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IMPROVED SURFACE COVERAGE WITH ENVIRONMENTALLY EFFECTIVE UNIVERSITY BOOM SPRAYER

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The effect of spray coverage on bollworm mortality was measured on mature cotton variety CM-495-PB planted at Post-graduate Agricultural Research Station (PARS) experimental fields, University of Agriculture, Faisalabad. Spray coverage was found directly related to mortality of cotton bollworms. Conventional over-the-row sprayers achieve very little deposit on leaves near the ground and on the underside surfaces of leaves throughout the canopy (2–5 %). Water Sensitive Papers were installed on three levels of plants (top, middle, and bottom) on both sides of the leaves to examine the spray coverage. The greatest spray coverage values on upper and lower leaf surfaces were 49.67 % and 65.87 % respectively at $V_2P_2O_2$ treatment, while for conventional system it was 35.6 % on upper sides of leaves and 0.4 % on lower sides of the cotton leaves. The relationship between spray coverage and bollworm mortality was established for drop-pipe university boom sprayer. Hundred percent mortality of American and spotted bollworm occured after one week for a surface coverage of 52 % and 61.75 % respectively. A software programme was developed to analyze spray coverage on the computer in Java language.
Keywords: Surface coverage, bollworm, boom sprayer, mortality

INTRODUCTION

Boom-sprayers are the most common method of applying pesticides to field crops in the more developed agricultural regions of the world (Rose, 1963). Modern agriculture calls for reduction in both the dosage applied and the toxicity of the pesticide. Therefore, less toxic and more 'environmentally safe' pesticide application methods are favoured. The use of costly pesticides requires uniform coverage and high cover density of all parts of the foliage, to achieve direct contact of the pesticide residue with the pest (Frankel, 1986).

Sprayers with drop-legs to place nozzles within the crop canopy can be of help in achieving improved deposition in dense canopies (Rose, 1963 and Frankel, 1986). The nozzles may be positioned to release the spray and direct it through the foliage to the underside of the leaves or, preferably, utilize an air-stream carrier to deliver the droplets to the plant parts. Moving in the canopy may involve the use of protective shields, inhibiting direct contact of the nozzle with the canopy (Matthews, 1992).

Holownicki et al., (2002) reported that most common artificial targets for spray coverage evaluation are water sensitive paper (WSP). They are widely used for visual assessment of spray coverage, spray distribution as well as for image analyses in spray application experiments. The WSP turns blue at relative humidity above 80 %, and, therefore, it cannot be used under very humid conditions. Yates and Smith (1992) reported that the spray deposition is not only a function of method of application of chemicals but also it depends on parameters like leaf surface area, forward velocity of sprayer, and nozzle orientation.

Grinsteinl et al., (1996) reported that the drop sprayer yielded a high cover density on both sides of the leaves on all parts of the plant and good control was obtained (85-95 % on both sides of leaf coverage). Use of drop-pipe sprayers resulted in leaf coverage of 200 droplets/cm^2 of more than 80% on both sides of the lower leaves of the plant and of close to 100% on the higher leaves (Gan-Mor et al., 1996).

Womac et al., (1993) reported that the drop nozzle sprayers either with or without air assistance provided a high degree of nozzles orientation control, spray coverage and spray targeting to leaf underside. Keeping in view the above cited literature, this study was designed to evaluate the leaf surface coverage of spray by the drop pipe university boom sprayer and its impact on insect mortality of cotton crop.

MATERIALS AND METHODS

A 3*3*3 factorial design was used to determined the effects of three sprayer fields velocities (2.5, 4.0, and 5.5 km/h), at three levels of spray pressures (300, 400, and 500 kPa), and at three levels of nozzle spraying angles (15°, 30°, and 45°) on spray coverage and their relative impact on insect mortality. Another treatment of control (conventional boom sprayer) was also applied on another plot for making the comparison. However, all the treatments were used in Randomized Complete Block Design (RCBD).

Water Sensitive Papers (WSP) cards were imported from Switzerland with the cooperation of Syngenta formerly named as Ciba Geigy. The samples of WSP were prepared in the laboratory and installed on both the upper as well as lower surfaces of cotton leaves as the artificial targets. The effect of spray coverage on mortality rate of bollworms was also to be noted. The mortality of the bollworms was calculated from the pest scouting data before and after spraying process using the following relationship (Mehmood,2004). The procedure consists of following steps:

$$M = \frac{N - n}{N} \times 100 \text{ ---------------------- } 1$$

Where, M = % age bollworm mortality, N = No. of bollworms before spraying, and n = No. of bollworms after spraying

Preparation of WSP samples

The water sensitive paper samples were cut to 26 x 50 mm dimensions with a great care wearing plastic gloves to prevent it from skin contamination. Each card was labeled with a special ball pen from backsides according to treatment so that its ink may not contaminate the WSP. Then the WSP cards were kept in special polythene bags to transport them in the field.

