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ON-FARM ASSESSMENT OF UNMANNED AERIAL VEHICLE (UAV) BASED SPRAYING TECHNOLOGY IN GREEN GRAM

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ABSTRACT

A study was conducted to assess the field performance of an unmanned aerial vehicle (UAV) based sprayer for pesticide application in green gram crop in Punjab during 2018 and 2019. The treatments include: T1- control (untreated); T2- pesticide application with knapsack sprayer; and T3- pesticide application with UAV based sprayer. The droplet size was significantly small in T3 (200.34 to 253.01 µm) compared to T2 (463.88 to 738.80 µm). The droplet density was significantly more in T3 compared to T2 at top, middle and bottom of the crop canopy. The maximum reduction in whitefly *Bemisia tabaci* (Genn.) incidence was observed three days after spray in T3 (36.84 and 42.72%) and T2 (28.71 and 29.70%). Thus, UAV based sprayer was found to be more effective producing smaller droplets, more droplets/ unit area, and in controlling *B. tabaci* in green gram.

Key words: Unmanned Aerial Vehicle (UAV), aerial spraying, efficacy, drone sprayer, green gram, *Bemisia tabaci*, droplet density, size, Volume Median Diameter (VMD)

Green gram *(Vigna radiata* L.*)* is rich in protein, fiber, and iron, and in India, it was cultivated in Punjab state in about 24.0 thousand ha with a production of 18325 mt (Anonymous, 2019b). It is seriously attacked by pests and diseases, and insecticide application to control such pests cause many hazards to humans (Weisenburger, 1993; Meivel et al., 2016). Since decades, knapsack sprayer is the most commonly used spray equipment by the Indian farmers, but these conventional sprayers are inefficient, produce coarse droplets, and have low spray quality. Moreover, the operator is highly exposed to dangerous chemicals with these conventional sprayers (Cao et al., 2017). Furthermore, timely spray application can prevent pest and disease outbreaks. These problems can be prevented by adopting aerial spraying technology keeping human beings away from chemicals (Anonymous, 2001). Aerial spraying technology has many advantages such as enhanced efficiency, mobility, and considerably higher area coverage in lesser time (Zhang et al., 2014). The use of Unmanned Aerial Vehicle (UAV) also results in improved spray quality, effectiveness and reduced labour cost (Zhou and He, 2016). Further, multi-rotor UAV does not require dedicated take-off area and are most suitable for complex terrain and small farms (Qin et al., 2016). This technology for spraying agrochemicals is considered as a highly effective and efficient way as compared to conventional manual spraying operation (Xiongkui et al., 2017).

Researchers across the globe conducted field tests with UAVs to measure bioefficacy, coverage rate, and spraying performance with different parameters like flight speed, altitude, and spray swath settings. Liu et al. (2014) observed that field coverage of UAV was 7-10 ha/ hr, which was 30x more than manual sprayer and 3-4x more than a tractor-mounted sprayer. He and Zhang (2014) found that the unmanned helicopter spraying system saved 50% pesticides and 90% water compared to high clearance crop sprayer. Zhou et al. (2013) compared aerial application with ground machinery and found that an aerial application could reduce cost by 14.59 USD/ ha. Parmar (2019) developed a boom spraying system for UAV platform and suggested that for attaining better droplet density and coverage in cotton crop canopy, UAV should be operated at lower flying height of 0.50 m above crop canopy and at forward speed of 2.0 m/ sec. The downward airflow generated by the rotor of UAV effectively improved the penetrability of droplets into the crop canopy. Due to the downward airflow, the droplets deposition area was broader at about 150%. Increase in rotor speed made more uniform droplet deposition (Zheng et al., 2016). In India, all policies regarding application of drone/ small UAVs are framed by Director General of Civil Aviation (DGCA). The recent policy (Reference No. 05-13/

2014-AED Vol. IV) is applicable to all Civil Remotely Piloted Aircraft Systems (RPAS) that are controlled from a remote pilot station (Singh et al., 2019). DGCA has categorized drones/ UAVs into five groups based on their total weight. Mini UAVs (2-25 kg) and small UAVs (25-150 kg) are most commonly used for mapping, crop yield assessment and pesticide spraying. In India, very limited research has been conducted on UAV based spraying system, which is challenging with knapsack sprayer, which also involve drudgery of labour. Keeping in view of the advantages of UAV spraying technology, the present study evaluated the feasibility of the UAV based spraying technology in green gram (*Vigna radiata* L.).

