on patternator at different nozzle pressure, nozzle height and wind spped are shown in Table 2. Deposition decreased with increasing nozzle hieght at constant pressure. The maximum and minimum deposition were at 15 cm and 60 cm of nozzle height. Table 1 also reveals that deposition decreased when wind was applied at constant pressure and nozzle height. From the above results, it was observed that nozzle height had an effect on deposition and deposit decreased with increasing nozzle height that followed Johnstone (1971) and Sarker (1993).

Table 2. Effect of nozzle pressure, nozzle height and wind on spray deposition at 0° of nozzle orientation

Nozzle height, cm	Wind speed, m/s	Spray deposition (ml/min) on patternator at pressure			
		1 kg/cm^2	2 kg/cm^2	4 kg/cm^2	6 kg/cm^2
15	0	445.80	616.50	773.50	870.17
30		436.58	596.33	750.67	853.00
45		428.42	578.00	729.08	825.00
60		418.33	567.50	712.13	800.33
15	2	414.50	569.50	713.75	807.00
30		409.57	555.33	662.83	742.33
45		403.50	543.50	639.83	718.67
60		376.92	485.25	573.50	633.50

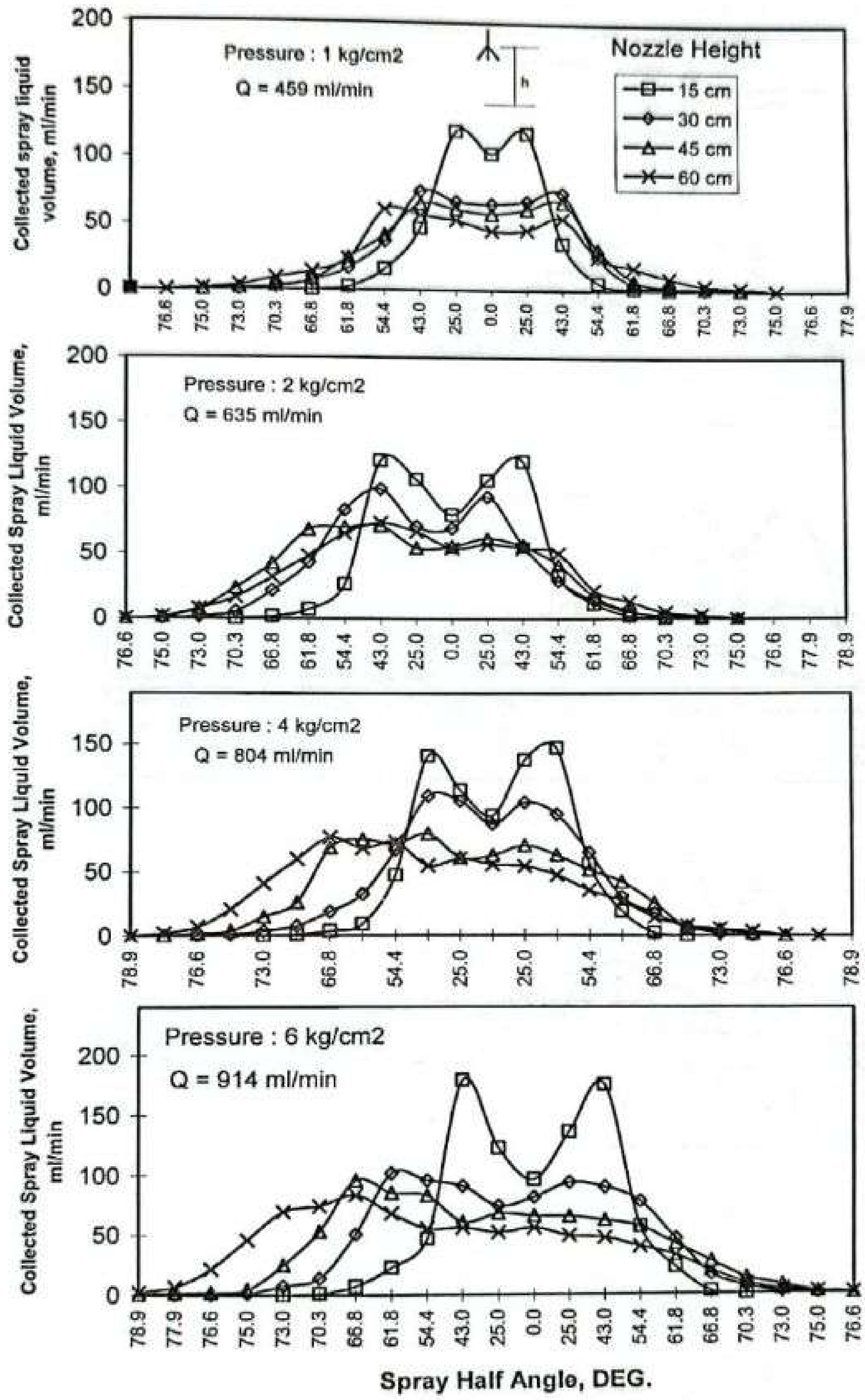

Fig. 7. Measurements of spray liquid distribution pattern plotted at different spary half anfle to show distribution uniformity at different pressure and height