Installation/Transportation of WSP

WSP was clipped on both sides of top, middle, and bottom leaves of plants to evaluate the spray coverage. Stainless steel clips were used instead of staples to affix the WSP. This made card removal easier. Six cards were placed at each level (treatment). All personnel stamping WSP on plants leaves wore plastic gloves to reduce card contamination through skin contact. Cards were removed 15-minutes after spraying and placed in special envelopes for transportation to the laboratory for analysis.

Development of Spray Coverage Software

A software program was developed in Java language for accurate and rapid measurements of spray coverage on WSP. Water sensitive papers are the most common artificial targets for spray coverage and deposit evaluation. This software program can only be used for WSP having dark blue to sharp blue dots and color contrast with background (i.e. yellow background and visible blue dots). Elaborate testing had been conducted to determine the accuracy of the software to calibrate it prior to measurements. Samples of dots on WSP of known dimensions and known percent area were used to set the resolution and gray level threshold of the image. The resolution of the scanner was such that dots as small as 50 micron in diameter could be considered. The software performed well in determining the spray coverage but, was found improper for counting number of droplets with diameter.

Basic Requirements of the software

The Software Program requires an IBM compatible PC based on a Pentium-I or higher computer, running in Windows 98, or NT, and a high resolution HP ScanJet flatbed scanner. The equipment used in this study was an Intel Pentium-4 desktop computer (1.7 GHz) with 128 MB memory, HP ScanJet 6200Cse flatbed scanner with USB port, and an HP DeskJet 890C color printer.

Procedure for Spray Coverage

Sprayed WSP were digitized with a high resolution HP ScanJet 6200Cse flatbed scanner with USB port with the help of corresponding software. Scanner resolution was set at 300 dpi. Then the droplet greater than or equal to 42.3 µm could be visualized. It was assumed that the deposition characteristics of droplets impinging WSP were similar to droplets impinging leaves. After scanning the cards they were converted and saved to JPG file format. These JPG files were opened in Adobe Photoshop version 7.0 software. A portion of the files were selected exactly 1 cm^2 with the help of Adobe Photoshop. For convenience, 1 cm^2 cards were saved to short named files with same JPG extension. Then each card was analyzed for spray coverage using the developed software.

RESULTS AND DISCUSSIONS

The cotton variety through out the field was CM-495-PB and field was considered to be uniform in fertility and other soil parameters. The analysis of variance was conducted in two ways; factor-wise, to identify the suitable factor level for optimum insect mortality as well as spray coverage, and treatment-wise, to compare the effectiveness of drop-pipe university boom sprayer to the farmer's conventional system of spraying.

The analysis of variance was carried out using PROC GLM (General Linear Model) procedures of the SAS Institute (1998). Spray coverage was determined on both surfaces of leaf (upper and lower) and also calculated the mean coverage. Statistical analysis was performed to determine upper surface coverage (USC), lower surface coverage (LSC), and mean surface coverage percentage (MSC). The analyzed results were discussed as following.

Effect of velocity on spray coverage

Velocity of sprayer had significant effect (α=0.05) on spray coverage (Table 5). Statistically analyzed results are presented in Table 1. It was found that the sprayer velocity significantly affected (α=0.05) the spray coverage. The percentage coverage value was significantly greater at V_2 (4.0 km/hr) field velocity than those of other two velocities. Spray coverage on upper, lower and mean leaf surfaces were 45.94, 60.90, and 53.42 % respectively at V_2 field velocity. Too low (2.5 km/h) or too high (5.5 km/h) velocities were not suitable for crop spraying operations with drop-pipe boom sprayer.

At very high velocity the plants moved with sprayer's drop-pipes and the spray could not hit at target leaves. At very low velocity the plants remained bent for long time and spray did not fall on target. A very careful analysis indicated that the increase in velocity from 2.5 to 4.0 km/hr increased the mean spray coverage, 1.13 times and from 4.0 to 5.5 km/hr decreased the mean spray coverage, 1.27 times.

