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Development and evaluation of multi nozzle backpack type power sprayer

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ABSTRACT

The study deals the development and evaluation of a multi-nozzle backpack type power sprayer, which can be used to spray at all stages of cotton crop by using the boom both in horizontal (during early stages of crop) and in vertical (during maturity stage) position. Three types of nozzles N1, N2 and N3 were evaluated in the laboratory at three pressures P1 (3.0 kg/cm^2), P2 (4.5 kg/cm^2) and P3 (6.0 kg/cm^2) and at three target distances D1 (540 mm), D2 (340 mm) and D3 (250 mm). Based on laboratory results, rate of discharge, angle of spray and swath width were found non-significant for nozzle N1 and N3. Therefore, nozzle N1 and nozzle N2 were selected for spraying on cotton crops at different stages of growth (60, 75, 90 and 105 days after sowing).Water sensitive paper was fixed on the plant at three locations of canopy (up and down of leaf). Uniformity coefficient and droplet density varied from 1.19 to 2.91 and 34.33 to 76.67. However, at a particular stage of crop the uniformity index and droplet density for some combination of locations was found non-significant. Field capacity of Nozzle N1 and N2 decreased from 0.34 ha/h to 0.09 ha/h and 0.28 ha/h to 0.09 ha/h when the position of boom was changed from the horizontal to vertical positions. Fuel consumption for spraying with nozzle N1 and nozzle N2 increased from 0.42 l/h to 0.60 l/h and 0.37 l/h to 0.50 l/h when the position of boom was changed from horizontal to vertical positions.

Key words: Boom sprayer, Cotton, Droplet density, Nozzles, Uniformity coefficient

Cotton is one of the important cash crops of India. India lags behind in the world in productivity because of poor pest and disease control. Farmers repetitively apply large quantities of pesticides to the crop to avoid crop damage. The consumption of pesticides in Punjab during 2016-17 was 5843 metric tonne, which was about 10.25% of total consumption in India (Anon, 2017a). The Indian consumption needs to be decreased by adopting integrated pest management (IPM) and improving the spray technology.

Small and marginal farmers use manually lever operated backpack sprayer because of its versatility, cost and design. Tractor operated boom sprayer and hydraulic sprayer (gun type) which have a wider swath width of spray cannot be used when the cotton crop is mature, due to less ground clearance of the tractor to take the advantage of wider swath of spray. The farmer generally used back pack type gun type power sprayer for spraying on cotton but when the height of cotton is above 1.5 m, the operation efficiency of the sprayer is retarded (Mahal *et al.* 2007). Spray swath of 3 m or more can be obtained by fitting a knapsack with the appropriate nozzle and adjusting the spray pressure of the system to provide adequate output (Anon, 2009). The efficiency of manual knapsack sprayers can be increased with the increase in the number of nozzle via reducing the number of trips made to cover the calibrated area (Ballinder and Serratum, 2005). The cost of operating the boom sprayer reduced 29% as compared with hand compression knapsack sprayer (Mathew *et al*. 1992). Need of farm mechanization was felt to develop sprayer for the small and marginal farmers for spraying in field (Das *et al.,*2015). Hollow cone nozzle was more efficient than fan type and solid cone nozzle for pesticides spray (Singh 1996). Economic application of chemical on the pest occupied area with the urgency to control pest population taking environment into consideration, is the most efficient chemical application method (Mathews and Thornhill 1994). At the air velocity of 20 m/sec and pump discharge of 2.5 l/min, the droplets between 100-150 microns penetrated better and spray coverage was uniform through the plant canopy (Wandakar *et al*. 2015).To Various methods of spraying in backpack type sprayer were studied besides the suitability in easy to use and cost effectiveness as compared to tractor type power operated sprayer and electrostatic sprayer. Boom type power sprayers are very effective to spray chemical and control of insects.

