Comparison of bio-efficacy of auto-rotate gun sprayer with knapsack sprayer for control of *Bemisia tabaci* in cotton crop

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ABSTRACT: An auto-rotate gun sprayer was evaluated for its bio-efficacy to control whitefly *Bemisia tabaci* (Genn.) in the cotton crop. Two experiments were conducted at six farmers' fields of south-western (cotton-growing region) Punjab. The number of adult whiteflies was counted before and 3, 7 and 10 days after spray. Water sensitive papers were attached at three different points of reach (top, middle, bottom) upper side and underside of the leaf on the plants to find performance parameters, *viz*. droplet diameter, droplet density, per cent area covered and volume of spray deposition. Droplet density, area covered and volume of spray deposition were found significantly higher in case of the auto-rotate gun sprayer as compared to a knapsack sprayer. However, the volume median diameter (VMD) of droplets was found significantly higher in the case of a knapsack sprayer of 347.85 µm as compared to an auto-rotate gun sprayer of 286.95 µm. The whitefly control in the cotton crop as compared to untreated treatment after 10th days of auto-rotate gun and knapsack sprayers spray by using pyriproxyfen100 g a.i./ha having bio-efficacy of 64.39 % and 65.65 % and by using flonicamid 75 g a.i./ha was found 85.72% and 74.70%, respectively. The cost of operation of the auto-rotate gun sprayer was found to be USD 4.11/ha as compared to knapsack sprayer with USD 6.85/ha. The cost, labour and time-saving in the spraying of the auto-rotate gun sprayer as compared to knapsack sprayer was found to be 39.98, 93.44 and 96.64%, respectively.

Key words: *Bemisia tabaci*, bio-efficacy, droplet density, volume median diameter, whitefly

India is the largest cotton producer in the world. The total cotton area was 11.87 million ha with the production of 30.15 million tons in India during the year of 2015-2016 (Anonymous, 2016). The country's total cotton sown area was lower down in the year 2014-2015 by 8 % as compared to 12.82 million ha. In Punjab, the cotton area has declined in 2016 as farmers shifted to other crops after incurring huge losses due to the whitefly pest attack in the year 2015. The cotton crop area in Punjab was 2.56 hundred-thousand ha lower by 43.11%, from 450 000 ha in the previous year. More than 90% of farmers have sown *Bacillus thuringiensis* cotton (Bt. cotton) (Anonymous, 2016a). The total cotton sown area declined in Punjab from year 2015 as farmers were reluctant to grow cotton fearing the whitefly pest attack that had damaged the crop massively due to this, farmers shifted to pulses, paddy and other crops (Anonymous, 2016a).

Whiteflies suck sap from the lower surface of leaves causes yellowing and upward curling of the leaves. The ideal conditions for the growth of whiteflies are hot and humid climate with the temperature around 27 °C and 70% relative humidity. Cotton losses due to whitefly (Grout and Stephen, 2019) infestation were estimated to be in the range of 15-20% and sometimes up to 30% (Kanthi, 2015). Mainly (90%) knapsack type sprayers are used by the farmers to apply pesticides and plant growth regulators (Cooper *et al*., 1998). This method is simple but has disadvantages of poor distribution and high labour costs (Anibude *et al.,* 2016). Mishra *et al.* (2015) observed that more than 80% of pesticides are deposited on the ground by using these sprayers. Over dosage of pesticide is common in most countries and its application leads to many problems, such as chemical waste and environmental pollution from spray drift (Laryea and No, 2004; Patel *et al*., 2016; Miranda-Fuentes *et al.,* 2017). A 40-50% reduction in pesticide consumption reduces the protection cost from USD50/ha to less than USD30/ha. Accurate timing of spraying results in a 100-200 kg/ha increase in seed-cotton yield (Silvie *et al*., 2001). Wise *et al.* (2010) study the effect of spray volume on control of fungal diseases was evaluated using the fungicides ziram and azoxystrobin applied with an airblast sprayer spray volume of the airblast sprayer also affected disease control by the protectant fungicide ziram more than by the systemic fungicide azoxystrobin, with 468 L/ha providing better control than 187 L/ha.