Table 1. Effect of sprayer velocity on spray coverage

Velocity	Spray Coverage (%)		
	USC	LSC	MSC
V_1	40.80 [b*]	54.03 [b*]	47.42 b*
V_2	45.94 [a]	60.90 [a]	53.42 [a]
V_3	36.18 [c]	47.94 [c]	42.06 [c]
Mean	40.98	54.29	47.63
LSD (0.05)	0.7945	1.0602	0.9272

*Means in each column followed by the same letter are not significantly different at 5 % probability level. V_1 = 2.5 km/h, V_2 = 4.0 km/h, and V_3 = 5.5 km/h

Effect of pressure on spray coverage

Statistically analyzed results for the effect of nozzle pressure on spray coverage are presented in the Table 2. Pressure affected significantly the USC, LSC, and MSC as shown in Table 2. The interaction of pressure with angle is non-significant at 5 % probability level. The increase in pressure from 300 to 400 kPa increased mean spray coverage 1.14 times and increase in pressure from 400 to 500 kPa decreased the mean spray coverage 1.05 times. Pressure P_2 gave significantly greatest mean coverage value than those at pressure P_1 and P_2.

Table 2. Effect of pressure on spray coverage

Pressure	Spray Coverage (%)		
	USC	LSC	MSC
P_1	38.07 [c*]	50.45 [c*]	44.27 [c*]
P_2	43.52 [a]	57.66 [a]	50.59 [a]
P_3	41.33 [b]	54.76 [b]	48.04 [b]
Mean	40.98	54.29	47.63
LSD (0.05)	0.7945	1.0602	0.9272

*Means in each column followed by the same letter are not significantly different at 5 % probability level. P_1 = 300 kPa, P_2 = 400 kPa, and P_3 = 500 kPa

Effect of spray angle on spray coverage

Effect of spray angle on uniformity of coverage showed the significant results at 5 % probability level. The interactions of angle with pressure and velocity at 5 % probability level are not significant as shown in Table 5. Percentage uniformity of coverage was significantly different at three levels of angle (15, 30, 45 degrees). The best results were achieved at $\theta_2 = 30^\circ$ at the crop height of 106.68 cm. Other two angles 15° and 45° were less effective.

Table 3. Effect of Angle on spray coverage

Pressure	Spray Coverage (%)		
	USC	LSC	MSC
θ_1	36.91 [c*]	48.89 [c*]	42.90 [c*]
θ_2	43.77 [a]	58.01 [a]	50.59 [a]
θ_3	42.24 [b]	55.98 [b]	49.11 [b]
Mean	40.98	54.29	47.63
LSD (0.05)	0.7945	1.0602	0.9272

*Means in each column followed by the same letter are not significantly different at 5 % probability level. $\theta_1 = 15^\circ$ $\theta_2 = 30^\circ$ $\theta_3 = 45^\circ$

USC = Upper surface coverage, LSC = Lower surface coverage, MSC = Mean surface coverage

Effect of treatment on spray uniformity of coverage

The effect of treatment on spray uniformity was statistically analyzed and presented in Table 4. The values of USC, LSC, and MSC at $V_2 P_2 \theta_2$ treatment were 49.67%, 65.87%, and 57.77% respectively, which were significantly greater than those at all other treatments. The spray coverage with conventional system was very low as compared to all treatments of the drop-pipe sprayer. The conventional system gave only 18 and 0.367 % coverage on upper and lower surfaces respectively. All the treatments of drop-pipe boom sprayer provided better coverage than the conventional system.

Effect of Mean Surface Coverage (MSC) on Boll-worm mortality

Regression analysis indicated that the quadratic models were the best to predict the spray coverage for bollworm mortality one day and one week after spraying. First derivative of quadratic models in Figure 1 indicated that 100 % mortality of American bollworm and spotted bollworm after one week could be achieved if the spray coverage would be 52 % and 61.75 % for respectively. It can be depicted from the graph that the excessive leaf surface coverage than the above mentioned figures could be only the wastage of insecticide, which would be harmful for crop and human environment. The quadratic models and coefficient of determination (2 & 3) for American and Spotted bollworm after one week are given below:

$$Y = -0.0284X^2 + 2.9419X + 23.036 \qquad R^2 = 0.944 \text{ (American Bollworm)} \qquad (2)$$

$$Y = -0.0197X^2 + 2.4339X + 24.5 \qquad R^2 = 0.944 \text{ (Spotted Bollworm)} \qquad (3)$$

Where, Y = Bollworm mortality (%) and X = MSC (%)

