



Development and evaluation of PAU multi-purpose sprayer to control whitefly (*Bemisia tabaci*) in cotton

SANTOSH KUMAR*, MANJEET SINGH, G S MANES and MANDEEP PATHANIA

Punjab Agricultural University, Ludhiana 141 004, India

Received: 24 July 2019; Accepted: 24 September 2019

ABSTRACT

A multi-purpose high clearance sprayer was developed with three types of spraying mechanism, viz. auto-rotate gun, drop-up boom and boom nozzles. The experiment was conducted during 2016 at Abohar in cotton growing region of South-western Punjab at six farm locations to evaluate sprayer performance and its bio efficacy against whitefly (*Bemisia tabaci*). It was observed that the auto-rotate gun sprayer produced lowest droplets VMD of 259.01 μm followed by boom type of 290.28 μm , drop-up boom type of 312.12 μm and knapsack sprayer of 328.50 μm , respectively. The maximum droplets density/cm² was found to be 31.67 (drop-up boom sprayer), 26.29 (auto-rotate gun), 21.34 (boom sprayer) and 18.13 (knapsack sprayer). However, more leaf area coverage was observed as 31.67% in drop-up boom sprayer followed by 26.29% of auto-rotate gun type, 21.24% of boom-type and 16.86% of knapsack sprayer. The higher whitefly control was obtained with a drop-up boom sprayer of 80.69-88.65% followed by auto-rotate gun sprayer of 80.31-85.10%, boom-type of 72.81-86.27% as compared to knapsack sprayer of 63.37-75.45%. Lowest operation cost was found to be ₹ 150/ha for auto-rotate gun-type followed by ₹ 239/ha for boom type and ₹ 291/ha for drop-up boom spraying system of multi-purpose high clearance sprayer, however, it was maximum ₹ 475/ha for knapsack sprayer. The similar, trend of cost saving was observed as 68.55, 49.82 and 38.80% per ha as compare to knapsack sprayer.

Key words: Boom sprayer, Bio-efficacy, High clearance sprayer, Multi-purpose sprayer, Sprayer, Whitefly and cotton

Cotton is an important *kharif* crop of the Punjab. It was grown on a 2.87 lakh ha area in 2017-18. The total production was 12.71 lakh bales with an average yield of 7.53 q/ha (Anon 2019). As per the latest data, the area under cotton in Punjab reduced by 43.11%, i.e. from 4.5 lakh ha in 2015-16 to 2.56 lakhs ha in the 2016-17 (Anon 2016). Whitefly is a small white insect of about 1.0 mm length and feeds on more than 500 plant species. Both adults and nymphs of whitefly suck sap from the under surface of leaves. The loss to cotton crop due to whitefly was estimated to be in the range of 15-20% and sometimes up to 30% (Kranthi 2015).

Spraying in cotton is a very tedious, labour-intensive and time-consuming job. More than 90% pesticides were applied by knapsack sprayers (Singh *et al.* 2013). This method is simple but has several disadvantages, i.e. poor spray distribution and high labour cost. More than 80% of pesticides are deposited on the ground by using these sprayers (Mishra *et al.* 2015). Over dosage of pesticide is common in most countries and it lead to many problems

such as wastage of chemical and environmental pollution from spray drift (Laryea and No 2004). Accurate timing of spraying results in a 100-200 kg/ha increase in seed-cotton yield (Silvie *et al.* 2001). Thus, there is a need of an efficient machine for spraying in row crops. In field crops like cotton the pest attacks especially whitefly resides on lower side of leaves. The control of these notorious pests can be achieved effectively if pesticides are applied properly at the correct rate, right time on right target which is possible with the help of appropriate spray equipment. Therefore, an effort was made to develop high clearance tractor mount sprayer named as “PAU Multi-Purpose High Clearance Sprayer” and its performance was evaluated with all three sprayer mechanisms for the whitefly control in cotton.