In India farmers have now started using tractor-mounted sprayers fitted with a gun having a pipe length of 60-300 m which is very beneficial to them due to its high field capacity. In the field, the tractor operated gun sprayer requires four persons, of which two are required for handling the pipe, with tractor standing outside the field (Narang *et al.,* 2015). But these types of sprayers are less efficient and very labour-intensive. A tractor-operated gun sprayer is not recommended technology with non-uniform spraying pattern and high discharge. Hence, an auto-rotate gun sprayer has been developed in collaboration with the industry, which has a better auto-rotating gun mechanism for uniform coverage with wider swath width and higher field capacity. This developed sprayer was evaluated at the farmers' fields for its performance; bio-efficacy and compared with the knapsack sprayer.

MATERIALS AND METHODS

Auto rotate gun sprayer description

The auto-rotate gun sprayer consists of base frame for mounting of different components, spray tank, boom, guns, DC motor and piston type hydraulic pump, three-point hitch system to attach with tractor three-point links. The boom is composed of a horizontal frame of mild steel angle iron on which two gun type nozzles (Teejet) were fitted at spacing of 8580 mm apart. The main advantage of auto-rotate gun sprayer over knapsack sprayer is the wide swath width which minimises the number of trips in the fields. The DC motor (car wiper) was used to give the rotary motion to the guns. The position of gun nozzle on the horizontal boom is toward the rear side of boom. The guns have coverage radius of 6000 mm from its centre point having gun rotation angle 120° (one third revolution) at operating pressure of 3430 kPa. The total covering width with these two gun nozzles was 16000 mm. These guns can be operated independently, if required. Power from the tractor PTO to hydraulic pump was transmitted through a V-belt drive. There was a provision to adjust the height of the boom with respect to the frame, which makes it suitable for spraying on different types of crops and at various growth stages of the crops. The total width of the wetted land of auto-rotating guns can be changed by adjusting sprayer angle of the hollow cone nozzle. The boom has a provision to fold in one step, to increase or decreases the spray swath width. Provision was also made to fold the boom for easy transportation or turning. A schematic diagram of the auto-rotate gun sprayer is shown in Fig. 1. It has a built-in tank to carry spray liquid with a large opening cap for easy cleaning.

It has a 600-l capacity tank which is sufficient for the desired field capacity. In order to maintain the homogeneity of the liquid spray, a built-in hydraulic agitator was used which consists of pipe with several side holes and closed at its free end. It was placed in the tank and fed with spray solution with the help of the pump. Liquid jets emerge from these holes, further initiating the agitation to the complete the homogeneity of the spray solution. The technical specification of the auto-rotate gun sprayer is shown in Table 1.

Table 1: Technical specification of auto rotate gun sprayer

Units	Particulars	Details
Tank	Spray tank capacity	600 litres
	Agitator	Hydraulic
Pump	Type	Hydraulic piston pump
	Make & model	ASPEE & PSB50A1N
	Recommended revolution range	700-900 rpm
	Required power	3.73 kW (5 hp)
	Operating pressure range	3430 kPa
	Range of boom height adjustment	0.5-1.5 m
Nozzles	No. of guns on boom	2
	Make	Teejet
	Spacing of guns on boom	8580 mm
	Max. gun discharge rate	0.83 l/sec

Experimental planning

Two experiments were conducted at farmers' fields of cotton belt area (30.1453°N 74.1993°E) of the south western arid-irrigated region of Punjab. The farmers' fields were selected where the incidence of whitefly (adults) count was observed above an economic threshold level (ETL). The ETL was taken as 6 whitefly adults/3 leaves (Narang *et al*., 2015). The selected fields were rectangular with a minimum area of 0.5 ha to conduct all treatment at the farmer's field. At all six fields, crop spacing was the same 675 mm within and between rows. To test the bio-efficacy of the auto-rotate gun sprayer, the experiment was conducted in two phases, *i.e.* first and second, the comparison was made with knapsack sprayer for control of whitefly pest in cotton crops.

To evaluate sprayer performance and bio-efficacy, first experiment was conducted on 20 July 2016 with the recommended dose of insecticide pyriproxifen 100 g a.i./ha (Sumitomo Chemical Agro Europe S.A.) regardless of sprayer volume at farmer fields *i.e.* F_1, F_2 and F_3, respectively. The second experiment was conducted on 12 August 2016 with the recommended dose of insecticide flonicamid 75 g a.i./ha (United Phosphorous Limited, India) regardless of sprayer volume at new three farmer fields *i.e.* F_5 and $_4$, FF_6, respectively to determine the bio-efficacy of the sprayer. The experimental plan, fields, crop stage and treatment plot size and total field area are depicted in Table 2.

