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Development of auto rotate gun sprayer for the control of whitefly *Bemisia tabaci* in cotton crop

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ABSTRACT : An auto rotate gun sprayer was developed for the control of whitefly*(Bemisia tabaci)* in cotton crop. The machine consist of two auto rotating gun,wiper motor, hose pipe, spray tank, boom, guns, and piston type hydraulic pump.The tractor having power of 35HP can be used for auto rotate gun sprayer.The analytical model suggests that time required for one oscillation of auto rotating gun was 1.54 seconds. Hencefor the distance traveled by sprayer in ð/3 rotation of auto rotating gun is 0.5 meters and time taken was 0.385 seconds. Therefore, the suggested forward speed of 1.29 m/s or 4.64 km/h for maximum uniformity of spray distribution.Theoretical field capacity of the sprayer was calculated 11.0 ha/h having swath width 24 m. The sprayer performance parameters i.e. Volume Median Diameter (VMD) 304.87µm, per cent area of coverage 26.54 per cent, droplet density 54.09 droplets cm^{-2}, and volume of spray deposition 25.51µlcm^{-2}. The developed prototype of an auto-rotate gun sprayer was work satisfactory during the laboratory test.

Key words : Analytical modelling, auto rotating gun, droplet density, sprayer, volume median diameter

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 t in India during the year of 2015-2016 (Anonymous 2016a).The country's total cotton sown area was lower down by 8 per cent to 12.82 million ha in the year 2014-2015. In Punjab, the cotton area has declined in 2016 as farmers shifted to other crops after incurring huge losses due to the whitefly attack in 2015. The cotton crop area in Punjab was 2.56 hundred-thousand ha lower by 43.11 per cent, from 450 000 ha in the previous year. More than 90 per cent of farmers have sown *Bacillus thuringiensis* cotton (*Bt* cotton) (Anonymous 2016b). The total area declined in Punjab from 2015 as farmers were afraid to grow cotton fearing the whitefly pest attack that had damaged the crop massively due to this, farmers have shifted to pulses, paddy and other crops (Anonymous 2016b).

Whitefly 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 per cent relative humidity. Cotton losses due to whitefly (Grout *et al.,* 2019) infestation were estimated to be in the range of 15-20 per cent and sometimes up to 30 per cent (Kanthi 2015). Mainly (90%) knapsack type sprayers are used by the farmers

to apply pesticides and plant growth regulators. 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 per cent 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 (Patel *et al.*, 2016; Miranda Fuentes *et al.,* 2017). A 40-50 per cent reduction in pesticide consumption reduces the protection cost from US$50/ha to less than US$30/ha. Accurate timing of spraying results in a 100-200 kg/ha increase in seed-cotton yield.

Mainly knapsack type sprayers are used by the farmers. But these types of sprayers are less efficient and very labour intensive. 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). In this technique, there are chances of over dosage of pesticide which may lead to many problems such as chemical waste and environmental pollution from spray drift. 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. Hence, an auto rotate type gun sprayer has been developed in collaboration with the industry, which is having more wider swath of about 30 m in a run and cover 8-10 ac/hour.

Development of auto rotate gun sprayer : 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 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 boom is horizontal to the ground surface and the direction 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 600L 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 a 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.

Evaluation of sprayer in the laboratory: Laboratory test was conducted to evaluate the sprayer performance parameter *i.e.* volume median diameter (VMD), droplets density/square cm, per cent area covered, and volume of spray deposition. Water sensitive paper method was used to evaluate the spray performance parameters (Mishra *et al.,* 2015, and Kumar *et al.,* 2020). In this method, water sensitive paper strips (76 × 26 mm) were placed in the direction of travel. The liquid application rate of the auto-rotate gun sprayer was 1250 l/ha at a travel speed range of 3 km/h was calibrated as per (IS:11429–1985).The oil and water sensitive paper method was used to evaluate various spray quality parameters such as droplet density (drops/cm^2), VMD (ìm) and coverage (%). Before the spray the oil and water sensitive papers were placed at 0.5 m interval on ground surface in each treatment and after spray the oil and water sensitive papers were collected and stored in zip lock polyethylene bag. 'Dropscan' software was used to determine VMD (ìm), droplet density (no. of drops cm-2) and area converge (%). The droplet size at which the cumulative percentage of volume contributed reached 50 per cent was taken as the volume median diameter (VMD) of the spray. The droplets in one square centimetre area of water sensitive 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 per cent strip area covered and µl/cm^2, respectively (Singh *et al.,* 2011).