MATERIALS AND METHODS

The study was conducted at the Research Farm of Punjab Agricultural University, Ludhiana (30°90”N,75°81”E, 247 masl) during 2018 and 2019 (Anonymous, 2019a). Field experiments were conducted to study droplet deposition parameters and pest control efficacy using UAV based sprayer and was compared with a traditional knapsack sprayer. The present study included: T1- control (untreated), T2- pesticide application with knapsack sprayer, and T3- pesticide application with aerial vehicle (UAV) based sprayer. The same variety of green gram (ML-2056) at recommended seed rate was sown. The location of field and pesticide were also kept same with plant to plant and row to row spacing being at 10 and 30 cm, respectively. Pesticide dimethoate 30%EC @617.8 ml/ ha was used in treatment T2 and T3 to control *B. tabaci* at water volume of 500 l/ ha and 20 l/ ha, respectively. The performance of the sprayers in terms of droplet size, droplet density, and reduction in *B. tabaci*) incidence was recorded.

A vertical take-off and landing (VTOL) type unmanned octacopter was selected as a UAV platform. The spraying platform consisted of a tank of 10 l capacity, miniature diaphragm pump, water hose/ pipeline, spraying nozzles, electronic control valve, and Li-Po batteries to provide the necessary power to the diaphragm pump. Four hollow cone nozzles having 925 µm orifice size were fixed below the BLDC motor mount bracket of the UAV platform at 620 mm spacing in a vertically downward direction for spraying pesticide. UAV based sprayer was operated at 2.0 m/ sec forward speed at a flying height of 1.5 m above the crop canopy (Fig. 1). The knapsack sprayer had a hollow cone nozzle of 1.0 mm nozzle orifice size and a pressure pump to provide a pressure of 0.8 MPa resulting in flow rate of 6.0 l/ min. The length of the lance of the sprayer was 81 cm. Before actual spray, trials were conducted to achieve the recommended spray application rate- UAV based sprayer gave 18.4 l/ ha while knapsack sprayer achieved 472.1 l/ ha. Further, the field trials were conducted on lesser windy days i.e. when wind speed was less than 5.4 km.h^{-1} (Qin et al., 2016).

Fig. 1. Pesticide application using UAV based sprayer in green gram

Spray deposition was observed on randomly selected plants with the crop canopydivided into three equal portions (top, middle, and bottom) according to the plant’s height (Fig. 2). The water sensitive paper (WSP) method was used to determined spray quality parameters as per the method prescribed by Ferguson et al. (2020). USB Digital Scale 1.0 software was used to analyze droplets on WSPs. Thereafter, volume contributed by droplets of the particular range was calculated as per the method prescribed by Singh et al. (2007) and based on that Volume Median Diameter (VMD), droplet density and droplet size of the sprayed particles were determined. The pesticide was used as per the recommended dose. Five plants/ plot were selected randomly from the sampling zone for efficacy against *B. tabaci*. The % reduction in *B. tabaci* was calculated following Qin et al. (2016). Split plot design was used to analyze the data, and also the interactions between the factors determined. Data were transformed to square root transformation before statistical analysis, and then compared between treatments using ANOVA. Treatments were replicated thrice. IMB SPSS 22.0 software was used for ANOVA computation and comparison of mean values done at p= 0.05.

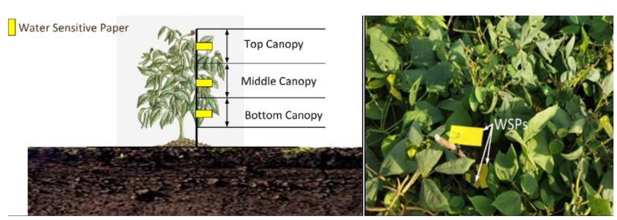

Fig. 2. Position of water sensitive paper at each sampling zone in green gram crop

RESULTS AND DISCUSSION

Droplet size is one of the most important parameters from the droplet distribution for effective spray application (Knoche, 1994). The mean droplet size (µm) observed during 2018 and 2019 presented in Fig. 3 reveal that it was smaller in treatment T3 (UAV based sprayer). This could be because of use of use ultra-low volume (ULV) spray nozzles. Also, downward airflow pressure generated by the UAV's propellers breaks down the droplet particles into a smaller size. These results agree with those of Sunada et al. (2005). The crop canopy had significant effect on droplet size, significant difference in bottom canopy was observed (Fig. 4). In UAV based sprayer, droplet size distribution was found uniform while in case of knapsack sprayer significant variation in droplet size distribution was observed. According to Qin et al. (2016) and Smith et al. (2000) droplet size between 50 to 400 µm should be optimum for a better and effective spray. In UAV based sprayer droplet size varied from 200.34 to 253.01 µm which falls in the optimum range, to penetrate the green gram canopy (top, middle and bottom). UAV based sprayer can penetrate such a canopy, with bottom canopy droplets being slightly smaller. This could be due to reason that suspended droplet particles were deposited in the bottom canopy for both types of sprayers.