Hence, there is need to develop a multi-nozzle backpack type power sprayer, which can be used at all stages of crop by using the boom both in horizontal (during early stages

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of crop) and in vertical (during maturity stage) position covering the full width and height of plant.

MATERIALS AND METHODS

Three types of hollow cone nozzles, nozzle N1, nozzle N2 and nozzle N3 were evaluated in the laboratory using patternator to find the rate of discharge, angle of spray and swath width. The study was conducted in research field of Punjab Agricultural University, Ludhiana during year 2017.

Development of boom sprayer and mounting of nozzles: The boom was developed for a knapsack sprayer. The mounting of nozzles (i.e distance between the two connective nozzles) on the boom should be such that spray on the crop should be uniform. To get uniform spray, the spray pattern of the nozzle was overlapped to get effective swath width. Nozzles are fitted for a particular target distance by overlapping the spray distribution of nozzles at pressure of 3.0 kg/cm^2 and other parts of sprayer were purchased from the local market. The sprayer consists of an engine of 1.1 KW having control valve assembly to regulate the pressure of the liquid. The pump could develop maximum pressure range if 1.5-2.5 Mpa at 5000-11000 rpm and its suction capacity was 3-3.7 l/min. A throttling lever was provided to increase or decrease the speed of the engine with a stop knob on the plate. A plastic tank having a capacity of 25 litres was used to store the pesticide solution and a fuel tank with capacity of 600 ml was attached to the sprayer tank. A rectangular frame made up of steel having length and width of 96 × 18 mm contains the 9 holes each at both sides having a diameter 10 mm with a distance of 10 mm respectively. These holes were provided to change the sprayer height according the plant height. This rectangular frame was attached to another two steel frames having length and width of (40 × 32) mm and (25 × 32) mm which is fixed at the bottom of the sprayer tank. Sprayer with mounted nozzles is shown in Fig 1.

Field evaluation: The size of each plot for field evaluation, in case of sprayer with boom in horizontal position was 48 × 4.66 m and for boom in vertical position was 48 × 0.675 m^2. The sprayer was evaluated on mixed hybrid cotton crop for four stages plant heights at a forward walking speed of 1.5 km/h. The row to row and plant to plant spacing was maintained as 67.5 cm × 30 cm, respectively. The sprayer was operated for the steady discharge at a pressure of 3.0 kg/cm^2 at walking speed of 1.5 km/h. Experiments of sprayer was conducted on water sensitive papers (card 2.6 × 7.6) cm^2 that were attached on the upper and under side of the leaves at three different heights of cotton canopy, i.e (Top, Middle and Bottom) for evaluation of spray spread. At stage 1 (60 days), the crop was sprayed keeping the boom of sprayer in horizontal position, whereas at stage 2, 3 and 4 (75, 90 and 105 days after sowing), the crop was sprayed keeping boom of sprayer in vertical position. All experiments were replicated thrice. A view of sprayer spraying at horizontal and vertical position on cotton crop is shown in Fig 1a,b.

After field evaluation, droplet analyser system was used to calculate the droplet size, droplet density and actual diameter of drops to evaluate the uniform distribution of drops in various locations of plant canopy. For the determination of NMD and VMD the values of spread factor taken from Anon. (2018) was used.

RESULTS AND DISCUSSION

Laboratory evaluation: The three different types of nozzles nozzle N1, N2 and N3 were evaluated on the

a. Boom in horizontal position b. Boom in vertical position

Fig 1 A stationary view of sprayer having boom in horizontal and vertical position.

patternator at three different target distance (distance between the tip of nozzle and surface of patternator) i.e. D1, D2 and D3 (540, 340 and 250 mm), at three different pressure P1, P2 and P3 (3.0, 4.5 and 6.0 kg/cm^2) respectively to simulate the distance between the nozzle and canopy of cotton plant at different stages of crop growth.