MATERIALS AND METHODS

PAU Multi-purpose sprayer with an elevated platform having clearance 1400 mm for 4-wheel tractors with spraying system was developed in the Department of Farm Machinery and Power, PAU, Ludhiana in collaboration with the industry. The sprayer attachments, i.e. auto rotate gun (T_1), drop-up boom (T_2) and boom sprayer (T_3), performance was compared with knapsack sprayer (T_4). The first experiment was conducted on 20.07.2016 with the insecticide Pyriproxifen 100 g a.i./ha at three different

*Corresponding author e-mail: caetsantosh@pau.edu

locations of Abohar region of South-western Punjab, i.e. Kikarkhera (L_1), Govindgarh (L_2) and Datarawali (L_3) having cotton crop variety Bio-100, RCH-653 and Bio-105, respectively to check the bio-efficacy of these spraying attachments against whitefly in cotton. Experiment was conducted at crop age of 77-83 days and crop height in the range of 900-1000 mm at vegetative growth stage. The field area for the PAU high clearance sprayer for its three sprayer mechanism was 0.40 ha and for the knapsack sprayer was 0.05 ha. Spray liquid application rate of auto rotate gun sprayer, boom sprayer, drop-up boom sprayer and knapsack sprayer were 600 l/ha, 800 l/ha, 1000 l/ha, and 300 l/ha, respectively with the travel speed of 2.5-3 km/h. For the first experiment, three field location, four sprayer and six strip position were selected as independent parameter, whereas volume median diameter (VMD), droplets/cm², percent area coverage, spray volume deposition μ l/cm² and bio-efficacy were selected as dependent parameter.

The second experiment was conducted with the same sprayer treatment combination and same spray volume application rate conducted on 12.08.2016 by using the insecticide Flonicamid 75 g a.i./ha at three new locations of Abohar region of South-western Punjab, i.e. Kikarkhera (L_4), Alamgarh (L_5) and Alamgarh (L_6) having cotton crop variety Ankur-2028, RCH-773 and RCH-771, respectively to check the bio-efficacy of these spraying attachments against whitefly in cotton. Experiment was conducted in same field area as experiment one for all four sprayers at crop age of 103-107 days and crop height in the range of 1500-2000 mm at vegetative growth stage. For the experiment two, field locations and sprayers were selected as independent parameter, whereas bio-efficacy was selected as a dependent parameter.

Assessment of VMD, droplet density, area coverage and spray volume deposition: Water sensitive paper method, used water-sensitive papers of 76 mm $\times$ 26 mm were attached on the upper and lower side of the leaves at three different heights (top, middle and bottom) (Mishra *et al.* 2015). The liquid application rate of the auto-rotate gun sprayer and knapsack sprayers were 1000 l/ha and 300 l/ha, respectively at travel speed range of 2-3 km/h was calibrated as per (IS:11429-1985). The strips were evaluated for the six leaf position, i.e. top upper (T), top under (TU), middle upper (M), middle under (MU), bottom upper (B) and bottom lower (BU) positions. Spray coverage and size distribution of spots on the strips were determined by using droplet analyzing system (Make: Radical Scientific Equipment). The number of droplets in one square centimeter area of water sensitivity paper was counted on each strip termed as droplet density. The percent area covered and volume of spray deposition was calculated in terms of mm/cm² of strip area and μ l/cm², respectively (Singh 2004 and Singh *et al.* 2011).

To evaluate the bio-efficacy of chemicals through different machines we have taken whitefly adult counts on randomly selected 20 numbers of plants in each treatment before, 3, 7 and 10 days after spraying. In each treatment,

the number of whitefly adults were counted on three leaves (one leaf from upper, middle and lower canopy) per plant. Untreated plots were served as a control to compare bio-efficacy among different treatments. The experiments were conducted using factorial randomized block design (RBD). General linear model (GLM) procedure was used for statistical analysis with the help of SPSS (Version 20) software. To test of significance, and their interaction effect of the performance parameter of the sprayer analysis of variance (ANOVA) and mean separation Duncan Multiple Range Test (DMRT) were applied.

RESULTS AND DISCUSSION

Development of PAU multipurpose high clearance sprayer: The PAU multi-purpose high clearance sprayer with three types of spraying arrangements were made namely auto rotate gun type, drop-up boom type and boom nozzles type which were operated by a single pump. The sprayer machine consists of a hydraulic pump, spray tank, suction port, discharge port, pressure gauge, and pressure control valve etc. The hydraulic piston pump was operated through V-belt drive arrangement by the power take-off of tractor. The height of boom can be adjusted up in the range of 300-2500 mm according to the crop height with the help of a control lever of hydraulic ram cylinder. Two control levers were used to open and close the boom, with the help of two separate hydraulic ram cylinders. Three pieces foldable boom was developed for easy transportation of machine on the road. Two liquid tanks having capacity of 500 l each (total 1000 l) were fitted over rear tyres to make it more balanced. Tanks were interconnected with each other and having built-in strainer to maintain homogeneity of sprayer solution inside the sprayer tanks. Drop-up boom sprayer has Boom nozzles which was used to spray on top canopy of plant and drop-up nozzles was used to spray below crop canopy up to 650-750 mm. The technical specification of multi-purpose high clearance sprayer is shown in Table 1.