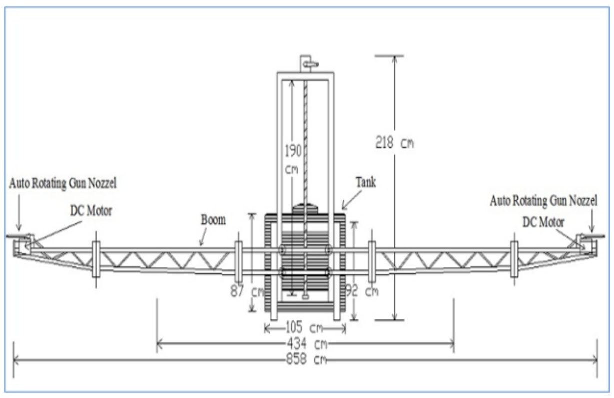

Fig. 1: Schematic diagram of tractor operated auto rotate gun sprayer

The independent, dependent parameters and their levels of experiments 1 and 2 are depicted in Tables 3 and 4, respectively. For experiment 1, farmer's field sprayers and strip positions were selected as an independent parameter whereas volume median diameter (VMD), droplets density, area covered, the volume of spray deposition and bio-efficacy were selected as dependent (random effect) parameters. However, the bio-efficacy is independent of the strip positions. Further, experiment 2, fields and sprayer were selected as a fixed parameter whereas bio-efficacy selected as a random effect.

Assessment of VMD, droplet density, area coverage and spray volume deposition

Water sensitive paper method was used to evaluate the spray performance parameters (Mishra *et al*., 2015, Kumar *et al*., 2020). In this method, water-sensitive papers strips (76 × 26 mm) were attached on the upper and lower side of the leaves at three different heights (top, middle and bottom) leaf position of the cotton plant. The position of strips was decided on the plant *i.e*. whole plant canopy divided into three equal parts and the strip were located at middle locations (neither outer nor inner leaves) of the plant canopy.

However, the top strips were located at the top well-matured leave of both the sides of the top upper and top under at same leaf. The water-sensitive papers were attached the same way at three different plants to replicate the treatment. The liquid application rate of the auto-rotate gun sprayer and knapsack sprayers were 1250 l/ha and 300 l/ha, respectively at a travel speed range of 3 km/h was calibrated as per (IS: 11429–1985). After the spray, the strips (2×3×3×6=108 samples strip) were collected and placed in Zip-Lock bags. The strips were evaluated for the upper and lower side of the leaf at the top, middle and bottom positions. Spray coverage and size distribution of spots on the strips were determined by using a droplet analysing system (Radical Scientific Equipment). The droplet analysing system consists of a microscope, closed-circuit digital (CCD) camera, a personal computer (PC) and a monitor to control the analysed image. The

Table 2: Experiment site selection for sprayer's performance and bio-efficacy tests

Farmer field	Crop variety	Crop age, days	Crop stage	Crop height range, mm	Treatment plots area, ha			
					S_1**	S_2**	Control	Total, ha
Experiment 1 was conducted to check sprayer performance and bio-efficacy by using insecticide pyriproxifen100 g a.i./ha.								
F_1	Bio-100	83	Vegetative	900-1000	0.40	0.05	0.05	0.50
F_2	RCH-653	77	Vegetative	800-900	0.40	0.05	0.05	0.50
F_3	Bio-105	78	Vegetative	900-1000	0.40	0.05	0.05	0.50
Total experimental area, ha								1.50
Experiment 2 was conducted at three new locations by using insecticide flonicamid 75 g a.i./ha to check the bio-efficacy of sprayers.								
F_4	Ankur-3028	103	Vegetative	1500-1800	0.40	0.05	0.05	0.50
F_5	RCH-773	107	Vegetative	1400-1700	0.40	0.05	0.05	0.50
F_6	RCH-773	106	Vegetative	1200-1500	0.40	0.05	0.05	0.50
Total experimental area ha.								1.50

Where, **S_1 is Auto-rotate gun sprayer, **S_2 is Knapsack sprayer.