Rate of discharge: The rate of discharge increased with increase in pressure and type of nozzle at 5% level of significance, however at a particular pressure, the rate of discharge for nozzle N1 and N3 was non-significant (Table 1). Rate of discharge was found lesser for nozzle N1 as compared to nozzle N1 and N3. The first order interaction of pressure and type of nozzle (N × P) showed that combination of P1N1 and P1N3; P2N1 and P2N3; and P3N1 and P3N3 respectively found to be non-significant at 5% level of significance. It indicated that nozzle N1 and N3 has same rate of discharge at a particular pressure.

Angle of spray: The angle of spray increased with increase in pressure and type of nozzle at 5% level of significance, however at a particular pressure, the angle of spray for nozzle N1 and N3 was found non-significant (Table 1). It indicated that nozzle N1 and N3 has same angle of spray at a particular pressure. Angle of spray was found lesser for nozzle N1 as compared to nozzle N1 and N3. the first order interaction of pressure and type of nozzle (N × P) show that combination of P1N1 and P1N3; P2N1 and P2N3 and P3N1 and P3N3 respectively found to be non-significant at 5% level of significance. It showed that at a particular pressure and nozzle N1 and N3 have similar angle of spray.

Swath width: The effect of the nozzle pressure and target distance was highly significant at 5% level of significance (Table 2). Also the first order interaction between the nozzles, pressure and target distance (Nozzle × Pressure), (Pressure × target distance) and (Nozzle × Pressure × target distance) are non-significant at 5% level of significance. Whereas, interaction between the type of nozzle and target distance (N × D) was significantly different. Similarly various interactions between the mean for Nozzle and target distance (N × D) in descending order for mean swath width were: N3D1, N1D1, N3D2, N1D2, N1D3, N2D1, N3D3, N2D2 and N2D3. The combination which were not found to be significantly different were: N1D1 and N3D1; N1D2 and N3D2; and N1D3, N2D1and N3D3 and N2D2and N2D3. Rest of the combinations are significantly different from each other. It indicate the same width can be achieved at a particular pressure with the combination of type of nozzle and target distance. Various interactions between target distance and pressure (D × P) in descending order for mean swath width were: D1P3, D1P2, D2P3, D1P1, D2P2, D3P3, D3P2, D2P2 and D3P1. The combinations which were not significantly different were: D3P3 and D2P2; D1P1

Table 1 Effect of different types nozzles at different pressure on the rate of discharge and angle of spray

Pressure, kg/cm^2	Rate of discharge, ml/min		Angle of spray, degree	
	Type of nozzle		Type of nozzle	
	N1N2N3	Mean for P	N1N2N3	Mean for P
P1	$495.93^{c}615.13^{b}705.66^{a}$	404.93^{c}	$105.77^{c}114.23^{b}119.40^{a}$	96.55^{c}
P2	$221.33^{f}270.33^{e}295.73^{d}$	500.83^{b}	$76.30^{f}81.96^{e}87.10^{d}$	103.80^{b}
P3	$497.52^{c}617.03^{b}706.50^{a}$	569.30^{a}	$107.60^{c}115.20^{b}120.80^{a}$	109.10^{a}
Mean for N	$605.57^{b}262.46^{c}607.01^{a}$		$113.13^{b}81.78^{c}114.53^{a}$	

*The value with same alphabet in a sub table are non-significant at 5% level of significance.

Table 2 The effect of different types of nozzles (N) at different pressure (P) and different target (D) on swath width

