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Research Article

Optimization of Nozzle Characteristics for Different Type of Sprayers

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ABSTRACT

Three different types of sprayers were evaluated in the laboratory for optimization of nozzle characteristics viz., pressure (3, 4, 5 kg cm-²) and nozzle height (53, 54.5 and 56 cm) in relation to discharge rate (l min-1), swath width (cm), spray angle (degree) and spray pattern. The swath width, spray angle and discharge rate increased with increase in pressure from 3 to 5 Kg cm^{-2} and height of nozzle from 53 to 56 cm for all types of sprayers. The coefficient of variation (CV) in spray distribution for all the three sprayers nozzle was influenced by the pressure. The coefficient of variation of self propelled high clearance sprayer (24.55) was less as compared to lever operated knapsack (53.97) and tractor operated gun sprayer (52.14). The lever operated knapsack and tractor operated gun sprayer performed better at pressure of 3 and 4 Kg cm^{-2} and nozzle height of 53 and 54.5 cm, respectively. The self propelled high clearance sprayer gives best results at a pressure of 5 Kg cm^{-2} and nozzle height of 53 cm.

Keywords: *Bio-efficacy, Droplets, Efficiency, Sprayer, Uniformity.*

INTRODUCTION

Cotton is the principal commercial crop and widely cultivated across the world in 70 countries over an area of 31.8 million hectares. India ranks first in terms of area under cultivation (11.3 million hectares) and production (6132 million kg). India produces one fourth of total global cotton production (Anonymous, 2018). There is significant growth in production, productivity and quality of Indian cotton during the last 50 year, but it is still way below the world average productivity and far below the general quality requirements (Gholap et al., 2012). The productivity of cotton in India was 541 kg ha^{-1} which is much lower than other top cotton growing countries like China (1558 kg ha^{-1}), USA (1000 kg ha$^{-1)}$, Brazil (1561 kg ha^{-1}), Australia (1737 kg ha^{-1}) and Pakistan (717 kg ha^{-1}) during 2018 (Anonymous, 2018). The main reason for low productivity was poor control of insects and pests, weed infestation and dry land farming conditions (Anonymous, 2016). The losses occurred in cotton due to insects and pests varied from 18.0 to 50.0 % (Dhaliwal et al., 2010).

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Spray technology plays an important role to minimize spray and to maintain biological efficacy (Zande et al., 2008). There are several types of sprayers available in the market to protect the crops from insects and pests. The performance of sprayer depends on many technological, technical and environmental factors. These include type of nozzles, appropriate spray parameters, temperature, and humidity as well as the instructions of plant protection products (Koszel, 2015). The problem of over dosage of pesticide is common in many countries and its application leads to wastage of costly chemical and environmental pollution from spray drift (Patel *et al*., 2016), which severely affects human and animal health The new concept of spraying is to spray the target pest more efficiently by selecting the optimum droplet size and density for maximum coverage. The spray distribution and plant coverage mainly dependent on factors such as droplet diameter, droplet density, droplet velocity, Physio-chemical properties of spray, density of plants, surface characteristics of foliage and meteorological conditions at time of spray application (Salyani et al., 2007, Giles et al., 2008, Guler et al., 2012). Therefore, there is a need to optimize spray parameters as pressure, nozzle height, swath width and discharge for improving the effectiveness of spray in cotton crop under local conditions for different type of sprayers.

MATERIALS AND METHODS

The different types of sprayers are evaluated in laboratory of testing center of Department of Farm Machinery and Power Engineering, COAE&T, CCS HAU, Hisar, Haryana, India for optimization of nozzle characteristics *viz*., pressure (3, 4, 5 kg cm^{-2}) and nozzle height (53, 54.5 and 56 cm) in relation to discharge rate (l min^{-1}), swath width (cm), spray angle (degree) and spray pattern.

Sprayers used

Three types of sprayer namely lever operated knapsack sprayer, tractor operated gun sprayer and self-propelled high clearance sprayer were selected for the study. A lever operated knapsack sprayer was consisted of a cylinder, a piston type pump, water tank (15 liter), lever, strainer, and spray lances, water cuts off valve and a solid cone nozzle made of brass. A tractor operated gun sprayer consisted of 500 liter polyethylene tank, pump (piston type), a gun type nozzle and arrangement for bundling the pipe. The self propelled high clearance sprayer consisted of two polyethylene tank having a capacity of 500 liters, a plunger type pump, controlling unit, filling unit and spraying nozzles. A total of 13 solid cone nozzles was mounted on a folding type boom fixed at a spacing of 67.50 cm.