Table 3: Independent and dependent parameter for experiment 1

Independent parameter	Levels	Dependent parameter
Farmer fields	3 (F_1, F_2 and F_3)	Volume median diameter, µm
Sprayer	2 (S_1 and S_2)	Droplets density, No. of droplets/cm
Strip position	6 (SP_1, SP_2, SP_3, SP_4, SP_5 and SP_6)*	Area coverage, %
		Volume of spray deposition, µl/cm^2
		*Bio-efficacy, No. of whitefly/3 leaves
Total treatment = 3×2×6×3= 108		

* Independent with respect to strip position. Strip position: SP_1 Top upper, SP_2 Top lower, SP_3 Middle upper, SP_4 Middle lower, SP_5 Bottom upper, and SP_6 Bottom lower.

Table 4: Independent and dependent parameters for experiment 2

Independent(fixed) parameter	Levels	Dependent(random effect) parameter
Farmer fields	3(F_4,F_5 and F_6)	Bio-efficacy (No. of whitefly/3 leaves)
Sprayer	2(S_1 and S_2)	
Total treatment= 3×2×3=18		

software used to analyse the droplets was the USB digital scale. The droplet size at which the cumulative percentage of volume contributed reached 50% was taken as the volume median diameter (VMD) of the spray. The number of droplets in 1square cm area of water sensitivity paper was counted on each strip termed as droplet density. The per cent area covered and the volume of spray deposition was calculated in terms of percent strip area covered and µl/cm^2, respectively (Singh *et al*., 2011).

The whitefly incidence was counted on 20 plants randomly selected in each treatment before and 3, 7 and 10 days after spraying. In each treatment, the number of whitefly adults was counted at three leaves of the plant and the mean value of whitefly population count per three leaves was recorded in the datasheet. Untreated treatment with its replication serves as a control to compare bio-efficacy. The factorial experiment was conducted using a factorial randomised block design (RBD). The general linear model (GLM) procedure was used for statistical analysis with the help of SPSS (Version 20) software. For the test of significance, mean separation and their interaction effect of the performance parameter of the sprayers, various tools, *i.e.* ANOVA and Duncan Multiple Range Test (DMRT) were applied.

RESULTS AND DISCUSSION

Volume median diameter (VMD)

The VMDs of an auto-rotate gun and knapsack sprayers were observed during the experiment with the help of droplet analysis results as shown in Fig. 2 and mean VMD of droplets shown in Table 5. It was found that the effect of field locations on VMD have non-significant difference at the *P*< 0.05 level of significance. This was due to the same operational parameters of the spraying machine at all field locations. It was also found that the auto-rotate gun sprayer produced fine droplets as compared to that of the knapsack sprayer for all the field locations F_1, F_2 and F_3. The auto-rotate gun sprayer produced fine spray droplets as compared to knapsack sprayer because it operated at a very high-pressure range of 3430 kPa. This pressure imparts energy to the spray fluid resulting in reduced surface tension of the spray solution which helps in breaking the sprayer solution into fine drops. The mean droplet size of an auto-rotate gun sprayer and knapsack sprayer were observed as 286.95 µm and 347.85 µm, respectively, which is significantly different at *P*< 0.05 level of significance. The droplet size of spray depends on the operating pressure of the nozzle, the surface tension of spray solution, type of nozzle used, etc. (Kepner *et al.,* 2003; Nadeem *et al*., 2019). The VMD of droplets decreased with the increases of operating pressure in studies on performance characteristics of selected hollow cone nozzles when the nozzle was tested at high pressure (Sukumaran, 2010). For the top, upper, middle-upper and bottom upper strip position of leaves, the VMDs were significantly higher at *P*< 0.05 as compared to the top under, middle under and bottom underside strip position of the leaf. However, the underside strip position was not significantly different at *P*< 0.05. From the ANOVA (Table 6), it was also found that all factors, *i.e.* sprayers, and strip positions and their interaction, affect significantly the VMD of droplets of spray at *P*< 0.05 level of significance.

