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PERFORMANCE TEST OF A DUAL-PURPOSE DISC AGROCHEMICAL APPLICATOR

Abubakar, M. S.
Department of Agricultural Engineering, Bayero University, Kano-Nigeria
abubakarms@gmail.com

ABSTRACT
The performance test of a dual-purpose disc agrochemical applicator for field crop was conducted with view to assess the distribution patterns/droplet sizes and uniformity of spreading and or spraying for the agrochemical application. The equipment performances for both granular and liquid chemical application were assessed and reported. Results obtained for NPK granular chemical indicate that at low (50 kg/ha) and high (150 kg/ha) application rates and 550 rpm disc speed, mean distribution pattern skewed to the left. The mean distribution pattern shape at medium (100 kg/ha) application rate was flattop; whereas for the HC amine 48 liquid chemical herbicide application, the average values of volume median diameter (VMD) and number median diameter (NMD) were 106 µm and 76 µm at 90 lt/ha application rates and 5000 rpm disc speed and 190 µm and 120 µm at 90 lt/ha application rates 2000 rpm disc speed, respectively. Results from the experimental tests shows that the average effective field capacity for the equipment with a prime mover was found to be 0.89 ha/hr or 7.12 ha/man-day for a 8 hour working day. It was concluded that the dual purpose disc agrochemical applicator could be used for the application of both granular and liquid chemicals by the rice growers.
Keywords: Performance test, Dual-purpose, Disc, Agrochemical applicator.

INTRODUCTION

One of the major problems of rice production is the shortage of labour resulting from migration from rural to urban areas, making it very difficult to meet peak demands for rice production. Thus, agricultural mechanization is needed to replace the labour which is not available or is very expensive (Chan and Cheong, 1986; Kanetani and Fauzi, 1991). In Malaysia, rice production power-intensive operations such as water pumping, land preparations, transplanting seedlings, harvestings and threshing are being mechanized but other operations like fertilizer and chemical (pesticides) applications are not yet fully mechanized, rather they are performed manually with motorized backpack knapsack sprayers which have many disadvantages. These include; lack of uniformity of input distribution applied to the crops, depending on high number of labour and drudgery in handling and loading of inputs on the field (Kanetani and Fauzi, 1991). Several authors have reported the problems of particle dynamics on a spinning disc in their studies of the impact of different parameters on the spreading and improvement on operation/control of centrifugal fertilizer spreaders in agriculture (Aphale *et al*., 2003; Olieslagers *et al*., 1996; Van Liedekerke *et al*., 2006; Van Liedekerke *et al*., 2009). Patterson and Reece (1962) examined the sliding motion and rolling motion of a single spherical granular material on a flat rotary disc equipped with radial straight vanes while neglecting particle bounce and assuming a near center feed. They also reported that the particle's radial velocity depends on the shape and the friction coefficient between a granular material and a rotary disc. For the same disc configuration, Inns and Reece (1962) showed that if a granular material begins its motion at a certain distance from the center of the disc, friction between the granular material and rotary disc can be neglected because the vertical velocity of the granular material is not lost on impact. Due to the physical discomfort and awareness of health risk associated with granular fertilizer and pesticide application such as operators' hazard when having direct contact with chemicals during field operation (Juste *et al*., 1990; Matthews, 2000). Nowadays, there has been a growing concern about the environmental problems (such as air and water pollution and decline in biodiversity) associated with the application of mineral fertilizer and pesticides (Matthews, 2000). For these reasons, accurate and uniform application of fertilizer/pesticides is absolutely important in minimizing environmental problems and costs. Consequently, the application methods of fertilizer/pesticides and the uniformity of the spread pattern have become important research topics in agricultural engineering (Juste *et al.,* 1990). Pearson *et al.* (1981) found that spinning disc sprayers gave effective spray droplets with 250 µm VMD than lower values of VMD. Ilhan *et al.* (2004) reported that 250-500 µm drop diameters for herbicide applications which is easier to deliver to the target surfaces. The high volume application methods used by some farmers to apply chemicals could result in higher costs compared to using low volume method, hence the development of dual purpose equipment for granular fertilizer and pesticides application in the paddy field. Despite the fact that there are many equipment developed to distribute granular material, none has been developed to date which can effectively spread granular material such as granular fertilizer and as well as spray liquid materials such as, liquid herbicides in the rice crop production processes.