Instruments used

A spray patternator was used to find the spray angle, spray pattern and a swath width of the nozzle (*i.e.* nozzle characteristics). It consists of piston type pump, water regulating valve, cutoff valve, pressure gauge and 36 V-shape channels (spacing 48 mm) for conveying the water to the glass tubes. The height and width of the nozzle assembly were adjustable.

Performance parameters

Discharge rate

The nozzle was mounted on the patternator and the pump was started. The liquid flow was set at a particular pressure. When the pressure of liquid flowing through nozzle gets stabilized, the discharge of liquid through a single nozzle was collected for one minute in the measuring glass and volume of collected liquid was noted. The process was repeated three times at each working pressures of 3.0, 4.0 and 5.0 kg cm^{-2}. The average volume of collected liquid at each pressure per unit time was the discharge rate at that pressure.

Swath width

The average width covered by the liquid sprayed from the nozzle from a height of 53, 54.5 and 56 cm above the surface at each pressure was termed as the swath width at that pressure and height of the nozzle. When the spray pattern of nozzle gets stabilized, we put the straight, plumb on the channel surface. After one second we withdraw the plumb and measure the width of the spray. The swath width was measured by measuring the distance between the outermost channels in which liquid was sprayed on either side of the nozzle over patternator. This process was repeated three times at the working pressures to measure the swath width of nozzle at that pressure and height.

Spray angle

The angle made from the liquid coming out of the nozzle at each operating pressure was measured and termed as the spray angle at that pressure. The spray angle was also calculated by the tangent to the height of the nozzle and half of the swath width.

Spray pattern

The nozzle was mounted at three different heights 53, 54.5 and 56 cm on the patternator. At pressure settings of 3.0, 4.0 and 5.0 kg cm^{-2}, liquid was sprayed from the nozzle. The sprayed liquid in one minute was collected from each channel of the patternator in the glass tubes and volume of liquid collected in the each tube was recorded. Each experiment was repeated three times. The average volumes of collected liquid from each channel were used to determine spray distribution pattern and the coefficient of variation (C.V.) of the sprayer.

RESULTS AND DISCUSSION

Discharge rate, spray angle and swath width at different height of single nozzle

The solid cone nozzle for self propelled high clearance sprayer and lever operated knapsack sprayer were operated at different pressures for one minute. The discharge from a selected solid cone nozzle at different operating pressures was studied. The discharge increased from 1445 to 1835 ml min^{-1} and 640 to 850 ml min^{-1} for lever operated knapsack sprayer and self propelled high clearance sprayer, respectively, with increase in pressure from 3 kg cm^{-2} to 5 kg cm^{-2} (Table 1). Similarly, the spray angle increased from 71 to 87 degrees and 70 to 83 degrees for lever operated knapsack sprayer and self propelled high clearance sprayer, respectively with increase in pressure from 3 to 5 kg cm^{-2}. Similarly, for tractor operated gun sprayer, the discharge increased from 1700 to 1990 ml min^{-1} and spray angle increased from 72 to 83 degrees with increase in pressure from 3 to 5 kg cm^{-2}, respectively and the maximum discharge occurred at the center of the nozzle. The discharge and spray angle increased with an increase in operating pressure for all three sprayers. The swath width of lever operated knapsack sprayer, tractor operated gun sprayer and self propelled high clearance sprayer increased from 74 to 83 cm, 72 to 84 cm and 70 to 83cm with an increase in nozzle height from 53 to 56 cm and pressure from 3 to 5 kg cm^{-2}, respectively. The swath width increased with increase in pressure and nozzle height for all types of sprayers. Large swath width at higher pressure with high heights could be achieved, but that would cause wastage of pesticides due to drift. The discharge rate of tractor operated gun sprayer was higher as compared to other two sprayers. Singh et al. (2002) and Narang et al. (2015) also analyzed that with an increase in pressure, discharge rate, spray angle and swath width increased for all types of sprayers.