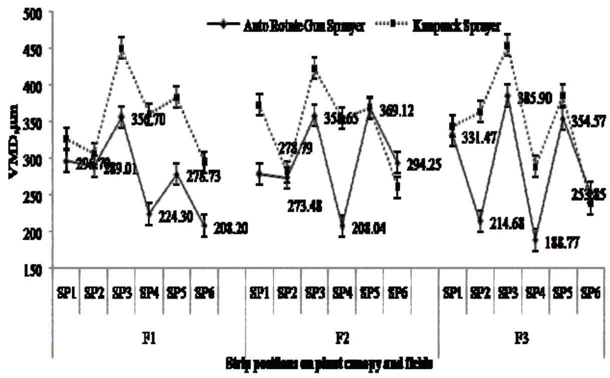

Fig. 2: VMD (mean ± SE) of droplets at different strip positions and fields

Droplet density

The droplet density of sprayers were affected by VMD of droplets, larger the VMD the lower droplets density and vice-versa. The droplets' density of an auto-rotate gun sprayer is shown in Fig. 3 and is significantly higher compared to the knapsack sprayer for all fields at the *P*< 0.05 level of significance. Droplets' density of field location F_1 was found significantly different from the field locations F_2 and F_3. However, the droplet density of F_2 and F_3 were not significantly different at *P*< 0.05. It may due to crop varieties. The droplet density was found more at the top upper, middle-upper and bottom upper strip position of the leaf as compared to the top under, middle under and bottom under strip position for both the sprayers. The droplet distribution at the upper strip position was found higher as compared to the lower leaf strip position. Cooper *et al*. (1998) observed higher droplets density at the upper side of the leaf as compared to the lower side of the leaf in low volume spraying on cotton in a comparison between spray distribution using charged and uncharged droplets applied by two spinning disc sprayers. Despite this, the density of the droplets of strip positions SP_1, SP_2, SP_3, SP_4, SP_5 and SP_6 were statistically significantly different at *P*< 0.05. However, from the analysis of variance shown in Table 6, it was found that all factors, *i.e.* fields, sprayers, strip positions and their interaction have a significant (*P*< 0.05) effect on numbers of droplets of spray.

Table 5: Mean Value of DMRT of various performance parameters of sprayers

		VMD	Droplet density	Area coverage	Spray deposition
Fields (F)	F_1	314.78^{a}	52.60^{a}	19.93^{a}	14.93^{ac}
	F_2	317.10^{a}	66.65^{bc}	39.72^{bc}	19.85^{b}
	F_3	320.32^{a}	66.92^{cb}	40.54^{cb}	15.04^{ca}
Sprayers (S)	S_1	286.95^{a}	74.18^{a}	34.23^{a}	19.55^{a}
	S_2	347.85^{b}	49.93^{b}	32.56^{b}	13.67^{b}
Strip Position (SP)	SP_1	325.23^{a}	89.01^{a}	54.06^{a}	28.51^{a}
	SP_2	288.24^{bd}	71.31^{b}	49.90^{b}	16.85^{be}
	SP_3	404.88^{c}	79.21^{c}	36.42^{c}	32.61^{c}
	SP_4	270.93^{df}	32.94^{d}	30.04^{d}	2.15^{df}
	SP_5	356.81^{e}	62.96^{e}	18.22^{e}	17.48^{eb}
	SP_6	258.32^{fd}	36.92^{f}	11.74^{f}	2.04^{fd}

Mean within column followed by the same letter in caption are not significant different at $P<0.05$

