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Effect of Disc Speeds and Discharge on Droplet Distribution Pattern of Spinning Disc Sprayer

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***Abstract* – The controlled droplet application technique means producing only the optimum sizes of spray droplet for a particular application is used in spinning disc sprayer. Controlled droplet application offers the way forward in improving spraying efficiency, eliminating waste and safeguarding the environment. Since there is no need to operate pump, the operator can spray more quickly, effectively and constantly on difficult terrain. Hand-carried spinning disc sprayer, have been used successfully to apply several standard wettable powder and emulsifiable concentrate formulations diluted in water for control of weeds, insects, pests and diseases on many crops (Matthews, 1982). The main aim of these sprayers is to reduce the need to carry large quantities of water and chemicals.. The minimum and maximum droplet density was found 21 and 329 droplets per cm^2 at rotational speeds 528 and 1583 m/min, respectively. Though droplet size (153 µm) and droplet density (167) per cm^2 were reasonable at disc speed of 6000 rev/min with the nozzle opening of 0.9 mm the application rate 12.17 l/ha is very less which will require very high concentration of pesticide. The high concentrated solution may be harmful to the operator. It is therefore recommended that the spinning disc sprayer with 1.5 mm opening and 6000 rev/min speed may be used. The droplet size of 159 µm and application rate of 29.55 l/ha are within acceptable limits.**

***Keywords* – Controlled Droplet Application Sprayer, Hand Sprayer, Low Volume Sprayer, Spinning Disc Sprayer.**

I. INTRODUCTION

The success of modern agriculture crop production can be partly attributed to the improving of pests and disease control. In a properly organized system, crop protection, therefore, is one of the most important means of increasing crop productivity. The spray fluid may be applied as sprays (very coarse sprays, coarse sprays, medium sprays or fine sprays). It is important to minimize the pesticide application rates and at the same time increase the application efficiency. The pesticides, insecticides, herbicides must be applied with suitable equipment in order to apply proper dose, to reduce the requirements of labour and hazards involved in application to provide comfort and to operate efficiently. To eliminate the problems of health hazards, environmental pollution and drudgery that are associated with high volume sprayers; low volume and ultra low volume sprayers were developed. The chemicals used for spraying are costly, so appropriate and effective equipment for uniform and effective application is essential. The liquid pesticides may be either contact or systematic type. Contact pesticides kill insects, weed, fungi etc by coming in contact with them. Contact type chemicals always require full coverage and normally achieved by small droplets produced by spraying machines. However, the systematic type of pesticide is taken in by the plant and full coverage is not required. The basic problem is to apply the required quantity of chemicals at the desired target with minimum wastage. Controlled droplet application (CDA) technique is used in spinning disc sprayer. Controlled droplet application means producing only the optimum sizes of spray droplet for a particular application. CDA offers the way forward in improving spraying efficiency, eliminating waste and safeguarding the environment.

Spinning disc provides a means of applying crop protection chemicals at volume rates lower than those possible with hydraulic nozzles. Hand-carried spinning disc sprayer, have been used successfully to apply several standard wettable powder and emulsifiable concentrate formulations diluted in water for control of weeds, insects, pests and diseases on many crops (Matthews, 1982). The main aim of these sprayers is to reduce the need to carry large quantities of water and chemicals. The small size of the droplets gives greater adherence to the surface on which they get deposited. The spray liquid required for spraying small droplets of diameter 100 µm and 200 µm are 5.238 and 41.90 l/min respectively (Matthews, 1982) indicating that application rate can be decreased significantly by applying sprays of smaller droplet size. Bode *et al.* (1972) conducted research on the effect of flow rate on the distribution pattern and droplet size spectrum of a spinning disc atomizer. The atomizer used was the radial type manufactured by Amchen products, Inc. Tests of the distribution patterns from the spinning atomizer were made at atomizer speeds of 2000, 3000 and 4000 rev/min, vehicle speed of 2 and 4 mph, and flow rates ranging from 30 to 90 ml/min.