Furthermore no equipment have been developed commercially which can distribute non- pressurized liquid on the crops. Most available liquid spreaders distribute liquid under pressure by nozzles and backpack with some type of pumping device which help to maintain enough pressure to push the liquid out of the nozzles on the crops. These pressurized devices make it very difficult to control the distribution, resulting inconvenient in backing heaving weight equipment, operator health hazard, spray drift hazard, and consequently damaging the crop and the environment. The objective of this paper is to assess the performance of a dual-purpose disc agrochemical applicator for field crops in respect to the distribution patterns/droplet sizes and uniformity of spreading and or spraying for the chemical application.

MATERIALS AND METHODS

Description of the dual-purpose disc agrochemical applicator

The dual-purpose disc agrochemical applicator consists of a hopper, orifices, discs and variable speed electric motor (Plate 1). The applicator employs the use of two discs rotating in an opposite direction driven by 0.204 hp electric motors (TM80-15150) and the rotational velocity can be varied continuously from almost zero to above 5000 rpm by means of a rheostat speed controller. Chemical materials (granular or liquid) inside the hopper fall freely by gravity through the orifices and drop directly on the rotating discs (impeller) subsequently are applied to the field. The disc is fitted with vanes for granular application and rotates at a speed of 550 and 1000 rpm while for liquid a plane flat disc rotates at a speed of 2000 and 5000 rpm to atomize liquid into fine spray.

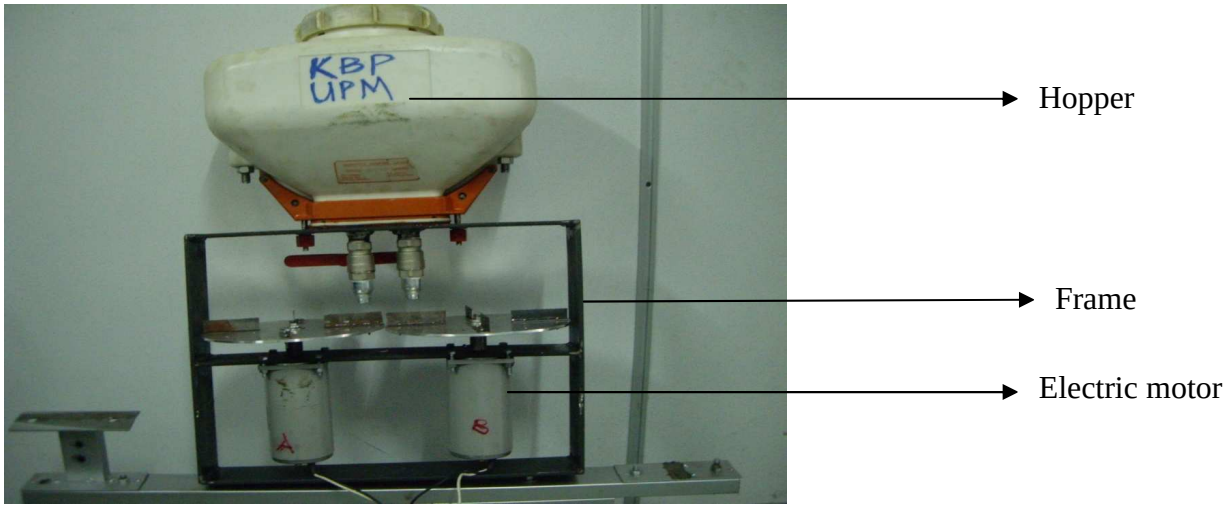


Plate 1: Photograph of the dual-purpose disc agrochemical applicator

Rotary disc and chemical (granular and liquid) characteristics (such as cone angle, disc diameter, vane length, particle size, moisture content, density, viscosity, surface tension, coefficient of friction) were taken into consideration during the equipment development. The detailed procedures are as reported in Inns and Reece (1962) and Abubakar *et al.* (2011). The agrochemical applicator performance tests (Plates 2 and 3) were conducted as recommended by ASAE Standard S341.4 Procedure for Measuring Distribution Uniformity and Calibrating Granular Broadcaster Spreaders in which array of collection trays were used for performing the tests (ASAE, 2009). This is because outdoor testing is the most representative of what performance is achievable in the field. A total of 36 transverse tests were conducted. Six tests each for both NPK granular chemical and HC amine 48 liquid chemical were carried out. Each test was repeated three times and the mean values were reported. The coefficient of variation (CV) (%) for the transverse spread pattern is commonly used to ascertain an acceptable working (swath) width for the agrochemical applicator. The CV (%) is the measure of the overall uniformity of the chemical application distribution pattern and was determined by overlapping the transverse distribution pattern at meter intervals working widths, the sample mean and standard deviation of the overlapped application rate were divided. The lower the CV (%), the more uniform the distribution pattern.

