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Performance Evaluation of Modified Self-Leveling Boom Sprayer

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ABSTRACT

Cotton farming is a popular agribusiness in Pakistan. About 70% of total pesticides used in the country is sprayed onto cotton crop. Studies indicate that nearly 50% of pesticide sprayed on different crops is lost to untargeted areas, which not only adds to the cost of production but also degrades the surrounding soil, water and air environment. A major reason for such a pesticide loss is use of inefficient spraying machines, which are unable to maintain specified nozzle pressure, nozzle discharge, nozzle height that affects spray pattern, droplet size, spray uniformity, etc. The proposed study was therefore conducted using self-leveling boom sprayer. This sprayer can level its boom for a specified nozzle height automatically during spray. Nozzles discharge, spray pattern, spray angle, etc were measured in the laboratory as well as in the field for pressure setting of 250, 300 and 350 kPa, respectively. The results indicated that the performance of self leveling boom sprayer was better at 350 kPa as compared to other two pressure values.

Key Words: Nozzle discharge; Nozzle pressure; Droplet size; Spray angle; Spray distribution; Cotton

INTRODUCTION

Cotton is one of the most valuable cash crop and a major source of edible oil in the country. This crop plays a significant role in the economy of Pakistan. It accounts for 11.5% value addition to agriculture and 2.8% of GDP (Anonymous, 1999-2000). Cotton provides raw material to about 450 textile mills, 1132 ginning factories, 500 oil mills (GOP, 2000). Cotton farming is an occupation of 1.5 million families and provides job to 54 percent of the labour force (Ahmad & Makhdum, 1992). The yield (641 kg ha^{-1}) is, however, very low as compared to many other cotton producing countries of the world. Cotton alone is consuming about 70% of the total pesticide sprayed on all crops.

According to recent trials conducted by Central Cotton Research Institute, Multan, Pakistan, about 50 percent of the pesticides applied to different crops is wasted during application, which not only adds to the cost of production but also causes environmental pollution and imbalance in the natural echo system (Rehman, 1994). Two major reasons for pesticide loss are unawareness of farmers and use of inefficient pesticides application machinery. Most of the cotton growing farmers in Pakistan use tractor mounted boom sprayer for pesticides application. As long as the uniformity of spray with tractor mounted boom sprayer is concerned, it varies on unleveled field due to changing boom height with respect to crop canopy. To combat this problem, the self-leveling boom sprayer of German origin was modified locally and evaluated both in the laboratory and field conditions.

MATERIALS AND METHODS

The proposed study was conducted with the technical assistance of the Agricultural Mechanization Research Institute, Multan. This study was planned to test and evaluate locally developed modified self-leveling boom sprayer under laboratory and field conditions. The sprayer comprised of seven sections with a self-leveling mechanism. Its length was 16.42 m with 22 nozzles spaced 70.60 cm apart. A hollow cone nozzle commonly used by the farmers of cotton growing area was used for laboratory and field studies. The sprayer was tested at three different pump pressures (250, 300 and 350 kPa) for different height of cotton crop. For each pressure reading spray angle, spray pattern, droplet size, discharge, spray distribution and swath width were measured. A patternometer was used to measure the discharge and spray pattern in the laboratory. A micro-photographic technique was used to measure the droplet size of a spray sample collected in shallow dishes containing silicon oil with low surface tension. A hand held microscope was used to determine the spray distribution and orifice size.

RESULTS AND DISCUSSION

The modified self-leveling boom sprayer was tested in the laboratory and field conditions for the following parameters. Each parameter is discussed as below.

Spray discharge. The discharge of a nozzle is a function of its design/type, orifice size, shape and operating pressure. A test bench was used to measure the discharge of the sprayer nozzles at the desired pressure in the laboratory. A graduated beaker and stopwatch were used to measure and record the discharge of the nozzles. Spray discharge was collected in still air for a period of 60 seconds. Total discharge of the boom at 250, 300 and 350 kPa pressure was observed to be 13.11, 15.62 and 17.82 L min^{-1} in the laboratory as compared to 12.34, 14.41 and 16.79 L min^{-1}, respectively in the field (Fig. 1). The discharge of the sprayer measured in the field was about one L min^{-1}. less than that of laboratory conditions, which is within acceptable range.

Spray pattern. An ideal nozzle will deliver uniform/even spray along its area of coverage. In order to determine the spray pattern of a hollow cone nozzle, a patternometer consisting of PVC semicircular inclined channels was used. The nozzle spray volume was collected in test tubes and evenness of the spray was determined by drawing a patternograph for different working pressures as shown in Fig. 1. The bar graph of spray pattern (Fig. 2) for 250 kPa followed almost a normal distribution, which is a sign of uniform spray pattern. For other two pressure setting, the pattern tends to deviate from normal distribution.