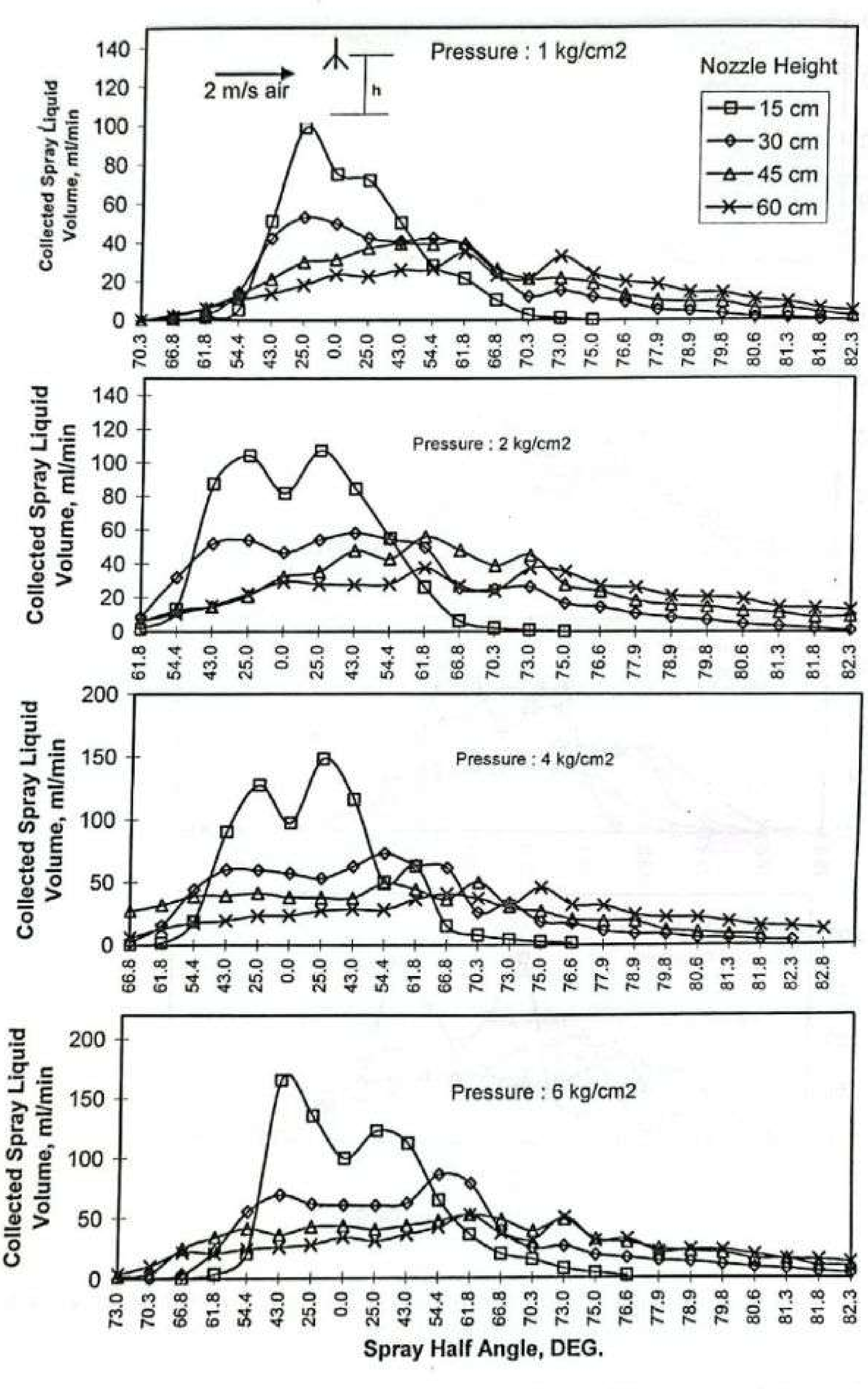

Fig. 8. Measurements of radial liquid distribution plotted at different spray half angle to show distribution uniformity at different pressure, height and wind velocity 2 m/s

4.5 Effect of nozzle orientation on distribution pattern

The effect of nozzle pressure and nozzle orientation on distribution pattern are shown in Fig. 9. The distribution pattern curves flattened with increasing angular displacement of nozzle upto 60° and the nozzle showed a steep distribution curve at nozzle orientation 90°. The distribution curve was found more steeper at 90° of nozzle orientation and was found more flat at 60° of nozzle orientation (Fig. 9).