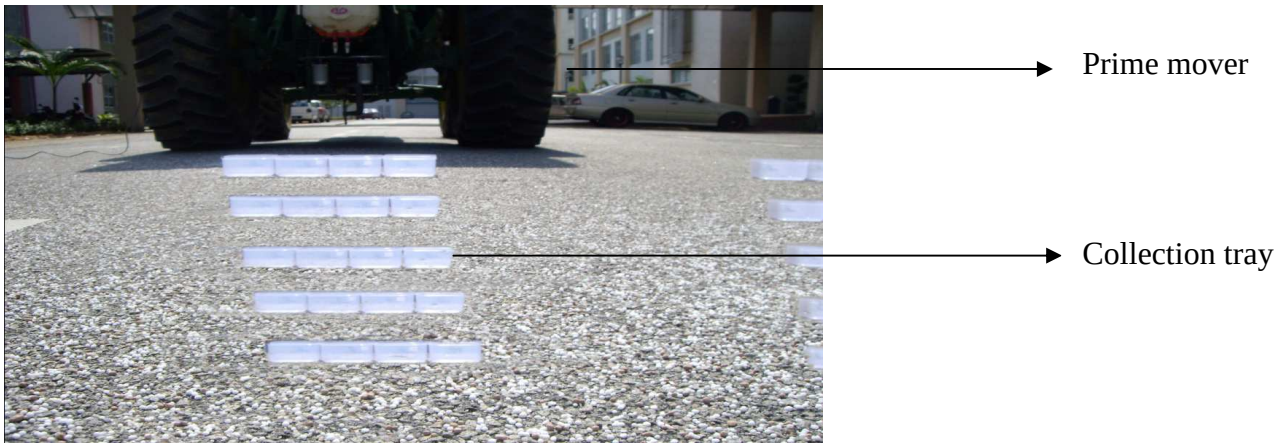
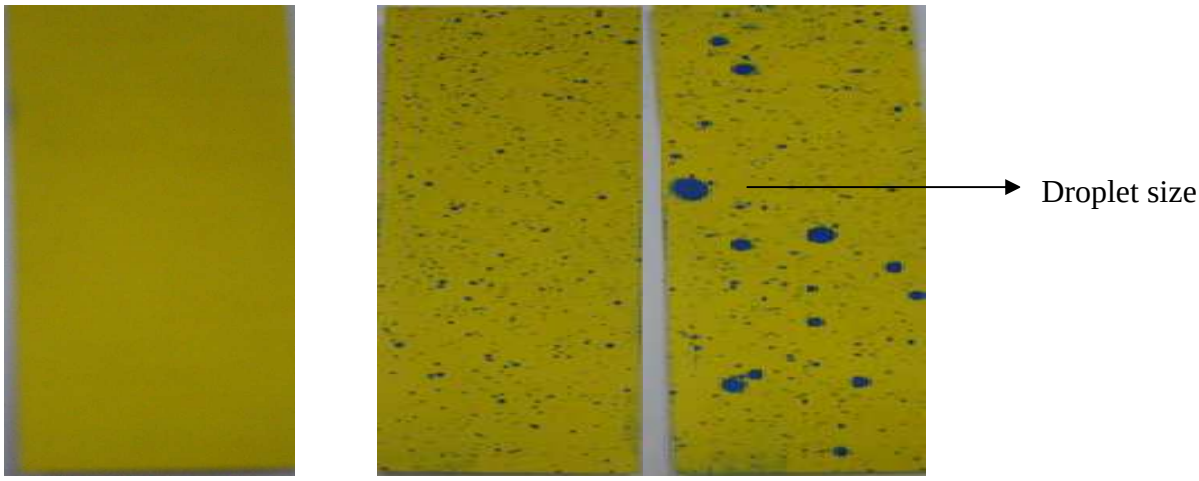


Plate 2: Collection trays arranged to capture the granular fertilizer distribution pattern



(a) (b)

Plate 3: Water-sensitive paper used to capture liquid droplet distribution size/uniformity (a) before, and (b) after liquid chemical