Fig. 1. Total discharge of self-leveling boom sprayer (22 nozzles) at different pressures under laboratory and field conditions

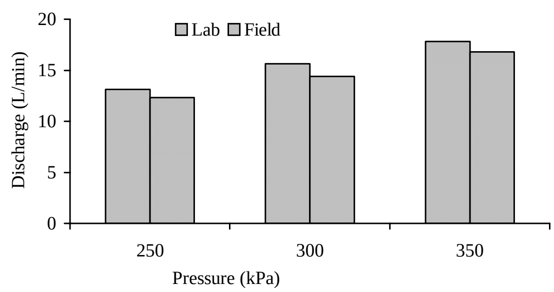

Fig. 2. Spray pattern of hollow cone nozzle for 250 kPa pressure

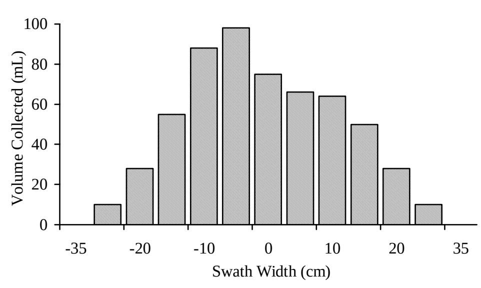

Table I. Effect of pressure on nozzle orifice size, spray angle, nozzle discharge and swath width

Pressure (kPa)	Orifice Dia. (mm)*	Spray Angle (Degrees)*	Nozzle Discharge (L/min)*	Swath Width (mm)*
250	1.15	57	0.592	540
300	1.15	62	0.715	600
350	1.15	65	0.810	640

* Mean of 22 nozzles on a boom

Spray angle. Spray angle is another important parameter of nozzle performance that establishes the correct nozzle spacing, overlapping and height of the application. Spray angle is dependent on type of nozzle, orifice size and operating pressure. As pressure increases, spray angle and swath width also increases. Spray angle of the nozzles was calculated in the laboratory using patternometer. Spray angle was found to be 57^0, 62^0 and 65^0 for 250, 300 and 350 kPa pressure settings, respectively. The recommended angle of hollow cone nozzle is 65^0 to 110^0.

Spray distribution. Spray distribution is defined as number of droplets deposited per unit area of target. Spray distribution is usually measured by using water sensitive strips or fluorescent powders. Both the techniques were used to test the spray distribution of nozzles. Average numbers of droplets from hollow cone nozzle were found to be 114 per cm^2. The recommended number of droplets is 100 per cm^2. This indicates that the sprayer is performing close to the recommended conditions.

Spray droplet size. Spray droplet size is the most important parameter of nozzle's performance. An optimum droplet size is one which gives most effective coverage of the target with minimum contamination of the environment. Spray droplets were measured using micro-photographic technique in which a microscope and 35mm SLR camera were used. This parameter was measured with the help of Central Cotton Research Institute (CCRI) Multan. Several different sizes of droplets were observed in the microscope. The observed sizes of droplets were categorized as Very small (72), small (115), medium (158), large (288) and very large (460) μm. Study conducted by Azimi *et al*. (1985) show that the larger droplets easily move down on to ground due to gravity and do not remain intact to the crop leaves. On the other hand, smaller droplets fly away with air and also do not reach to their targets.

Orifice size and shape. Orifice size of nozzle plays a critical role in its discharge and uniformity. Orifice sizes were measured with the help of a hand-held microscope before and after the spray season of cotton crop. The orifice size of hollow cone nozzle was 1.15 mm which did not change even after the spray season as shown in Table I.

Field efficiency of self-leveling boom sprayer. Field efficiency of a sprayer is the ratio of effective field capacity to the theoretical field capacity. Theoretical field capacity (TFC) refers to as that the machine is operating in the field at an optimum forward speed with rated width for 100% of the time. It may be calculated as:

TFC = Speed*Boom Width/10

Where

Speed = km/h

Boom Width = m

Sprayer speed 4.2 km/h and actual boom width of 16.42 m were used to find TFC. On an average theoretical field capacity turned out to be 7 ha/h for 3 trials. Effective field capacity was calculated by dividing the actual area (ha) sprayed and time spent in spraying. The actual spraying time was calculated by subtracting the time lost in turning, refilling, and other stoppages, etc from the total time spent in the field. Average effective field capacity for 3 trials came out to be 3.47 ha/h. The field efficiency was thus calculated as 50%, which was little below than the recommended (55-65%) by Hunt (1983).

CONCLUSIONS

The following conclusions may be drawn from the results discussed above.

1. Pressure had significant effect on spray angle, swath width, spray distribution, droplet size and discharge.
2. The measured droplet size varied from 72 µm to 460 µm. This shows that bigger droplet size can easily move down and lost to ground surface. Small droplets move along with air and lost by drift to non-targeted areas.
3. The patternograph indicated that the discharge was significantly less for radii greater than 15 cm from the center of the nozzle.
4. The nozzle discharge measured in the field increased from 0.5mL to 0.8 L min^{-1} when pressure increased from 250 to 350 kPa.
5. Variation in different operating parameters (discharge, spray angle, etc) was less along the boom at nozzle pressure of 350 kPa as compared to 250 and 300 kPa.
6. The field efficiency of self-leveling boom sprayer was about 50%, which is less than the recommended (55-65%). The reason for low efficiency may be a long boom, which affects the maneuverability of the sprayer in the field.

RECOMMENDATIONS

1. The sprayer should be operated at 350 kPa to minimize variation in discharge and pressure along the length of boom.
2. Imported hollow cone nozzles should be used in the field for better performance.
3. The weight of machine should be reduced for better field maneuverability.
4. The field efficiency of the sprayer is not sufficient. For better efficiency tank capacity, boom length and weight of the sprayer should be reduced.

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