Spray distribution by single nozzle

The spray distribution pattern of different type of spray nozzles was studied and observed that the minimum volume of spray was collected at the outer edges, which increased towards the focal point of the nozzle (Fig 4.1 to Fig 4.9). The average value of liquid collected from each channel of patternator into glass tubes was used to calculate the coefficient of variation in the spray distribution (Table 2). The coefficient of variation for lever operated knapsack sprayer, tractor operated gun sprayer and self propelled high clearance sprayer varied from 53.97 to 74.74, 51.95 to 78.51 and 24.55 to 36.71, respectively. The lever operated knapsack sprayer performed better at a pressure of 3 kg cm^{-2} and nozzle height of 53 cm. The tractor operated gun sprayer performed better at 4 kg cm^{-2} pressure and nozzle height of 54.5 cm. Similarly, the solid cone nozzle for self propelled high clearance sprayer performed better at 5 kg cm^{-2} pressure at a height of 53 cm. Hassen et al. (2013) observed that by increasing nozzle angle and pressures the value of the coefficient of variation decreased.

Table 1: Effect of pressure and nozzle height on nozzle characteristics

Pressure ($Kg\ cm^{-2}$)	Nozzle Height (cm)	Swath Width (cm)	Discharge Rate ($ml\ min^{-1}$)	Spray angle (degree)
Lever operated knapsack sprayer				
3	53	74	1445	71-73
	54.5	78		
	56	80		
4	53	76	1750	s79-82
	54.5	77		
	56	81		
5	53	77	1835	84-87
	54.5	80		
	56	83		
Tractor operated gun sprayer				
Pressure ($Kg\ cm^{-2}$)	Nozzle Height (cm)	Swath Width (cm)	Discharge Rate ($ml\ min^{-1}$)	Spray angle (degree)
3	53	72	1700	72-74
	54.5	78		
	56	80		
4	53	74	1910	75-77
	54.5	77		
	56	82		
5	53	75	1990	80-83
	54.5	80		
	56	84		
Self propelled high clearance sprayer				
Pressure ($Kg\ cm^{-2}$)	Nozzle Height (cm)	Swath Width (cm)	Discharge Rate ($ml\ min^{-1}$)	Spray angle (degree)
3	53	70	640	70-73
	54.5	74		
	56	78		
4	53	72	750	77-80
	54.5	77		
	56	80		
5	53	75	850	81-83
	54.5	80		
	56	83		

Table 2: Effect of nozzle height and pressure on spray distribution

Lever operated knapsack sprayer			
Nozzle Height (cm)	Pressure (kg, cm^{-2})	Standard deviation	Coefficient of variation (%)
53	3	47.80	53.97
	4	65.97	70.02
	5	68.14	70.32
54.5	3	45.66	54.88
	4	62.57	63.77
	5	62.89	68.93
56	3	69.01	69.33
	4	64.12	68.45
	5	77.10	74.74
Tractor operated gun sprayer			
Nozzle Height (mm)	Pressure (kg, cm^{-2})	Standard deviation	Coefficient of variation (%)
53	3	29.88	53.17
	4	37.76	54.96
	5	40.97	62.12
54.5	3	28.20	52.14
	4	36.31	51.95
	5	40.45	56.70
56	3	28.59	78.51
	4	40.36	57.97
	5	41.96	60.92
Self propelled high clearance sprayer			
Nozzle Height (mm)	Pressure (kg cm^{-2})	Standard deviation	Coefficient of variation (%)
530	3	16.15	32.19
	4	16.86	36.71
	5	13.16	24.55
545	3	15.31	32.51
	4	16.38	35.64
	5	16.57	33.77
560	3	14.28	33.02
	4	14.12	30.53
	5	16.45	35.96