This study uses water-sensitive paper (WSP) to evaluate the droplet sizes formed by the dual-purpose rotary disc chemical applicator. The water-sensitive paper images were captured using high resolution camera 1:1.4/12.5m (HF12.5HA-1B) after allowed to dry for 30 minutes and then were scanned using Program FlexScan 2D. The percentage spray droplets cover, number of droplets per square centimeters, size distribution of droplets and volume/mass deposited, droplet density per unit area, the VMD and NMD of their spectrum on each paper were estimated and analyzed using Matlab software program. The VMD and NMD of the spray droplet spectrum were determined to ascertain the spray characteristics. Before the experiment the applicator was calibrated into three different flow rates for both granular and liquid chemicals. The openings of the orifices for the applicator were set at position low (50 kg/ha), medium (100 kg/ha) and high (150 kg/ha) for NPK granular fertilizer and low (50 lt/ha), medium (70 lt/ha) and high (90 lt/ha) for HC amine 48 liquid chemical herbicide. These application rates were obtained from the adjusting of the chemical flow onto rotary discs by manually operated valves to achieve constant application rate and were deemed as typical target operator of the equipment. The disc speed was set at 550 and 1000 rpm and 2000 and 5000 rpm for NPK granular chemical and HC amine 48 liquid chemical, respectively. Analysis of variance (ANOVA) was conducted for each of these uniformities using SAS 9.1 statistical software to identify statistical significant differences between the various combinations.

RESULTS AND DISCUSSION

Tables 1 and 2 show the mean values of the coefficient of variation (CV) (%) for the urea granular distribution uniformity and the volume median diameter for the liquid chemical. The CV of 18% was obtained at the overlapping transverse distance of 2 m and combinations of 550 rpm disc speed and 100 kg/ha application rate (Table 1).

Table 1: Average values of coefficient of variation (CV) (%) at different disc speeds and application rates for the NPK granular chemical

Disc speed (rpm)	Application rate (kg/ha)	Coefficient of variation (CV) (%)	Distance (m)
550	50	24	3
	100	18	2
	150	45	5
1000	50	27	4
	100	40	4.5
	150	65	6.5

Table 2: Average values of VMD, NMD, and ratio of VMD/NMD at different disc speeds and application rates for HC amine 48 liquid chemical

Disc speed (rpm)	Application rate (lt/ha)	Mean VMD (µm)	Mean NMD (µm)	CU (VMD/NMD)
2000	50	275	182	1.51
	70	220	150	1.47
	90	190	120	1.58
5000	50	184	125	1.47
	70	136	94	1.45
	90	106	76	1.39

Table 2 presents the average values of volume median diameter (VMD), number median diameter (NMD), and ratio for coefficient of uniformity (CU) VMD/NMD for HC amine 48 liquid chemical herbicide. The average values of VMD and NMD obtained were 106 and 76 µm at 90 lt/ha application rate and 5000 rpm disc speed and 190 and 120 µm at 90 lt/ha application rate 2000 rpm disc speed. The average values for coefficient of uniformity of the droplet spectrum (CU) expressed as VMD/NMD were found to be in the range from 1.39 to 1.58 for HC amine 48 liquid chemicals respectively. The best liquid chemical coefficient of uniformity (CU) (1.39) was obtained at the combinations of 5000 rpm disc speed and 90 lt/ha application rate (Table 2). This findings is in agreement with the study conducted by Lefebvre (1993). It was observed that 79% of the droplets size produced with both liquid chemicals were within 100-250 µm whereas the balance percentage was above 250 µm. This shows that the dual-purpose disc agrochemical applicator converts more liquid into fine droplets in comparison with that of reported results for manual knapsack with flat fan pressure nozzles sprayers with 60-70% droplets larger than 250 µm. Results for the NPK granular chemical show that an increased in application rates and disc speed caused the change in mean distribution patterns (Figures 1 & 2). Figure 1 shows that at low (50 kg/ha) and high (150 kg/ha) application rates and 550 rpm disc speed distribution pattern skewed to the left. Whereas the mean distribution pattern shape at medium (100 kg/ha) rates was flattop (Figure 2). It was observed that as the application rate increased from low, through the medium to high, the mean distribution pattern changed from low left sided to devastating peaks in the center pattern. Results of the present experiment also revealed that when the application rate increased together with the increase of disc speed, the mean distribution pattern became worst more and more. This agreed with the work of Aphale *et al.* (2003) that reported that the mean distribution width increased with an increase in the disc rotational speed. Grift *et al.* (2006) also reported that the distribution pattern uniformity is sensitive to some variations such as the increased in rotational speed of the disc.