Volume median diameter (VMD): The auto rotate gun type sprayer mechanism was found the lowest VMD as 144.00 μ m at middle under (MU) strip position at L_1 and highest as 353.30 μ m on bottom upper strip position on cotton leaf at L_3 location of field (Fig 1a). Because of volume median diameter is inversely proportional to the diameter of nozzle orifice and also inverse square root of pressure (Kepner *et al.* 2003). For the drop-up boom type sprayer mechanism lowest VMD was 184.00 μ m on middle under (MU) strip position at L_1 and highest 390.63 μ m on top under (TU) strip position at L_2 . However, for the boom type of sprayer mechanism the lowest VMD was observed as 132.60 μ m on top under (TU) strip position at L_3 and highest as 387.50 μ m at bottom upper (B) strip position of plant leaf at L_1 . And, for knapsack sprayer the lowest VMD was found as 221.29 μ m at middle under (MU) strip position of plant leaf at L_3 and highest as 394.08 μ m on bottom upper (B) strip position of plant leaf at L_1 . From the factor mean Table 2 it was found that the VMD of auto rotate gun type, drop-up boom type and boom sprayer differ

Table 1 Technical specification of multi-purpose high clearance sprayer

Machine unit	Particular		Detail
Prime mover	Source of power , hp		Tractor, 35
	Ground clearance & track width, mm		1100 & 2060
	Tyres size front & rear		7.5"×20" & 9.5"×32"
Attachments	Auto rotate gun type	Drop-up type nozzles	Boom type nozzles
Nozzle (Make: Teejet)	2 Nos.(gun type)	13 Nos.(Hallow cone) (TXA8004VK)	14 Nos.(Hallow cone) (TXA8002 VK)
Operating pressure, kg/cm ²	30-35	18-20	18-20
Nozzle spacing on boom, mm	9300	675	675
Nozzle height from boom, mm	At the	650-750	-
Gun rotations per minute	35	-	-
Radius, mm	1200	-	-
Angle of rotation, degrees	120	-	-
Coverage strip per nozzle,mm	2500	-	-
Swath, mm	20000	10250	10250

Table 2 Factor means of DMRT test of various sprayer experiment parameters

		VMD	Area coverage	Droplets-density	Spray deposition
Locations	L ₁	311.20 ^b	22.20 ^a	73.19 ^a	20.21 ^a
	L ₂	337.41 ^c	39.54 ^b	69.19 ^b	27.61 ^b
	L ₃	284.69 ^a	41.22 ^c	61.61 ^c	25.91 ^c
Sprayers	T ₁	285.48 ^b	34.05 ^b	77.19 ^a	25.39 ^a
	T ₂	259.28 ^a	38.62 ^c	79.40 ^b	26.32 ^b
	T ₃	351.55 ^{dc}	32.64 ^{ab}	57.91 ^c	21.20 ^c
	T ₄	348.08 ^c	31.97 ^a	57.49 ^a	25.39 ^a
Strip locations	T	320.37 ^a	58.67 ^a	92.74 ^a	42.70 ^a
	TU	236.07 ^b	28.58 ^b	73.85 ^b	20.85 ^b
	M	430.17 ^c	48.76 ^c	78.84 ^c	42.98 ^a
	MU	245.68 ^d	14.35 ^d	51.18 ^d	8.09 ^c
	B	369.27 ^e	39.96 ^e	64.71 ^e	27.55 ^d
	BU	265.03 ^f	15.60 ^d	46.66 ^a	05.30 ^a

Superscript latter different represent differ significantly. (P<0.05)

significantly between each other. However, VMD of boom type sprayer mechanism (T₃) was not differed significantly with the (T₄) knapsack sprayer. Despite of it, VMD had differed significantly for different position of strip. However, the locations of plots have also differed significantly due to crop varieties and environments. Form the ANOVA all parameters and their interaction have significant effect on VMD of droplets.