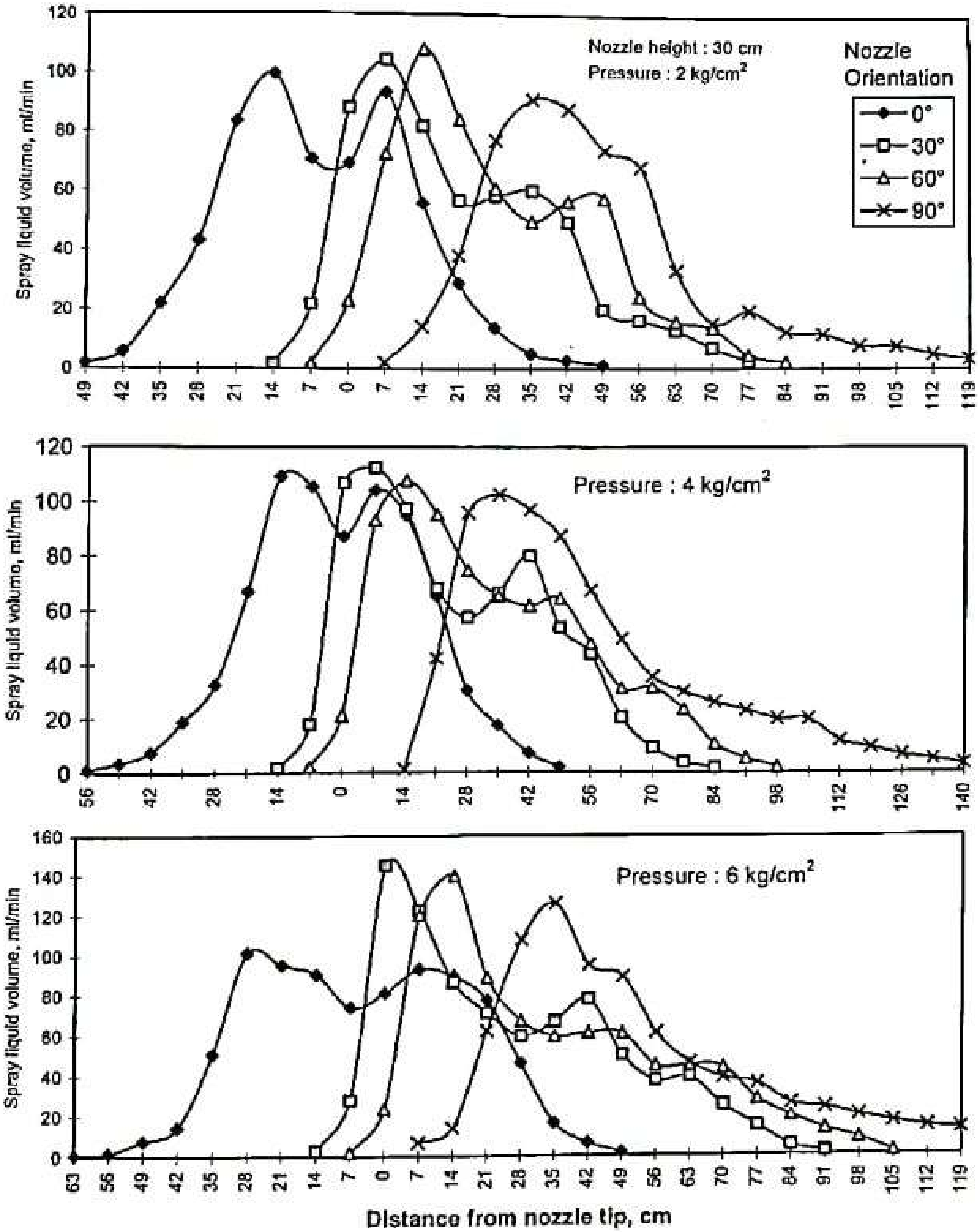

Fig. 9. Measurements of spray liquid distribution plotted to show distribution uniformity at different pressure, nozzle orientation and 30 cm of nozzle height