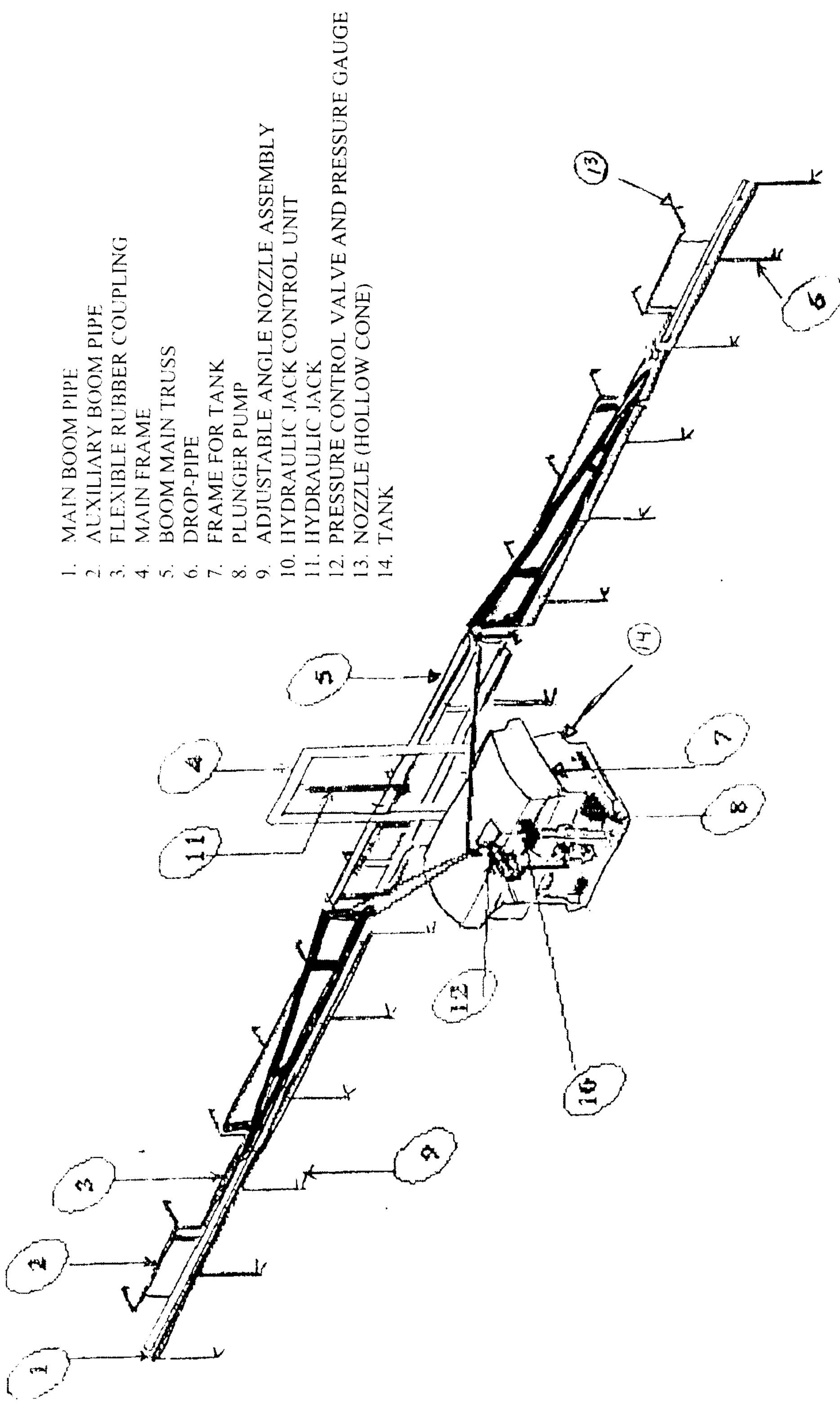
Table 4. Effect of treatment on spray uniformity of coverage