Droplets density: Numbers of droplets per square centimeter of sprayers used at different field location is depicted in Fig 1b. Auto rotate gun type (T₁) of mechanism was produced maximum number of 85.75 droplets/cm² on middle upper strip position at L₁, and minimum was found as 11.60 droplets/cm² on bottom under strip position at L₃. The

drop-up boom (T₂) was found maximum as 81.35 droplets/cm² on top upper strip position at L₁ and minimum were found as 14.40 droplets/cm² on bottom upper position at L₂. However, the average numbers of droplets were found in drop-up nozzle sprayer followed by auto rotate gun, boom type sprayer mechanism and knapsack sprayer which were 31.67, 26.29, 21.34 and 18.13 droplets/cm², respectively. For drop-up boom sprayer mechanism the highest number of droplets per square centimeter was found because of two types of sprayer nozzles, boom and drop-up nozzle both sprayer top and bottom side of crop canopy. Factor means (Table 2) showed that the sprayers have significantly affected on number of droplets. Despite of this the auto rotate gun sprayer and drop-up boom type sprayer have significant difference with the knapsack sprayer. It was also found that the droplets density of boom type sprayer was not significantly differing with knapsack sprayer. However, it was found that the number of droplets differed significant for all the strip position on plant leaf. From the ANOVA all parameters, location, sprayer, strip position and their interaction had significant effect on droplets density at P<0.5% level of significance.

Percent area covered: The highest percent area coverage was 73.00% in case of boom type of sprayer at L₂ on top strip position but suddenly the area coverage by this type of sprayer drop because of position of boom which drop the droplets vertical with the ground surface. However the lowest area of coverage was observed at the bottom under strip position of leaf for all type of sprayer mechanism (Fig 1c). The highest average area of coverage was observed for drop-up boom sprayer as 31.67% followed by auto rotate gun type, boom type and knapsack type of sprayer as 26.29, 21.24 and 16.86%, respectively. The auto rotate gun type sprayer mechanism has approximate same due to sprayer angle parallel to horizontal surface which target perpendicular to the plant canopy. In boom type sprayer the