II. REVIEW AND LITERATURE

Bouse et al. (1990) conducted a study on the effect of spray mixtures on droplet size. Water was used as the diluents in all the spray mixtures. A laser imaging spray droplet spectrometer system was used to measure the droplet size distribution. The effect of rice herbicide formulations, concentrations and tank mixtures; surfactants; polymers; and spray nozzle orientation in an air stream was determined in relation to the size of spray droplets produced by hollow cone nozzles. The study concluded that higher speed, increased nozzle orientation and different spray pressures reduced the droplet size, increased the percent of spray volume of small droplets, and increased the drift hazard.

Singh et al. (1992) conducted an experiment to evaluate the field performance of a hand held electrostatic spinning disc sprayer. The experiment was conducted to compare the deposition patterns of charged and uncharged sprays. The charged sprays were applied with a hand held electrostatic spinning disc sprayer and a standard knapsack type hydraulic nozzle sprayer. Target plants were rice, soybean and corn. The droplet density on water sensitive paper was determined at plants elevations. The result showed that the spinning disc sprayer showed better pattern, droplet size and coverage than the other sprayers.

Tajuddin, A. and Balasubramanian, M. (1994) carried out experiments on the atomization characteristics of a low volume spinning disc sprayer. A low volume spinning disc sprayer was developed and tested to study the effect of various spinning disc speed on droplet density, numerical mean diameter and volume mean diameter with different discharge rates at different sampling distance from the spinning disc. The droplet size distribution from a spinning disc atomizer depends on rotational speed or centrifugal force for a given rate of flow. Numerical mean diameter and volume mean diameter increased as the disc speed decreased. As the distance of capturing the droplets increased the discharge rate increased.

Qi Lijun et al. (2003) reported the spray pattern and drift potential of a spinning disc. A spinning disc may achieve a good droplet distribution with low volume spray method. The special spray pattern formed by the droplet atomized by a spinning disc have high potential to drift compared with that produced by hydraulic nozzles. The initial velocity of a droplet and the spray pattern of spinning disc were analyzed to estimate its characteristics in terms of droplet distribution and drift ability. Comparisons were made between spinning disc and standard fan nozzle to evaluate the drift potential of the spinning disc. Results showed that spinning disc was not suitable for target spraying when they are mounted in a boom, but might perform well on over all spray with low or ultra low volume spray, which would benefit in arid and semiarid areas.

III. MATERIAL AND METHODS

The instruments used and the methodology adopted to carry out the experiment for determining the distribution pattern of the spinning disc sprayer are presented as follows:

Laboratory testing

a) Independent variables

1. Disc diameter - 8.4 cm as supplied by the manufacturer.
2. The discharge to be varied by providing nozzles of following diameters: 0.9, 1.2, 1.5, 1.8 and 2.1 mm.
3. Peripheral speed of the disc: 528 (2000, rev/min), 792 (3000, rev/min), 1056 (4000, rev/min), 1319 (5000, rev/min) and 1583 m/min (6000, rev/min).

b) Dependent variables

1. Discharge
2. Droplet size

Instruments to be used

1. Tachometer
2. Potentiometer
3. Anemometer
4. Image analyser

Controlled droplet applicator (spinning disc sprayer): The spinning disc sprayer also known as controlled droplet applicator (CDA), an ultra low volume (ULV) sprayer is commercially available for application of pesticides, weedicides or other wettable agricultural chemicals. These sprayers have been developed especially for semi-arid climates, where availability of water is limited. The spinning disc sprayers are not very expensive. They are light in weight and are operated by a rechargeable battery. The sprayers are specially suited for spraying insecticides or fungicides in the field crops like cotton, pigeon pea, sorghum, millet, etc.

Construction and working principle of spinning disc sprayer: A commercially available spinning disc sprayer is shown in Fig 1. The sprayer basically consists of a bottle, disc, spray head, motor, nozzle, wire cord and terminals. When the spinning disc is in operating position the flow of the liquid from the bottle to the nozzle takes place due to gravity, which falls on the rotating disc. Due to the rotation of the disc and the serration on the edge of the disc the liquid is broken into droplets and is thrown away from the disc covering a distance of 0.5 to 1.25 m on either side. Thus the sprayer works on the principle of centrifugal energy.

Major components of the sprayer: The major components of sprayer are bottle, disc, spray head, dc motor, nozzle, wire cord handle switch and battery.