Pressure, kg/cm^2	Mean for(N×D×P)															Mean for P
	N1			N2			N3			Mean for N×P			Mean for D×P			
	D1	D2	D3	D1	D2	D3	D1	D2	D3	N1	N2	N3	D1	D2	D3	P
P1	75.67	59.33	55.00	52.43	42.00	36.00	75.33	63.33	49.00	63.33^{c}	43.47^{f}	62.55^{cd}	67.81^{bc}	54.88^{ed}	46.66^{e}	56.45^{c}
P2	79.00	70.00	62.00	62.00	48.00	45.00	79.03	76.00	55.20	70.33^{b}	51.66^{e}	70.07^{b}	72.33^{b}	64.66^{c}	56.73^{d}	64.02^{b}
P3	85.07	72.67	64.93	65.33	53.10	52.10	86.67	85.30	65.30	74.22^{a}	56.84^{de}	79.09^{a}	78.56^{a}	70.35^{bc}	60.77^{c}	70.52^{a}
Mean For N×D	79.91^{a}	67.33^{b}	60.64^{c}	59.22^{c}	47.70^{d}	44.36^{d}	80.34^{a}	74.08^{b}	56.50^{c}				Mean for D			
												72.90^{a}	63.29^{b}	54.72^{c}		
Mean for N		69.29^{a}			50.42^{b}			70.30^{a}								

*The value with same alphabet in a sub table are non-significant at 5% level of significance.

and D2P3; D2P1 and D3P2; D2P1 and D3P1.It indicate that same swath width can be achieved by changing the combination of target distance and pressure. Moreover, various interactions between the type of nozzle and pressure (N×P) in descending order for mean swath width were: N3P3, N1P3, N1P2, N3P2, N1P1, N3P1, N2P3 and N2P2 (Table 2) the combinations which were not significantly different were: N1P3 and N1P2; N1P1; N3P3 and N3P1 and N2P3. The swath width increased with increase in pressure at particular type of combinations of nozzle and target distance from target. Swath width increased with the increase in pressure at a particular target distance. The swath width increased with increase in pressure for all type of nozzles. At a particular target distance the swath width was lesser in nozzle 2 as compared to nozzle N1 and N3. Some combination of nozzle and pressure (N×P), target distance and nozzle (D×N) and target distance and pressure (D×P) were found non-significant. It indicated that same swath width can be achieved with the change in combination of pressure, target distance and type of nozzle.

Development of adjustable boom for sprayer: At a particular pressure, the rate of discharge, angle of spray and swath width of nozzle N1 and N3 were non-significant, whereas, for N2, these parameters were significantly different from nozzle, N1 and N3 (Table 1 and 2). Hence, nozzle N1 and N2 were selected for the development of boom sprayer for field study and nozzle N3 was rejected having same behaviour as of nozzle N1. After overlapping of the spray patterns, the effective swath width of nozzle decreased and effective discharge rate increased. The specific discharge rate varied from 12.15 ml/min-cm and 7.22 ml/min-cm to 12.91 ml/min-cm to 7.57 ml/min-cm for nozzle N1 and N2 respectively where the target distance was decreased from D1 to D3 (Table 3). The variation in specific discharge for a particular nozzle is due to difference in the coefficient of variation.

Field evaluation of developed sprayer: The field evaluation of the sprayer was conducted in terms droplet size (NMD, VMD, UC).

Droplet size: The volume median diameter (VMD) varied from 108.56 to 309.52 micrometre at different crop stages (Table 4). The number median diameter (NMD) varied from 52.32 to 216.82 micrometre at different locations of the crop for nozzle N1. At crop stage 1, the uniformity coefficient at locations L1, L2 and L6; L4 and L6 was non-significant, which means that these location combination have uniform distribution whereas UC for location L3 was significantly different from rest of the locations. At crop stage 2, the UC for locations L1, L2, L3 and L4; L2 and L4 was non-significant which indicates that there is no variations while L5 is significantly different from other locations. At crop stage 3, the uniformity coefficient at locations L1, L2, L5 and L6 was non-significant depicting a uniform distribution of spray at these locations whereas, L3 and L4 are also non-significant with each other but they are significant with other locations. At crop stage 4, UC for locations L1, L2, L5 and L6 was non-significant whereas L3 and L4 were significantly different from within and from other locations also. This indicated that for nozzle N1, uniformity coefficient for locations L1, L2, L5 and L6 showed the significant trend for uniform distribution at all crop stages.