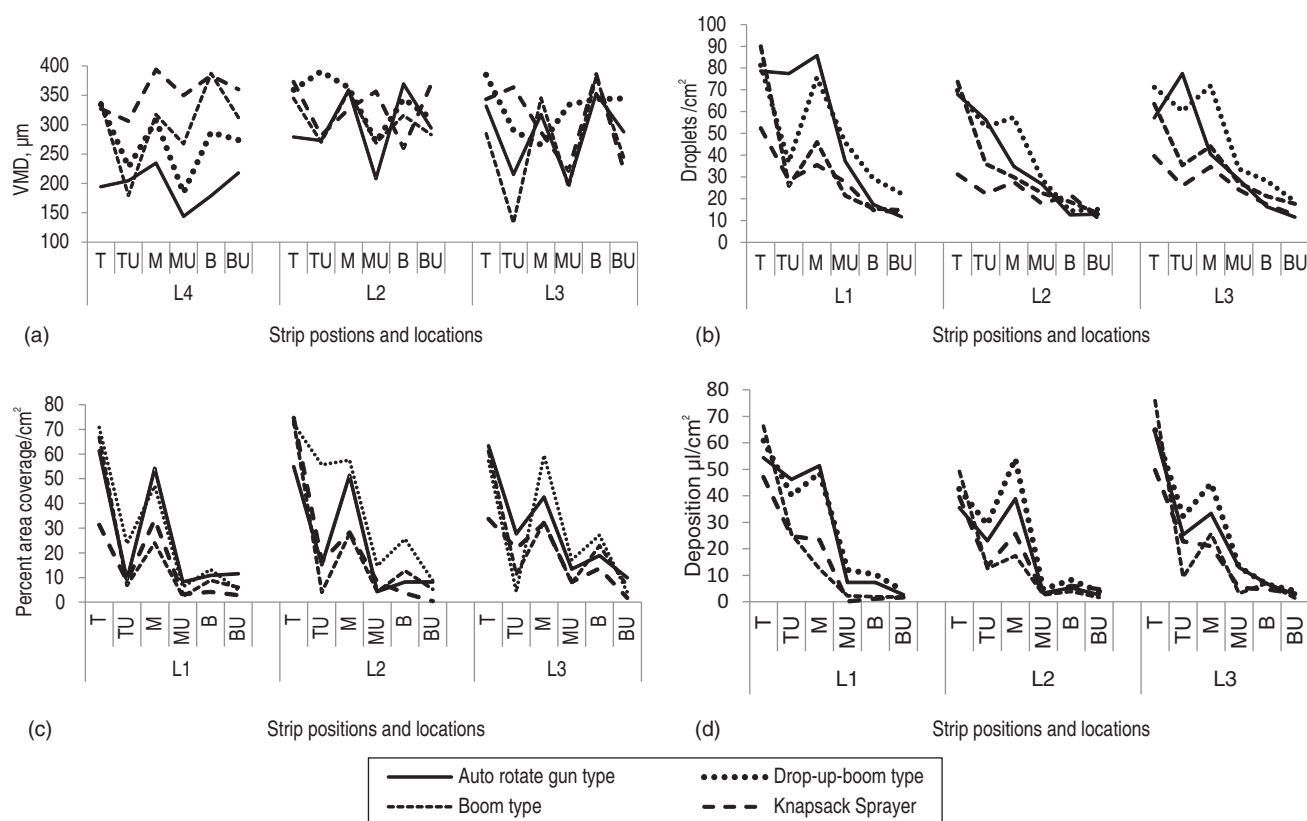


Fig 1 Sprayer performance parameters (a) VMD, (b) droplets density, (c) Percent area covered and (d) volume of sprayer deposited at different strip position and locations of different spraying attachments.

droplets fall in vertical direction on the leaf surface most of the sprayer drops tarp by the top canopy of plant which becomes difficult to reach the drop at lower canopy due to this lesser percent coverage. For the knapsack sprayer percent area of coverage was decreased from top to bottom canopy of plant due to uneven spray pattern, less operating pressure, top leaf also covers the lower leaf of plant which reduce the penetration distance of sprayer droplets ultimately reduce effective coverage. It was also observed that the top sides of leaf strip position have higher percent area coverage as compared with under sides of leaf strip position because of strip position. From the factor mean Table 2 revealed that the percent area coverage of sprayer and have significant difference with boom sprayer and knapsack sprayer. The sprayer auto rotate gun type and drop-up type of sprayer also have differed significantly with each other. The locations of sprayer have differed significantly it was due to operating machine parameters. However, for the strip location on leaf, percent area of coverage have differed significantly and for middle under and bottom under location of leaf have not significant different. From the ANOVA all the independent parameter location, sprayer, strip position and their interaction also differed significantly on percent are a coverage.

Deposition of spray volume: The boom sprayer was found highest volume deposition on top upper strip position of leaf at L₃, L₁ and L₂ location which was 75.85, 66.34 and 49.17 µl/cm², respectively (Fig 1d). This was due to

position of sprayer boom over the crop canopy. The drop-up boom sprayer produced highest average sprayer volume deposition for all strip position and location of sprayer as 26.87 µl/cm² followed by auto rotate gun, boom type and knapsack sprayer which were 23.49, 17.79 and 16.50 µl/cm², respectively. The drop-up boom spray mechanism, was high deposition due more numbers of nozzles on the boom results more deposition of spray volume compare to other sprayer undersides of leaf spray. This is because of strip positions on the plant leaf. From the factor mean (Table 2) it was observed that the depositions of various sprayers, i.e. auto rotate gun, drop-up boom and boom type of sprayer differ significantly between each other. But spray deposition of auto rotate gun type sprayer has not differed significant with the knapsack sprayer. The locations of sprayer have differed significantly it was due to operating machine parameters. However, all independent parameter location, sprayer, strip position and their interaction also have differed significantly for sprayer volume deposition.

Bio-efficacy of sprayers against whitefly adults: Efficiency of different sprayers for controlling whitefly adults using insecticide pyriproxyfen 100 g a.i./ha before, 3, 7 and 10 days after treatment at three different locations was presented in Fig 2A. All the sprayers were effective and significantly in reducing whitefly adult population over untreated control at L₁, L₂ and L₃, respectively. The maximum per cent reduction in whitefly population after 10 days of spraying ranged from 67.5-84.1% whitefly adults/3

leaves at L_1 , L_2 and L_3 , respectively, was obtained with boom type sprayer which was statistically at par with drop up boom type sprayer of 65.0 to 78.6% and auto rotate gun type sprayer of 64.4-78.2% at three different locations.

However, knapsack sprayer was resulted in least 53.9-80.3% reduction in whitefly population efficacy after 10 days of spray at all the experimental locations. This indicates that auto rotate gun, drop up boom type nozzles performed better in reducing 65-85% whitefly adult population as compared to knapsack sprayer which resulted in 54-80% control.