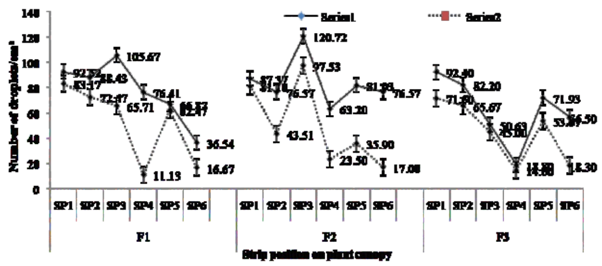

Fig. 3. Droplets density (mean ± SE) at different strip positions and fields

Area covered

To achieve uniform coverage across the swath width of the boom, nozzle height and nozzle spacing must be considered. The above parameters adjust properly to minimise the overlapping and gapping of the spray pattern (Kepner *et al*., 2003). Per cent area of coverage of auto-rotate gun sprayer was significantly higher as compared to the knapsack sprayer at $P<0.05$. At F_1, F_2 and F_3 fields, it was found that the auto-rotate gun sprayer covered more strip percentage area as compared to knapsack sprayer for all the strip position of the leaf. The maximum strip area of coverage was found at the middle-upper side of the strip position of the leaf at field F_3 for an auto-rotate gun-type sprayer. This was due to the sprayer angle of the gun. In case of the knapsack sprayer, the per cent area strip coverage was found maximum at all upper strip positions and continuously decreased from top to bottom strip position of leaf due to the uneven height of lance above the crop canopy, non-uniform pattern and fewer droplets of spray. Further, for all strip positions have significant differences in per cent area of coverage at the $P<0.05$ level of significance. An auto-rotate gun sprayer and knapsack sprayer also have a significant difference in the percent area of coverage at $P<0.05$. From the ANOVA (Table 6), it was also found that all factors, *i.e.* fields, sprayer, and strip position and their interactions have a significant effect on percent area of coverage of leaf at $P<0.05$.

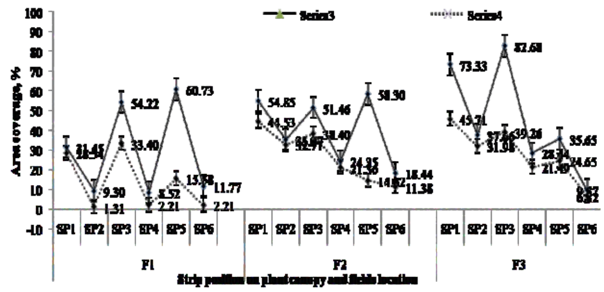

Fig. 4: Area covered (mean± SE) of droplets at different strip positions and fields

Volume of spray deposition

The volume of spray deposition was found more on the upper side of the top, middle and bottom strip positions as compared to the lower side of strip positions of the leaf on the plant as shown in Fig. 5. This was due to no abstraction on the upper side of the leaf, a high number of droplets reached on the leaf and per cent area covered as compared to the lower side of the strip position. Minimum volume of spray deposition of 3.71 µl/cm^2 for auto-rotate gun sprayer at bottom lower leaf position at F_3 field and 2.18 µl/cm^2 for knapsack sprayer at F_1 farmer field due to height of plants, density of leaf, VMD of droplets and strip positions, *i.e.* upper and lower side of the leaf has affected the penetration of drop inside the plant canopy resulting less volume of liquid deposition.

Finally, it was found that the upper side strip position of leaf gets more deposition as compared to the underside strip position of leaf for all farmer fields of the experiment shown in Fig. 5. The volume of sprayer deposition was found more at the upper side (top, middle, and bottom of the plant) of the strip as compared to the lower side of strip position of plant this was due to no abstraction on the

Table 6: ANOVA table for sprayer performance parameters of Experiment 1

Source	Dependent Variable	Type III Sum of Squares	d.f.	Mean Square	*F*- value	Sig.*P*<0.05
Sprayer	VMD, µm	100134.82	1	100134.80	103.96	0.00
	Area coverage, %	75.21	1	75.21	21.38	0.00
	Droplets density, No./cm^2	932.15	1	932.15	104.01	0.00
	Volume of spray deposition, µl/cm^2	15869.20	1	15869.20	1736.06	0.00
Location	VMD, µm	557.68	2	278.84	0.29	0.74
	Area coverage, %	9804.82	2	4902.41	1394.03	0.00
	Droplets density, No./cm^2	568.97	2	284.48	31.74	0.00
	Volume of spray deposition, µl/cm^2	4833.12	2	2416.56	264.36	0.00
Strip position	VMD, µm	283821.79	5	56764.35	58.93	0.00
	Area coverage, %	25539.51	5	5107.90	1452.46	0.00
	Droplets density, No./cm^2	14756.66	5	2951.33	329.33	0.00
	Volume of spray deposition, µl/cm^2	46550.27	5	9310.05	1018.50	0.00
Location * Sprayer	VMD, µm	4684.08	2	2342.04	2.43	0.09
	Area coverage, %	3368.37	2	1684.18	478.90	0.00
	Droplets density, No./cm^2	307.42	2	153.71	17.15	0.00
	Volume of spray deposition, µl/cm^2	1864.33	2	932.16	101.97	0.00
Location * StP	VMD, µm	24287.12	10	2428.71	2.52	0.01
	Area coverage, %	8801.93	10	880.19	250.28	0.00
	Droplets density, No./cm^2	1464.37	10	146.43	16.34	0.00
	Volume of spray deposition, µl/cm^2	19065.59	10	1906.56	208.57	0.00
Sprayer * StP	VMD, µm	33815.39	5	6763.07	7.02	0.00
	Area coverage, %	11366.48	5	2273.29	646.42	0.00
	Droplets density,No./cm^2	409.17	5	81.83	9.13	0.00
	Volume of spray deposition µl/cm^2	3527.08	5	705.41	77.17	0.00
Location * Sprayer * StP	VMD, µm	43472.45	10	4347.24	4.51	0.00
	Area coverage, %	6503.82	10	650.38	184.94	0.00
	Droplets density, No./cm^2	413.90	10	41.39	4.61	0.00
	Volume of spray deposition, µl/cm^2	8850.45	10	885.04	96.82	0.00
Error	VMD, µm	69346.96	72	963.15		
	Area coverage, %	253.20	72	3.51		
	Droplets density, No./cm^2	645.22	72	8.96		
	Volume of spray deposition, µl/cm^2	658.14	72	9.14		
Total	VMD, µm	11440700.20	108			
	Area coverage, %	186217.233	108			
	Droplets density, No./cm^2	49300.551	108			
	Volume of spray deposition, µl/cm^2	517165.431	108			