The uniformity coefficient of droplet size at different crop stage for nozzle N2 is given in Table 4. At crop stage 1 the uniformity coefficient at location L1 and L3; and L1 and L6 was non-significantly different from locations L2, L4 and L5. It indicated that there is no trend of UC with locations. At crop stage 2, the uniformity coefficient at location L1 and L6 was non-significant but all other location it was significant. It indicated that canopy of the plant affect the uniformity coefficient of spray when it is too close to the target. At crop stage 3, locations L2 and L4; L3 and L5 was non-significant whereas L1 and L6 were significant with each other. This indicated that the uniformity coefficient have definite trend from L2 to L4 location. For crop stage 4, locations L1, L2, L3 and L4; L3 and L6 were non-significant whereas for locations L5 it was significant than other locations. This indicated that from locations L1 to L4, there was a uniformity of droplets size.

Droplet density: At crop stage 1 for nozzle N1, the droplet density at location L1 and L2 was non-significant whereas for locations L2, L3, L4, L5 and L6, it was non-significant (Table 5). It showed that droplet density was uniform for locations L2 to L6 except for location L1. At crop stage 2, the droplet density at locations from L1, L2 and L5; L1, L2, L4 was non-significant whereas location L3 and L4 was significantly different. At crop stage 3, the droplet density at all location was non-significant with each other. This indicated that there was uniformity of droplet density at all the locations. For crop stage 4, the droplet density at locations L2 to L6 were non-significant except L1 which was significant at different locations of plant canopy.

At crop stage1 for nozzle N2, the droplet density at location L2 to L5 was non-significant whereas L1 and L6 were significant from each other. It showed that droplet density was uniform for location L2 to L6 except for location L1 and L6 (Table 5). At crop stage 2, the droplet density at all the locations from L1 to L6 was non-significant, whereas location L3 and L6 was significantly different from each

Table 3 Effective discharge rate and effective swath width after overlapping at pressure 3.0 kg/cm^2

Target distance, mm	Type of nozzle	Coefficient of variation,%	Effective swath, cm	Effective Discharge, ml/min	Specific discharge rate, ml/min-cm
D1	N1	16.25	42	510.44	12.15
	N2	11.65	35	252.62	7.22
D2	N1	8.6	38	490.32	12.90
	N2	7.58	33	238.72	7.23
D3	N1	11.88	36	464.7	12.91
	N2	16.32	31	234.6	7.57

Table 4 Uniformity coefficient of droplet size at different location of plant canopy at Different crop stage for nozzle N1 and N2

Crop stage	Parameters	Location of the plant canopy					
		L1 (UPT)	L2 (UPM)	L3 (UPB)	L4 (UNT)	L5 (UNM)	L6 (UNB)
Stage 1	NMD	141.38	128.43	96.8	58.4	88.18	52.39
	VMD (N1)	243.27	215.30	309.52	150.80	174.61	142.75
	UC	1.72[d]	1.68[d]	3.19[a]	2.58[bc]	1.97[cd]	2.73[b]
	NMD	74.08	171.03	64.5	163.62	139.67	65.38
	VMD (N2)	196.22	219.21	187.85	233.72	262.78	156.87
	UC	2.64[ab]	1.28[d]	2.91[a]	1.42[d]	1.89[c]	2.4[b]
Stage 2	NMD	65.39	57.6	91.98	75.71	65.32	52.32
	VMD(N1)	145.35	134.12	201.56	166.32	113.4	108.56
	UC	2.21[b]	2.32[ab]	2.19[b]	2.5[a]	1.73[c]	2.07[b]
	NMD	70.91	60.45	82.09	154.2	135.61	65.6
	VMD(N2)	158.63	145.01	153.54	201.01	196.2	145.67
	UC	2.23[b]	2.39[a]	1.88[c]	1.31[e]	1.45[d]	2.22[b]
Stage 3	NMD	83.26	120.2	105.88	80.46	123.56	73.77
	VMD (N1)	134.84	192.63	245.21	205.69	190.35	119.56
	UC	1.61[b]	1.6[b]	2.31[a]	2.55[a]	1.54[b]	1.62[b]
	NMD	66.13	78.56	92.53	111.23	103.54	61.87
	VMD (N2)	137.62	155.13	169.23	213.52	186.03	102.65
	UC	2.08[a]	1.97[ab]	1.82[bc]	1.91[ab]	1.79[bc]	1.65[c]
Stage 4	NMD	96.43	212.62	121.78	93.65	216.82	95.23
	VMD (N1)	122.34	253.23	286.3	248.23	272.54	130.48
	UC	1.26[cd]	1.19[d]	2.35[b]	2.65[a]	1.25[cd]	1.37[c]
	NMD	62.11	90.25	102.78	114.2	165.16	75.21
	VMD(N2)	118.61	165.45	183.44	221.51	198.4	115.61
	UC	1.9[a]	1.83[a]	1.78[ab]	1.93[a]	1.19[c]	1.53[b]