Anemometer: Anemometer is the device, which is used to measure the velocity of air. It consists of a low frictional ball bearing, which allows free vane movement, resulting in accuracy at both high and low velocities. The vane wheel is sensitive balanced, which freely response to air flows. The velocity of air measured is directly seen in the display. The velocity of air flowing from the spinning disc sprayer was measured with the help of anemometer. The velocity of air was measured at 0.5, 1, 10, 20, 30, 40, and 50 cm from the outer surface of the disc to study its dissipation pattern and ability to carry droplets.

Computerized image analyzer: Image analysis is the science of making geometric and densitometry measurements on images from any source. Its main application is in quantitative microscopy, providing rapid, accurate and satisfactory significant data, replacing the traditional subjective methods. The image analyser was used to measure the droplet size on the LEICA QWin software programme. The LEICA QWin is a window based image analysis toolkit running under the industry standard Microsoft Windows environment. LEICA QWin provides several classes of measurement ranging from interactive manual measurement of the object to fully automated 'hands-off analysis.

IV. Results and Discussion

Spray droplet distribution pattern: The number of droplets per unit area obtained at various rotational speeds of disc and nozzle opening gives the distribution pattern of the spray droplets. The data of droplet density (Table.1) showed that the number of droplets per cm^2 increases significantly with increase in discharge and peripheral speed of the spinning disc. The numbers of droplets per cm^2 are so high that they cross the recommended limits of 25-30 droplets per cm^2 for droplet size more than 200 μm and 50-100 droplets per cm^2 for droplet size 100-200 μm.

Conclusions

The number of droplets at higher speed of disc showed that there is possibility of over dozing of pesticides. The numbers of droplets per cm^2 were lowest (21) at 528 m/min disc speed for 0.9 mm nozzle opening. However the numbers of droplets per cm^2 were very high (329) at 1583 m/min disc speed for 2.1 mm nozzle opening. These results show that there exists great possibility to increase or decrease the number of droplets per unit area by adjusting the discharge of pesticide solution and speed of the disc. The Plate 1 shows that the droplets are not equally distant in the middle of swath particularly at higher discharge of liquid and higher speeds of the disc. Very high concentration of the droplets in the middle of spray pattern caused overlapping of the droplets and non-visibility of individual droplets.

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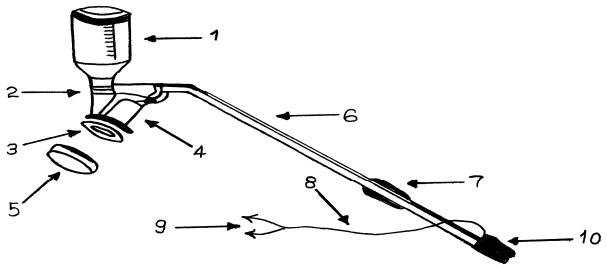

1.Bottle 2. Head 3. Disc 4. Motor 5. Cover 6. Handle 7. Handle grip 8. Wire cord 9. Connection to rechargeable battery 10. Switch.

Fig. 1.Components of spinning disc sprayer

Plate 1. Droplet distribution pattern for 1.2 mm nozzle opening at different speeds (A) 2000,rev/min (B) 3000,rev/min (C) 4000, rev/min (D) 5000, rev/min (E) 6000 rev/min.

Table 1. Effect of disc speeds and discharge on droplet distribution pattern

Nozzle opening, mm	Rotational speed, m/min	Discharge, ml/min	Droplet size, µm (Mean)	No. of droplets per cm^2
0.9	528	22.99	212	21
	792	23.55	167	82
	1056	24.31	159	108
	1319	24.87	155	136
	1583	26.64	153	167
1.2	528	36.79	219	47
	792	39.21	168	158
	1056	43.31	161	219
	1319	49.58	158	248
	1583	57.48	157	272
1.5	528	55.79	230	67
	792	58.21	174	195
	1056	62.31	171	262
	1319	69.00	161	294
	1583	77.48	159	304
1.8	528	76.06	239	78
	792	81.88	180	210
	1056	90.17	172	280
	1319	101.00	164	315
	1583	108.00	161	322
2.1	528	98.00	250	88
	792	107.87	189	223
	1056	114.23	181	295
	1319	124.53	171	322
	1583	132.00	170	329

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