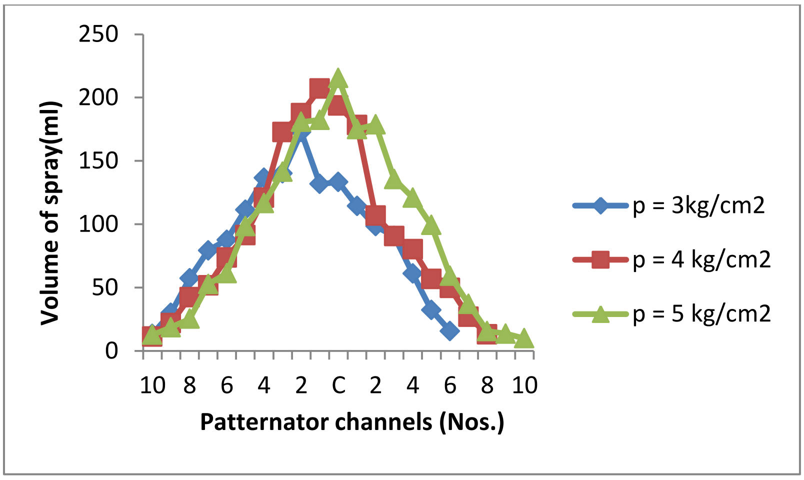

Fig. 1: Spray distribution of Lever operated knapsack sprayer when nozzle at 53 cm height

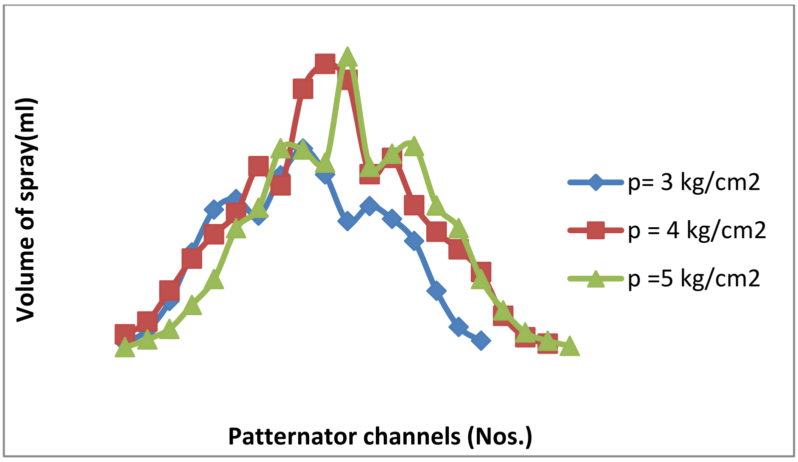

Fig. 2: Spray distribution of Lever operated knapsack sprayer when nozzle at 54.5 cm height

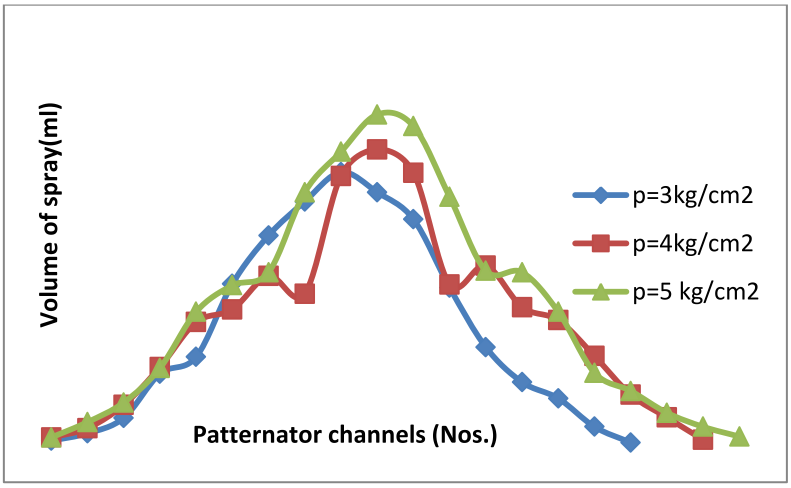

Fig. 3: Spray distribution of Lever operated knapsack sprayer when nozzle at 56 cm height

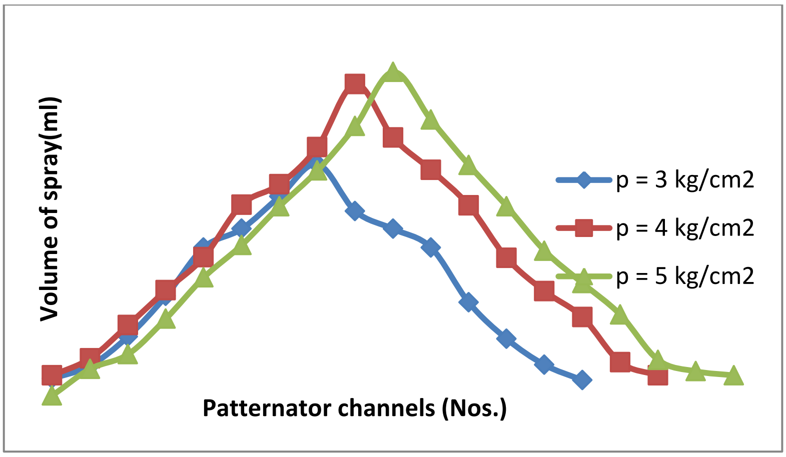

Fig. 4: Spray distribution of Tractor operated gun sprayer when nozzle at 53 cm height