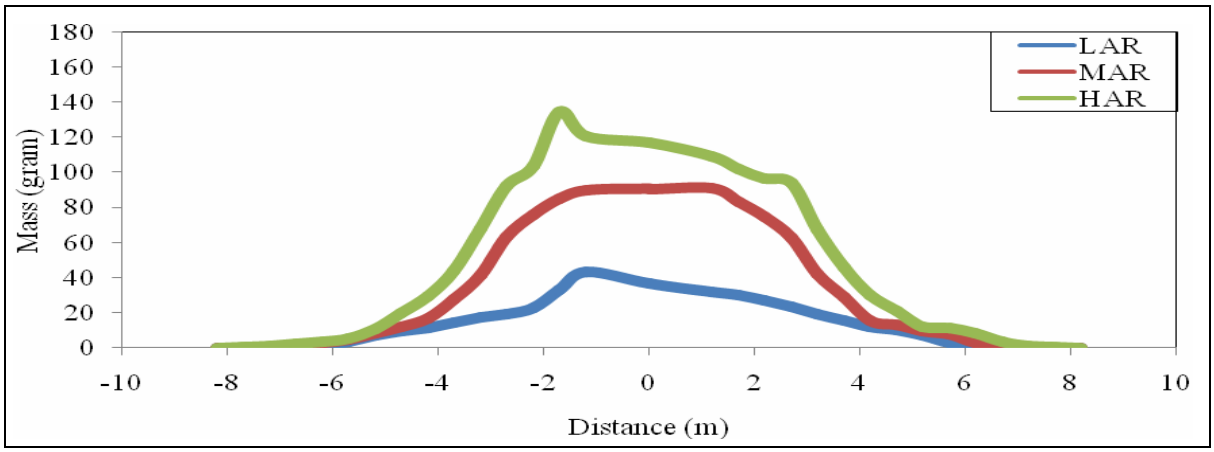


Figure 1: NPK granular distribution patterns for low, medium and high application rates at 550 rpm disc speed

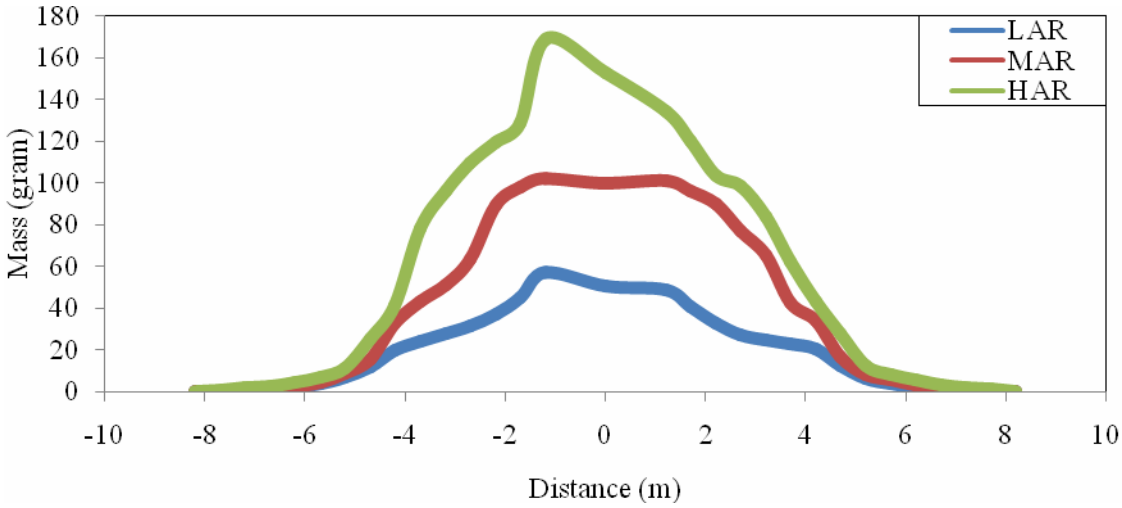


Figure 2: NPK granular distribution patterns for low, medium and high application rates at 1000 rpm disc speed