Spray coverage and size distribution of spots on the cards were determined by a scanner (HP Scanjet 2400) with a resolution of 600 dpi none interpolated and analyzed by means of the computer DropScan® (WRK of Arkansas, Lonoke, AR; and WRK of Oklahoma, Stillwater, Ok; Devore Systems, Inc., Manhattan, KS) was used to analyze the water and oil sensitive cards. The total area of the pieces of card was analyzed by the software program. The droplet size spectra parameters measured were volume median diameter, droplets and per cent area coverage. VMD is the droplet diameter (mm) where 50 per cent of the spray volume is contained in droplets smaller than this value. Drop scan software converts each individual image spot area to the actual droplet diameter by using the equation.

$$D_d = 1.06\ A_s^{0.455} \quad \text{(i)}$$

Where, D_d is actual droplet diameter µm; A_s is spot area cm^2

Motion of auto rotating guns : A model is a representation or an abstraction of a system

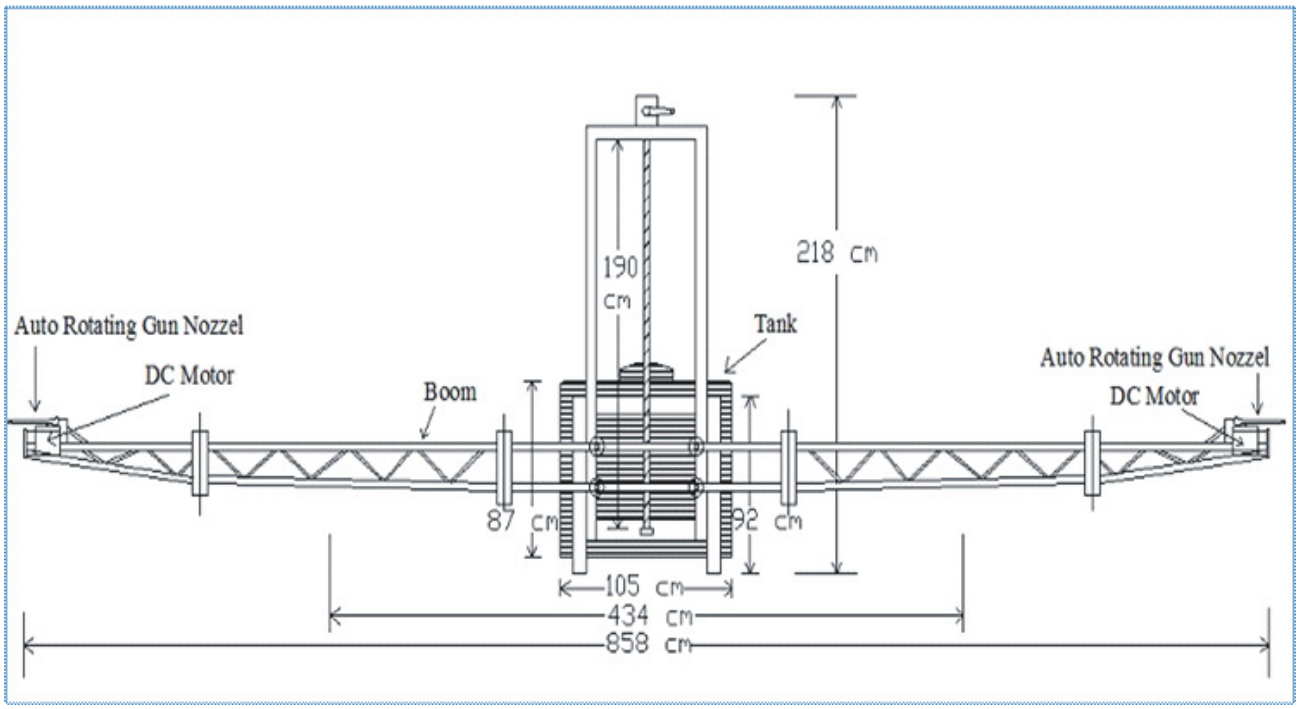

Fig. 1. Schematic diagram of tractor operated auto rotate gun sprayer

Table 1. Technical specification of developed auto rotate gun sprayer

Units	Particulars	Details
Source of Power	Tractor	35 hp
Tank	Spray tank capacity	600 litres
	Agitator	Hydraulic
Pump	Type	Hydraulic piston pump
	Make and model	ASPEE and PSB50A1N
	Recommended revolution range, rpm	700-900
	Required power, kW	3.73 (5 hp)
	Pump pressure,kPa	3430
	Range of boom height adjustment, m	0.5-1.5
Nozzles	No. of guns on boom	2
	Make	Teejet
	Spacing of guns on boom, m	8.58
	Max. gun discharge rate, l/sec	0.83
	Nozzle rotations per minute	39
	Radius, m	12
	Angle of rotation, degrees	120
	Coverage strip per nozzle, m	2.5
	Height of nozzle from target, m	1.5
	Forward speed (maximum), km/h	2-3

or process. An analytical model was also developed for optimizing the forward speed for uniformity of spray distribution. The auto rotating gun is oscillating at speed of 39 oscillating/min in simple harmonic motion. Therefore the equation of path curves generated by spray droplets were (Anonymous 2017):

Y_1= a sin x (ii)

Y_2= a sin (x - è/2) (iii)

Y_3= a sin (x + è/2) (iv)

Where Y_1= displacement of centerline of spray distribution, m;Y_2= displacement of top most particle of spray, m;$Y_{3=}$ displacement of lower most particle of spray, m;a = amplitude, m;x= angular velocity, rad/s andè= maximum angular displacement, degree.