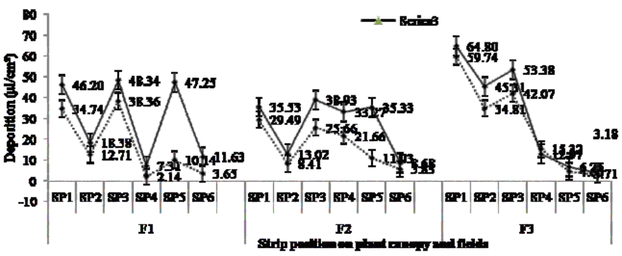

Fig. 5: Volume of spray deposition (mean± SE) at different strip positions and fields

upper side of the strip of the leaf. A similar result of deposition was found (Singh, 2005) in study design and development of a tractor-mounted air-assisted sprayer for cotton at different strip positions on the plant. It was also found that the F_1 field has significantly different from the field F_2 and F_3 at the *P*< 0.05 level of significance. However, field F_1 and F_3 have non-significant difference from each other. It was also found that the auto-rotate gun sprayer (S_1) and knapsack sprayer (S_2) differ significantly at *P*< 0.05 level of significance. It may due to crop varieties, crop height and machine operating characteristics. However, the factors *i.e.* fields, strip positions, and their interaction were found to effect significantly on the volume of sprayer deposition at *P*< 0.05 level of significance.

Bio-efficacy of sprayers for control of whitefly

The bio-efficacy of pyriproxifen of 100 g a,i./ha for control of whitefly adult population in cotton at three different fields of south-western Punjab by using two different sprayers are depicted in Fig. 6. There is a significant decrease in the population of whitefly adults was recorded in both the treatments as compared to control. Infield F_1, after 7 and 10 days of sprays the auto-rotate gun sprayer showed significant reduction in whitefly adult population over knapsack sprayer ($F_{(2,3)}$ = 5.4, 3.6 whitefly adults/3 leaves and *P* = 0.014 for auto-

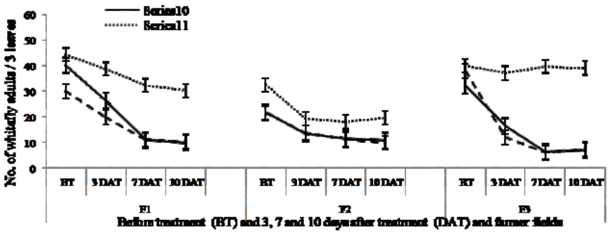

Fig. 6: Bio-efficacy (mean±SE) of sprayers using insecticide pyriproxifen 100 g a.i/ha for control of whitefly

rotated gun sprayer and $F_{(2,3)}$ 10.5, 5.4 whitefly adults/3 leaves and P = 0.014 for knapsack sprayer). Similarly, at other fields *viz*. F_2 and F_3, both the auto-rotate gun sprayer and knapsack sprayer have differed significantly at $P<$ 0.05 level of significance with each other in reducing the whitefly adult population 7 and 10 days after spraying.