The results obtained from the second experiment, with another recommended insecticide flonicamid 75 g a.i./ha to check the efficiency of different sprayers at all three locations before and after 3, 7 and 10 days of treatment. All the treatments were found statistically better control of whitefly adult population over untreated control whitefly adults/3 leaves at L_4 , L_5 and L_6 , respectively, after 10 days of spraying. Drop-up boom type, auto rotate gun type and boom type spray mechanisms performed better with 85.62, 83.23, and 76.71% reduction of whitefly and was statistically at par with each other when compared to knapsack sprayer which showed 70.63% reduction of whitefly adults/3 leaves at L_4 , L_5 and L_6 , respectively, in whitefly adults after 10 days of treatment (Fig 2B).

Percent reduction of whitefly adults with all the three mechanisms of multi-purpose high clearance sprayer (i.e. drop-up boom, auto rotate type and boom type) varied from 72-88% as compared to knapsack sprayer which showed 63-75% reduction in whitefly adults after 10 days of spray at three different locations. The higher efficacy with this pump may be due to large spray volume and high operating pressure which results in better deposition and good coverage of crop. The reduction in whitefly population in case of multi-purpose high clearance sprayer was resulted because of its drop-up boom type of sprayer mechanism a greater number of droplets per unit area, large area coverage and high deposition of spray solution over and underside of leaf.

Cost, time and labour saving of sprayer operation: The cost involved in spraying with different sprayers used was calculated by straight line method under two heads fixed cost and operating cost. Cost of PAU multi-purpose high clearance sprayer and knapsack sprayer was taken as ₹ 3.5 lakh and ₹ 2000, respectively. Maximum effective field capacity for auto rotate gun type sprayer was found to be 2.84 ha/h followed by boom type of 1.78 ha/h, drop-up type sprayer mechanism of 1.46 ha/h and knapsack sprayer of 0.08 ha/h. The minimum cost of operation were found to be ₹ 150 per ha for auto rotate gun type which