Table 3. Effect of nozzle pressure and nozzle orientation on spray deposition at 30 cm of nozzle height and zero wind velocity

Nozzle orientation	Spray deposition (ml/min) on patternator at different pressures		
	2 kg/cm^2	4 kg/cm^2	6 kg/cm^2
0°	596.33	750.67	853.00
30°	590.00	737.00	836.67
60°	575.83	733.00	813.50
90°	569.50	728.67	824.17

Deposition on patternator at different nozzle pressure and nozzle orientation at 30 cm of nozzle height are shown in Table 3. Deposition decreased with increasing angular displacement of nozzle from the vertical at constant height. The maximum and minimum deposition were at 0° and 90° of nozzle orientation.

4.6 Distribution uniformity

The distribution uniformity of spray increased with increasing pressure and nozzle height (Table 4). The distribution uniformity increased significantly with increasing nozzle height that followed the results of Wang *et al.* (1995). The mean differences of uniformity were statistically significant with LSD value 6.086, 9.854, 3.107 and 4.227 at nozzle pressure 1, 2, 4, and 6 kg/cm^2, respectively. The lowest uniformity was found at 15 cm height and the highest uniformity was found at 60 cm of nozzle height at constant pressure. Table 3 also revealed that distribution uniformity of spray increased with wind speed at constant pressure and constant nozzle height.

Table 4. Spray distribution uniformity at different pressure, height and wind speed for nozzle (Naboti 910M); Nozzle Orientation = 0° ; Wind speed = 0

Nozzle Height, cm	Spray distribution uniformity, %			
	P = 1 kgf/cm^2	P = 2 kg/cm^2	P = 4 kg/cm^2	P = 6 kg/cm^2
15	14.58^{C}	17.89^{C}	19.83^{C}	20.44^{C}
30	17.70^{BC}	20.60^{BC}	25.30^{B}	28.24^{B}
45	21.48^{AB}	28.96^{AB}	33.86^{A}	36.83^{A}
60	26.00^{A}	34.95^{A}	34.29^{A}	39.18^{A}
LSD value	6.086	9.854	3.107	4.227
Significant level	0.01	0.01	0.01	0.01
	Wind speed = 2 m/s			
15	16.87^{D}	17.61^{D}	22.72^{D}	23.28^{D}
30	22.51^{C}	27.27^{C}	28.53^{C}	28.25^{C}
45	40.02^{B}	43.62^{B}	55.52^{B}	57.13^{B}
60	57.08^{A}	64.25^{A}	64.82^{A}	64.99^{A}
LSD value	3.321	6.468	4.800	2.407
Significant level	0.01	0.01	0.01	0.01

*Mean value bearing different letter(s) are significantly different and bearing same letter(s) are statistically identical

The distribution uniformity of spray changed significantly with angular displacement of nozzle at constant nozzle height and constant pressure (Table 4). The mean differences of uniformity were statistically significant with LSD value 4.31, 6.516 and 3.10 at nozzle pressure 2, 4, and 6 kg/cm^2, respectively. The lowest uniformity was found at 90° of nozzle orientation and the highest uniformity was found at 60° of nozzle orientation. Table 4 also revealed that distribution uniformity increased with increasing nozzle inclination until it reached at 60° and then distribution uniformity decreased rapidly.

4.7 Interaction effect of pressure and nozzle height on distribution uniformity (D_u) of spray

The interaction effect of pressure and nozzle height on spray liquid distribution uniformity is shown in Fig. 10. The lowest value of D_u was 15.727% and it was found at combined effect of pressure 1 kg/cm^2 and nozzle height 15 cm. The highest value of D_u was 52.087% at combined effect of pressure 6 kg/cm^2 and nozzle height 60 cm.

Table 4. Spray distribution uniformity at different pressure and nozzle orientation of nozzle (Naboti 910M) at nozzle height 30 cm

Nozzle Orientation, deg.	Spray distribution uniformity, %		
	P = 2 kg/cm^2	P = 4 kg/cm^2	P = 6 kg/cm^2
0	20.61^B	25.30^B	28.24^B
30	28.28^A	32.99^A	36.35^A
60	29.70^A	34.07^A	37.86^A
90	16.66^B	25.43^B	26.49^B
LSD value	4.31	6.516	3.10
Significant level	0.01	0.01	0.01