*The value with same alphabet in a sub table are non-significant at 5% level of significance. **UPT, UPM, UPB=upper top, middle and bottom & UNT, UNM, UNB=underside top, middle and bottom.

other. This indicated that the droplet density showed the similar distribution for number of droplets in these locations. At crop stage 3, droplet density for all locations was non-significant. This indicated that there was the uniformity of droplet density at all the locations. For crop stage 4, the droplet density at L1 to L5 was non-significant whereas L6 was non-significant for L2, L4 and L5. This indicated that no. of droplets from L1 to L5 are same but L6, L2, L4 and L5 were also having a same no. of droplets at particular locations.

Rate of work: Field capacity for Nozzle N1 and N2 decreased from 0.34 ha/h to 0.09 ha/h and 0.28 ha/h to 0.09 ha/h when the position of boom was changed from or horizontal to vertical position. Fuel consumption for

Table 5 Droplet density at different locations of plant canopy at different stages of crop growth for nozzle N1 and N2

Crop stages	Nozzle	Locations of the plant canopy					
		L1 (UPT)	L2 (UPM)	L3 (UPB)	L4 (UNT)	L5 (UNM)	L6 (UNB)
Stage 1	N1	60.00[a]	47.33[ab]	37.67[b]	45.67[b]	36.33[b]	34.33[b]
	N2	58.67[a]	51.33[ab]	41.33[ab]	54.67[ab]	52.00[ab]	39.00[b]
Stage 2	N1	54.33[abc]	61.33[ab]	42.67[c]	48.67[bc]	66.00[a]	40.33[c]
	N2	55.33[ab]	50.33[abc]	58.67[a]	47.33[b]	51.00[abc]	43.00[c]
Stage3	N1	64.33[a]	51.00[a]	53.67[a]	48.33[a]	48.00[a]	56.00[a]
	N2	63.00[a]	52.67[a]	58.33[a]	59.67[a]	50.67[a]	66.33[a]
Stage 4	N1	76.67[a]	50.33[b]	57.33[b]	51.00[b]	45.33[b]	48.00[b]
	N2	63.37[a]	52.00[ab]	62.33[a]	55.33[ab]	58.33[ab]	43.33[b]

*The value with same alphabet in a sub table are non-significant at 5% level of significance. **UPT, UPM, UPB=upper top, middle and bottom and UNT, UNM, UNB=underside top, middle and bottom.

spraying with nozzle N1 and nozzle N2 increased from 0.42 l/h to 0.60 l/h and 0.37 l/h to 0.50 l/h when the position of boom was changed from or horizontal to vertical positions.

From the studies it can be concluded that the rate of discharge and angle of spray increased with increase in pressure and type of nozzle at 5% level of significance, however at a particular pressure, the rate of discharge and angle of spray for nozzle N1 and N3 was non-significant. The swath width increased with increase in pressure at particular type of combinations of nozzle and target distance from target. Uniformity coefficient and droplet density at a particular stage of crop in some combination of locations was found non-significant.

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