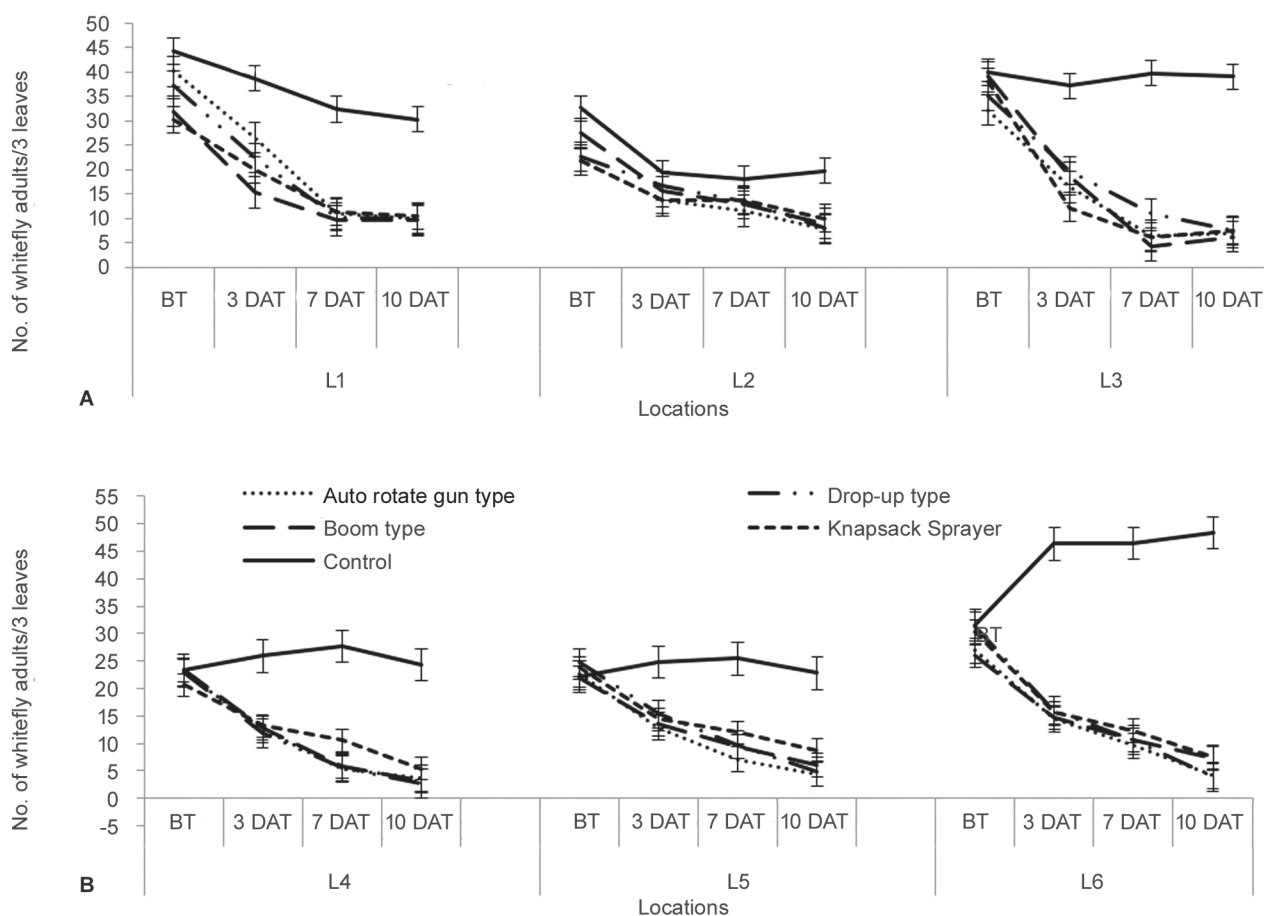


Fig 2 Sprayer's bio-efficacy (mean±SE) by using insecticide (A) pyriproxyfen 100 g a.i./ha and (B) flonicamid 75 g a.i./ha to control of whitefly.

was followed by of ₹ 239, 291 and 475 per ha for boom, drop-up type mechanism of multi-purpose high clearance sprayer machine and knapsack sprayer, respectively. Similar trends were observed in case of cost saving which were 68.55, 49.82 and 38.80% per ha as compared to knapsack sprayer. Also similar trend were observed in case of time and labour saving which having 97.20, 95.52 and 94.56% per hectare as compare to knapsack sprayer.

ACKNOWLEDGEMENTS

The authors acknowledge financial assistance provided by the Department of Agriculture Punjab, Chandigarh and PAU, Ludhiana, India. The work reported here was conducted as a part of project entitled “Cotton Development programme in Punjab for *Kharif* 2016”.

REFERENCES

- Anonymous. 2019. Package of practices for *kharif* crops. Punjab Agricultural University, Ludhiana, pp 34-35.
- Anonymous. 2016. Agricultural statistics at glance. Government of India, Ministry of Agriculture & Farmers Welfare, Department of Agriculture, Cooperation & Farmers Welfare, Directorate of Economics and Statistics, p 135.
- Indian Standard 11429-1985.1985. *Methods for Calibration of Sprayers*. Bureau of Indian Standards, Delhi, India. (Re-affirmed 1999).
- Kanthi K R. 2015. Whitefly—the black story. *Cotton Statistics and News* **23**: 1–4.
- Kepner R A, Bainer R and Barger E L.2003. *Sprayers. Principles of Farm Machinery*, Ist eBook Edns, pp 288-295. CBS Publications and Distributors Pvt Ltd.
- Laryea G N and No S Y. 2004. Electrostatic spray and atomization for agricultural application. *Atomization* **14**: 33–53.
- Singh M, Ghanshyam C, Mishra P K and Chak R. 2013. Current status of electrostatic spraying technology for efficient crop protection. *Agricultural Mechanization in Asia, Africa, and Latin America* **44**(2): 46–53.
- Mishra P K, Singh M, Sharma A, Sharma K and Mahal A K. 2015. Studies on effectiveness of electrostatic spraying for cotton crop. *Agricultural Mechanization in Asia, Africa, and Latin America* **46**(2): 17–22.
- Silvie P, Deguine J P, Nibouche S, Michel B and Vaissayre M. 2001. Potential of threshold-based interventions for cotton pest control by small farmers in West Africa. *Crop Protection* **20**: 297–301.
- Singh G, Kumar S S, Dixit A, Manes G S and Singh A. 2011. Spray distribution pattern of different sprayers on cotton using droplet analyzer. *Journal of Research SKUAST-J*, **10**: 33–40.
- Singh S K. 2005. ‘Design and development of a tractor mounted air assisted sprayer for cotton’. Ph D thesis, Punjab Agricultural University, Ludhiana India.