The most crucial factor in precision spraying is droplet density and it depends upon the canopy structure of crop (Xu et al., 2006a; Xu et al., 2006b; Rawn et al., 2007). The mean droplet density (number of droplets/cm^2) observed in the study reveal that the droplet density was more with UAV based sprayer compared to that of Knapsack sprayer. This might be due to smaller droplets generation by the UAV based sprayer and higher coverage. Treatments had significant effect on droplet density, and significant difference in droplet density in the bottom canopy was observed. According to Qin et al. (2016), crop in the upper and outside regions are likely to gain more depositions than are those inside the crop canopy. Similar trend was found with UAV based spray; droplet density (140.81 droplets/ cm^2) at top canopy was 4.18x higher compared to that of knapsack sprayer in 2018; also at middle canopy, it was significantly higher with UAV spray. The coverage at bottom canopy was

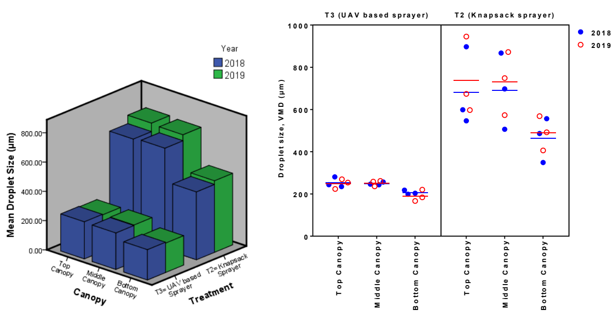

Fig. 3. Canopy wise droplet size (µm) in green gram

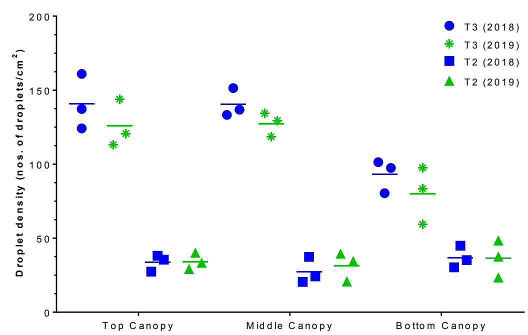

Fig. 4. Droplet density in crop canopies (2018, 2019)

Table 1. Efficacy of sprays against *B. tabaci* in green gram (% reduction)

Treatments	Mean number of whitefly adults/ three-leaves									
	Before spray	1 DAS	3 DAS	7 DAS	10 DAS	Before spray	1 DAS	3 DAS	7 DAS	10 DAS
			2018					2019		
T1= Untreated control	6.60 (2.57)a	7.33 (2.71)a	8.13 (2.85)b	8.87 (2.98)b	9.80 (3.13)b	6.60 (2.57)a	7.00 (2.65)a	7.53 (2.74)b	7.80 (2.79)b	8.53 (2.92)b
T2= Knapsack sprayer	6.73 (2.59)a	6.13 (2.48)a [8.91]	4.80 (2.19)a [28.71]	5.27 (2.29)a [21.78]	6.07 (2.46)a [9.90]	6.53 (2.56)a	5.73 (2.39)a [14.85]	4.73 (2.18)a [29.70]	5.47 (2.34)a [18.81]	5.73 (2.39)a [14.85]
T3= UAV based sprayer	6.33 (2.52)a	6.00 (2.45)a [5.26]	4.00 (2.00)a [36.84]	5.20 (2.28)a [17.89]	5.73 (5.73)a [9.47]	6.87 (2.62)a	5.73 (2.39)a [16.50]	3.93 (1.98)a [42.72]	5.20 (2.28)a [24.27]	5.73 (2.39)a [16.50]
S. Em. ±	0.25	0.44	0.68	0.66	0.68	0.20	0.27	0.57	0.44	0.50
CD (0.05)	0.75	1.32	2.03	1.99	2.04	0.60	0.81	1.70	1.33	1.51
CV	0.568	1.75	4.148	3.97	4.18	0.37	0.66	2.88	1.78	2.29

Note: DAS: Days after spray; Those in () square root transformed values and [] % reduction over control; Mean values in the same column showing similar alphabets at par.

lesser as compared to the top and middle canopy in both the treatments. Similar trend was observed during 2019. These results agree with those of Zhang et al. (2016).

Before spraying, *B. tabaci* incidence/ three-leaves in green gram was very consistent and more than the economic threshold level (ETL)- 6.33 to 6.73 and 6.53 to 6.87 whiteflies, during 2018 and 2019, respectively (Table 1); after 3rd day of spray, this significantly reduced with both UAV and knapsack sprayer sprays; at 7th day it increased to 5.20 (T3) and 5.27 (T2) during 2018 and to 5.20 (T3), and 5.47 (T2) during 2019, and it was still significantly lower than treatment T1. Similar trends were found after 10th day of spraying.

Thus, the UAV based sprayer was more effective against *B. tabaci* in green gram with maximum reduction at 3rd day after spray. Also, there was more droplet deposition and more efficacy.

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