In the second experiment the bio-efficacy of flonicamid at 75 g a.i./ha for control of whitefly adult population in the cotton crop at three different farmer's field *viz*. F_4, F_5 and F_6 by using two different sprayers are depicted in Fig. 7. There is a significant decrease ($P<$ 0.01) in the population of whitefly adults were recorded in both the treatments as compared with control. A farmer field F_4, after 7 and 10 days of spray using the auto-rotate gun sprayer showed the highest reduction in whitefly adult population as compared to knapsack sprayer ($F_{(2,3)}$ = 11.0, 9.9 whitefly adults/3 leaves and $P<$ 0.05 for auto-rotated gun sprayer and $F_{(2,3)}$ = 11.2, 10.4 whitefly adults/3 leaves and $P<$ 0.05 for knapsack sprayer. Similarly at other fields *viz*. F_5 and F_6, auto-rotated gun sprayer proved to be most efficient ($F_{(2,3)}$ = 7.1, 4.5 whitefly adults/3 leaves and P = 0.028) in reducing whitefly adult population as compared to knapsack sprayer ($F_{(2,3)}$ = 12.0, 8.7 whitefly adults/3 leaves and P = 0.028) after 7 and 10 days of spray. The bio-efficacy results in the second experiment are shown in Fig. 7 with the auto-rotate gun sprayer having better control of whitefly compared to knapsack sprayer.

Labour, time and cost of spraying

Actual field capacity, time and labor requirement were found as 2.4 ha/ h, 0.42 h/ ha and 0.42 h/ha, respectively

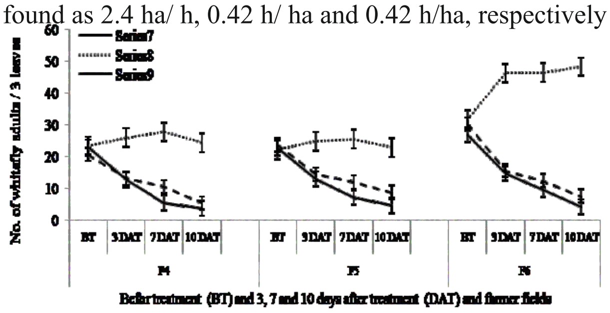

Fig. 7: Bio-efficacy (mean± SE) of sprayers using insecticide flonicamidat 75 g a. i./half or control of whitefly

for auto-rotate gun sprayer as compared to knapsack sprayer as 0.08 ha/h, 12.5 h/ha and 12.5 h/ha, respectively this was due to high field capacity of developed machine. The per cent cost, labour and time saving by using auto-rotate gun sprayer was 39.98, 93.44 and 96.64%, respectively as compared to knapsack sprayer. These were due to its wide boom and gun nozzles which increases the field capacity. The cost of operation for using an auto-rotate gun sprayer was found to be USD 4.11/ha as compared to knapsack sprayer of USD 6.85/ha. However, the two persons were required for the auto-rotate gun sprayer and one for the knapsack sprayer.

CONCLUSION

The VMD of the auto-rotate gun sprayer was found fine as compared to the knapsack sprayer due to its high operating pressure. Droplets density, per cent area of coverage and deposition was found significantly higher of the auto-rotate gun sprayer as compared to knapsack sprayer for all the upper and lower strip position of leaves due to small VMD of droplets. Bio-efficacy of knapsack sprayer was found higher in the first experiment and the second experiment, the bio-efficacy of the auto-rotate gun sprayer was found higher as compared to knapsack sprayer. From the results of the second experiment, it was found that the auto-rotate gun sprayer provided better bio-efficacy of flonicamid at 75 g a.i./ha for control of whitefly in cotton crop. The per cent cost, labour and time saving by using the auto-rotate gun sprayer was 39.98, 93.44 and 96.64%, respectively as compared to knapsack sprayer. The cost of operation for using an auto-rotate gun sprayer was found to be USD 4.11/ha as compared to a knapsack sprayer of USD 6.85/ha. The contradictory bio-efficacy results of two experiments emphasise the need for appropriate insecticide relative to the sprayer being used to achieve better control of insects. The results of this study also demonstrate that insect control is not only influenced by a sprayer but also the individual characteristics of the insecticide being selected for the given target insect.

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