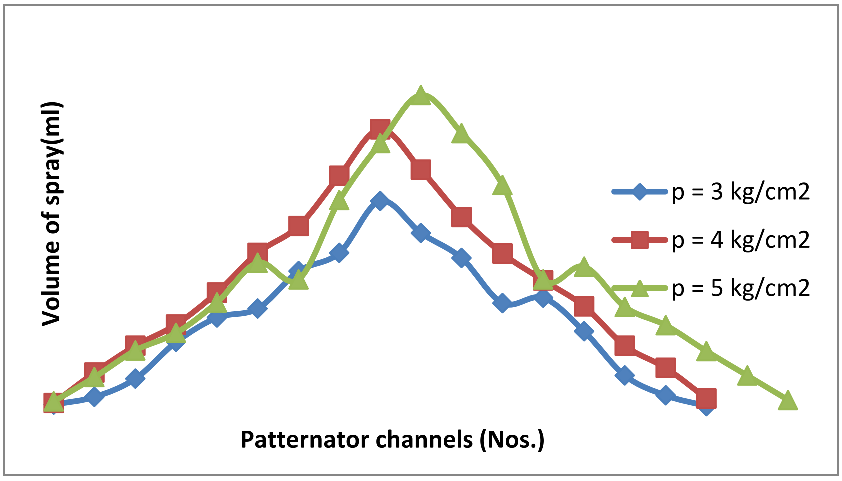

Fig. 5: Spray distribution of Tractor operated gun sprayer when nozzle at 54.5 cm height

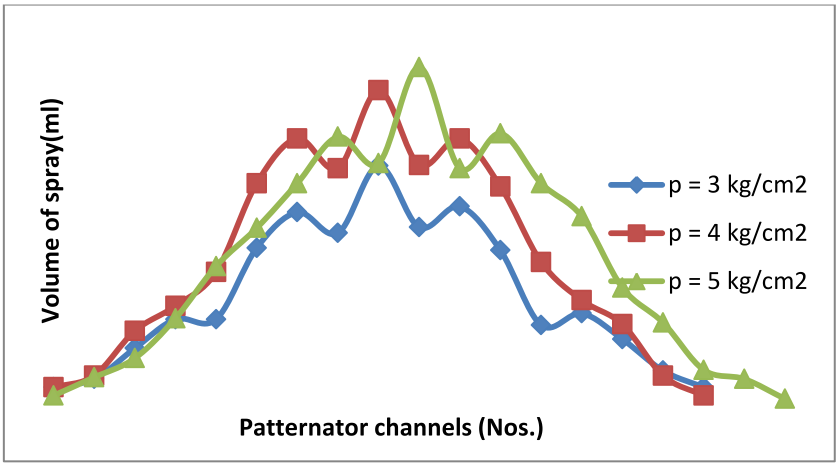

Fig. 6: Spray distribution of Tractor operated gun sprayer when nozzle at 56.0 cm height

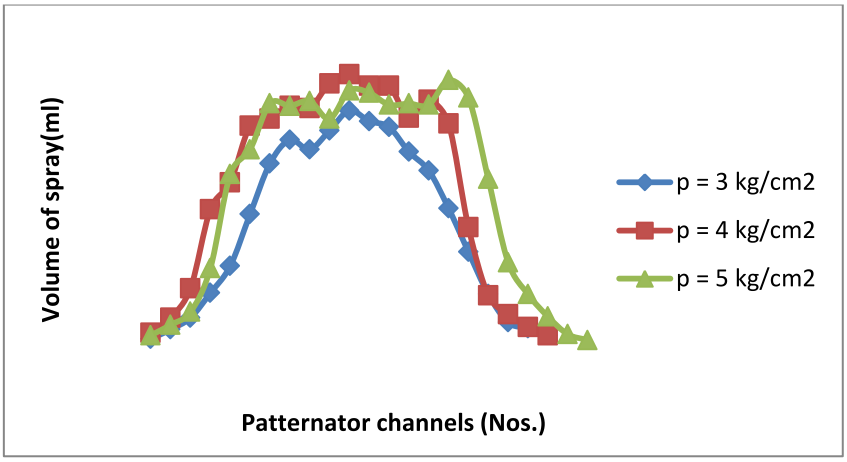

Fig. 7: Spray distribution of Self propelled high clearance sprayer at 53.0 cm nozzle height