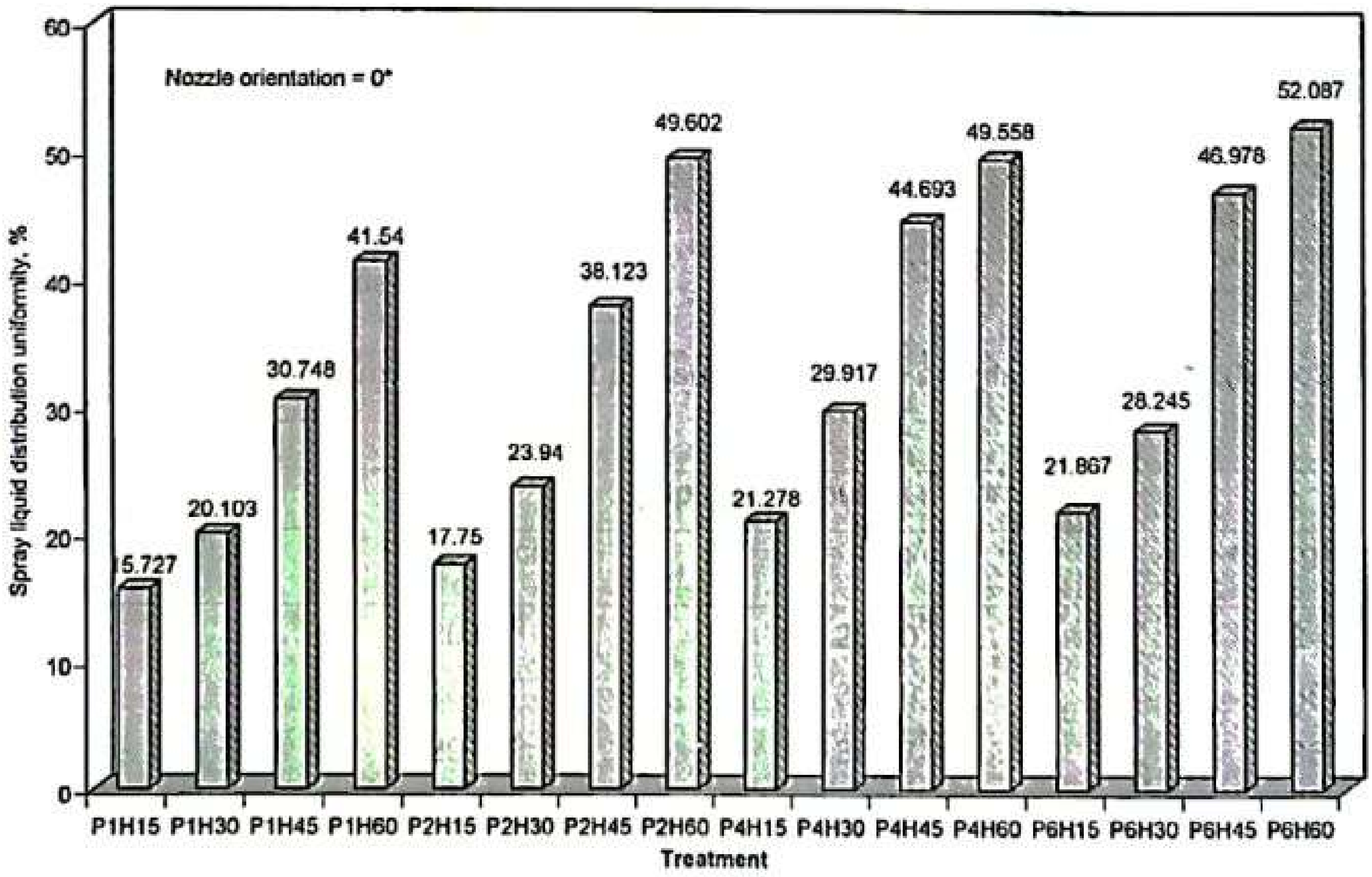

Fig. 10. Interaction effect of pressure and nozzle height on spray liquid distribution uniformity

5. Conclusion

On the basis of results of this study the following conclusion are drawn:

i) he performance of the selected nozzle was good. It is easy to control the discharge of nozzle to fulfill the requirement of crop field by varying the nozzle pressure.

ii) The maximum distribution uniformity of spray can be obtained by adjusting nozzle height and pressure.

iii) The deposition can be maximized by adjusting nozzle height at windy condition to get better distribution uniformity.

i) For the selected nozzle, the maximum distribution uniformity was 52.087% at an interaction effect of pressure 6 kg/cm^2 and nozzle height 60 cm.

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