Key: LAR = low application rate at 50 kg/ha, MAR = median application rate at 100 kg/ha, HAR = high application rate at 150 kg/ha

Plate 5 presents the droplet size volume median diameter (VMD) at 90 lt/ha application rate 2000 rpm disc speed. Plate 6 shows that the droplet size VMD at 90 lt/ha application rate and 5000 rpm disc speed. It was found that the VMD of the spray droplet sizes decrease with increasing liquid flow (application) rate and disc speed. This shows that the dual-purpose disc agrochemical applicator converts more liquid into fine droplets in comparison with that of reported results for motorized knapsack with flat fan pressure nozzles sprayers with 60-70% droplets larger than 250 µm (Matthews, 2000). Also the result in this study was similar to that of Lefebvre (1993) whose found out that droplets size in the range of 120 to 300 micron in VMD be the most effective for chemical application. Also the equipment average effective field capacity for the agrochemical application using high clearance tractor was 7.12 ha/man-day for a 8 hour working day, compared to the motorized knapsack sprayer in addition to cost of labour, covered only 1.2 ha/man-day which is 6 times lower than when the new equipment was used. Statistically, the effect of flow rate and disc speed was significant at $P < 0.01$ level for all combinations.

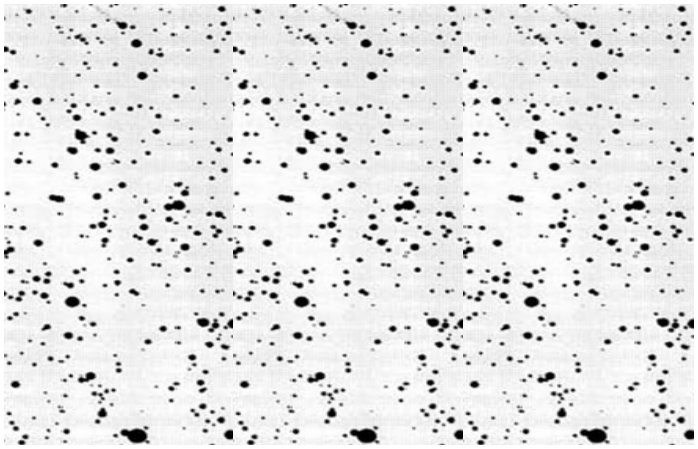


Plate 5: HC amine 48 liquid chemical spray droplets size VMD at 90 lt/ha rate and 2000 rpm disc speed

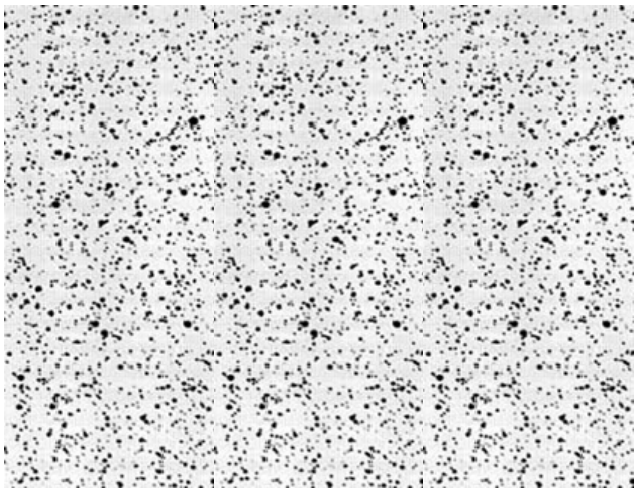


Plate 6: HC amine 48 liquid chemical spray droplets size VMD at 90 lt/ha rate and 5000 rpm disc speed

CONCLUSION

The following conclusions were drawn this study:

1. The study revealed that the new developed equipment (dual-purpose disc agrochemical applicator) could apply chemical (both granular and liquid) with better uniformity and higher economical benefit than the manual or motorized backpack chemical applicator.
2. The distribution patterns/droplet sizes and uniformity of spreading/spraying of the dual-purpose disc agrochemical do vary with change in application rate and disc speed, also a spray of almost uniform drop size is formed when a liquid chemical is atomized under suitable conditions and the machine has the potential of addressing the risk to human health and the environment.
3. The study shows that the dual-purpose disc agrochemical applicator converts more liquid into fine droplets in comparison with that of reported results for manual knapsack with flat fan pressure nozzles sprayers with 60-70% droplets larger than 250 µm.

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