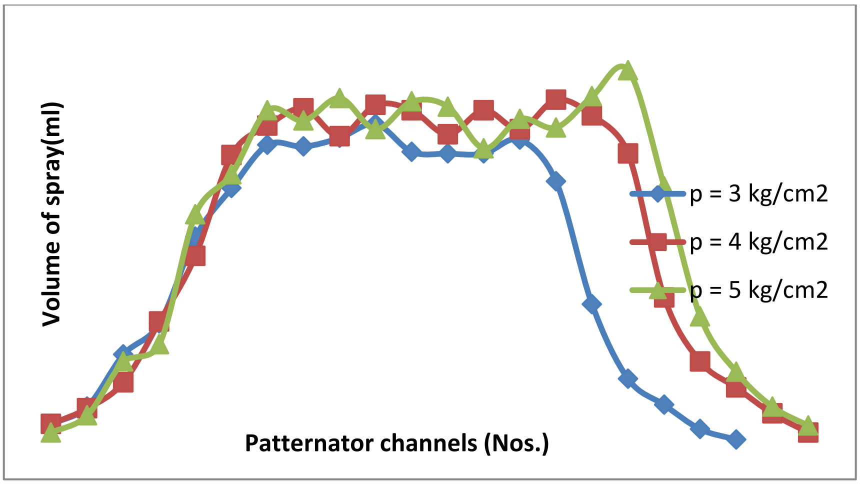

Fig. 8: Spray distribution of Self propelled high clearance sprayer at 54.5 cm nozzle height

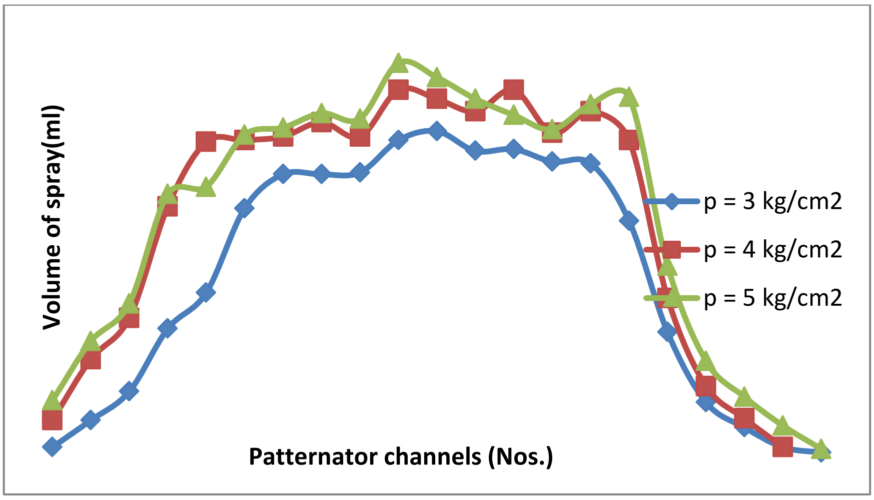

Fig. 9: Spray distribution of Self propelled high clearance sprayer at 56.0 cm nozzle height

CONCLUSION

With an increase in pressure from 3 to 5 kg cm^{-2} and height of nozzle from 53 to 56 cm swath width, spray angle and discharge rate increased for all the three sprayers' nozzles. The coefficient of variation (CV) in spray distribution for all the three sprayers nozzle was influenced by the pressure. The coefficient of variation of self propelled high clearance sprayer (24.55) was less as compared to lever operated knapsack (53.97) and tractor operated gun sprayer (51.95). The lever operated knapsack sprayer and tractor operated gun sprayer performs better at pressure of 3 and 4 Kg cm^{-2} and nozzle height of 53 and 54.5 cm, respectively. The self propelled high clearance sprayer gives best results at a pressure of 5 Kg cm^{-2} and nozzle height of 53 cm.

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