Optimizing for maxima and minima conditions, thesecond derivative of equation ii, iii and iv were:

"'/"x' (Y_1, Y_2, Y_3) = 0 (v)

Y_1^o = - a sin x = 0

a = sin x (vi)

Y_2^o = - a sin (x - è/2) = 0

a = sin (x - è/2)

(vii)

Y_3^o = -a sin (x +è/2) = 0

a = sin (x + è/2)

(viii)

Solutions of the above equations were positive, therefore it satisfies the condition of maximum uniformity of spray distribution (eq.vi, vii and viii). The designed angle of oscillation of the auto rotating gun was 120°. So è = 2ð/3, hence by putting the value angleè in the equation ii, iii and iv, the final equations of path curve for the uniformity of spray distributionwere as follows:

Y_1= a sin x (ix)

Y_2= a sin (x - ð/3) (x)

Y_3= a sin (x + ð/3) (xi)

For one oscillation of auto rotating gun, time required was 1.54 seconds. Hencefor the distance traveled by sprayer in ð/3 rotation of gun is 0.5 meters and time taken was 0.385 seconds. The forward speed of 1.29 m/s or 4.64 km/h is required for maximum uniformity of spray distribution.

Spray performance parameters of auto rotate gun sprayer: The auto rotate gun sprayer was developed in the Department of Farm Machinery and Power Engineering, PAU Ludhiana. The developed sprayer machine work was observed during the lab test and found satisfactory. The results of performance parameters like VMD, percentage area coverage,

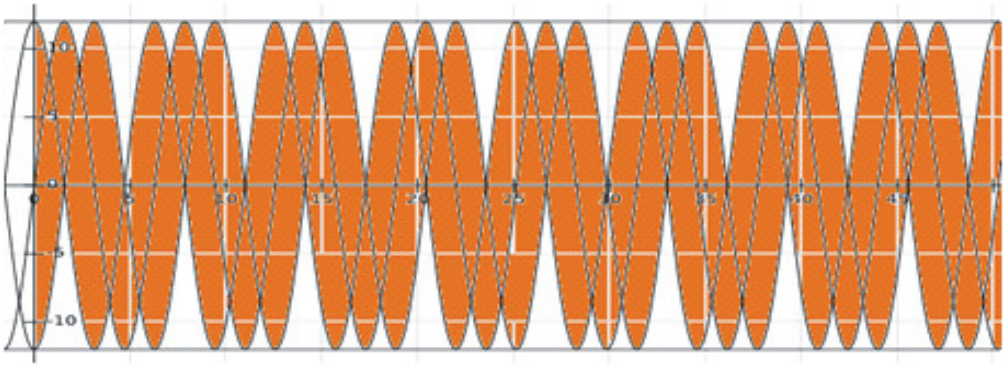

Fig. 2. Spray pattern followed by one rotating gun under simple harmonic motion

droplet density and deposition measured with the help of drop-scan softwareof water sensitive paper used in laboratory test are presented in Table 2.The volume median diameter of spray produced by the auto rotate gun sprayer was observed as 204.36, 378.79 and 331.47 µm for three replications of water sensitive paper and the corresponding percent area coverage, droplets density and volume of sprayer deposition were found as 21.45, 24.48, 33.33 per cent; 62.52, 47.37, 52.4 droplets cm^{-2} and 16.26, 35.68 and 24.59 µLcm-², respectively. From the results of water sensitive paper the average values of VMD, percent area coverage, droplet density and spray volume deposition were found 304.87, 26.54, 54.09 and 25.51 respectively for the developed auto rotate gun sprayer.

Table 2. Performance parameter of auto rotate gun sprayer observed during the lab test

S. No.	VMD, µm	Per cent area coverage	Droplet density/ cm^2	Deposition (µL/cm^2)
1.	204.36	21.45	62.52	16.26
2.	378.79	24.85	47.37	35.68
3.	331.47	33.33	52.40	24.59
Mean	**304.87**	**26.54**	**54.09**	**25.51**

Theoretical field capacity of the sprayer was calculated 11.0 ha/h having swath width 24 m and at forward speed of 4.64 $km.h^{-1}$. Field evaluation of developed auto rotate gun sprayerwill be carried out in cotton for control of whitefly and other insect and pest control in different crops.

CONCLUSIONS

Auto rotate gun sprayer was developed by mounting 2 guns having oscillating motion in an arc with the help of wiper motors, the developed prototype of auto-rotate gun sprayer worked satisfactory during the laboratory test. The analytical model suggestsfor one oscillation of auto rotating gun, time required was 1.54 seconds. Hencefor the distance traveled by sprayer in ð/3 rotation of gun is 0.5 meters and time taken was 0.385 seconds. The advised forward speed of 1.29 m/s or 4.64 km/h for maximum uniformity of spray distribution.The average values of VMD, percent area coverage, droplet density and spray volume deposition were found 304.87, 26.54, 54.09 and 25.51, respectively for the developed auto rotate gun sprayer. Theoretical field capacity of the sprayer is 11.0 ha/h having swath width 24 m and at forward speed of 4.64 km/h.

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