Upper		Lower		Mean	
TRT	UOC (%)	TRT	UOC (%)	TRT	UOC (%)
V2P2O2	49.67 ^{a}	V2P2O2	65.867 ^{a}	V2P2O2	57.76 ^{a}
V2P3O2	48.27 ^{ab}	V2P3O2	63.933 ^{ab}	V2P3O2	56.1 ^{ab}
V2P2O3	47.87 ^{ab}	V2P2O3	63.467 ^{ab}	V2P2O3	55.67 ^{ab}
V2P1O2	47.27 ^{bc}	V2P1O2	62.667 ^{abc}	V2P1O2	54.97 ^{bc}
V2P3O3	47 ^{bc}	V2P3O3	62.333 ^{bc}	V2P3O3	54.67 ^{bc}
V1P2O2	46.73 ^{bc}	V1P2O2	61.867 ^{bc}	V1P2O2	54.3 ^{bc}
V1P2O3	45.33 ^{cd}	V1P2O3	60 ^{cd}	V1P2O3	52.67 ^{cd}
V2P2O1	45.06 ^{cd}	V2P2O1	59.73 ^{cd}	V2P2O1	52.4 ^{cd}
V2P1O3	45 ^{cd}	V2P1O3	59.667 ^{cd}	V2P1O3	52.33 ^{cd}
V1P3O2	44.93 ^{cd}	V1P3O2	59.467 ^{cde}	V1P3O2	52.2 ^{cd}
V1P3O3	43 ^{de}	V1P3O3	57 ^{def}	V1P3O3	50 ^{de}
V3P2O2	42.43 ^{ef}	V2P3O1	56.23 ^{ef}	V3P2O2	49.33 ^{de}
V2P3O1	42.36 ^{ef}	V3P2O2	56.233 ^{ef}	V2P3O1	49.3 ^{ef}
V2P1O1	40.97 ^{efg}	V2P1O1	54.233 ^{fg}	V2P1O1	47.6 ^{efg}
V3P2O3	40.7 ^{efgh}	V3P2O3	53.967 ^{fgh}	V3P2O3	47.33 ^{efgh}
V1P2O1	40.63 ^{fgh}	V1P2O1	53.767 ^{fgh}	V1P2O1	47.2 ^{fgh}
V1P1O2	39.66 ^{ghi}	V1P1O2	52.6 ^{ghi}	V1P1O2	46.13 ^{ghi}
V3P3O2	39.2 ^{ghij}	V3P3O2	51.93 ^{ghij}	V3P3O2	45.56 ^{ghij}
V1P1O3	38.43 ^{hij}	V1P1O3	50.9 ^{hij}	V1P1O3	44.66 ^{hij}
V3P3O3	37.86 ^{ijk}	V3P3O3	50.13 ^{ijk}	V3P3O3	44 ^{ijk}
V1P3O1	36.93 ^{jkl}	V1P3O1	48.867 ^{jkl}	V1P3O1	42.9 ^{jkl}
V3P1O2	35.8 ^{kl}	V3P1O2	47.533 ^{kl}	V3P1O2	41.66 ^{kl}
C	35.63 ^{kl}	V3P1O3	46.333 ^{lm}	V3P1O3	40.66 ^{lm}
V3P1O3	35 ^{lm}	V3P2O1	44.067 ^{mn}	V3P2O1	38.66 ^{mn}
V3P2O1	33.27 ^{mn}	V3P3O1	42.933 ^{n}	V3P3O1	37.66 ^{n}
V3P3O1	32.4 ^{n}	V1P1O1	41.833 ^{n}	V1P1O1	36.7 ^{n}
V1P1O1	31.56 ^{n}	V3P1O1	38.367 ^{o}	V3P1O1	33.66 ^{o}
V3P1O1	28.96 ^{o}	C	0.367 ^{p}	C	18 ^{p}

Means in each column followed by the same letter are not significantly different at 5 % probability level.
(V = field velocity, km/hr) (P = pressure, kPa) (O = nozzle angle)

Table 5. Factor-wise ANOVA for spray coverage (%) at (USC, LSC, MSC)

Source	df	USC		LSC		MSC	
		F Value	Pr > F	F Value	Pr > F	F Value	Pr > F
B	2	-	-	-	-	-	-
V	2	304.06	0.0001	301.18	0.0001	302.49	0.0001
P	2	95.87	0.0001	94.12	0.0001	94.89	0.0001
()	2	165.80	0.0001	164.17	0.0001	164.91	0.0001
V*P	4	6.15	0.1004	5.86	0.1006	5.99	0.1005
V*()	4	2.16	0.0870	2.12	0.0915	2.14	0.0895
P*()	4	0.13	0.9726	0.12	0.9728	0.12	0.9730
V*P*()	8	0.84	0.5759	0.82	0.5920	0.82	0.5852
Error	52	-	-	-	-	-	-
Total	80	-	-	-	-	-	-


1. MAIN BOOM PIPE
2. AUXILIARY BOOM PIPE
3. FLEXIBLE RUBBER COUPLING
4. MAIN FRAME
5. BOOM MAIN TRUSS
6. DROP-PIPE
7. FRAME FOR TANK
8. PLUNGER PUMP
9. ADJUSTABLE ANGLE NOZZLE ASSEMBLY
10. HYDRAULIC JACK CONTROL UNIT
11. HYDRAULIC JACK
12. PRESSURE CONTROL VALVE AND PRESSURE GAUGE
13. NOZZLE (HOLLOW CONE)
14. TANK

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