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Bio-efficacy of Unmanned Aerial Vehicle based spraying to manage pests

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ABSTRACT

An agricultural spraying system for UAV platform was developed at the Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana during 2019 to spray pesticides in cotton, rice and moong crops for the control of pests. The developed aerial spraying system was operated at three flying speeds, i.e. S1 (2.0 m/s), S2 (3.0 m/s) and S3 (4.0 m/s) and at three flying heights, i.e. H1 (0.50 m), H2 (0.75 m) and H3 (1.0 m). Whitefly and brown plant hopper (BPH) were the targeted pest and its bio-efficacy data were collected after spray application. Results indicated that flying height and forward speed had significant effect on bio-efficacy in all the three crops. In cotton, whitefly populations varied between 19.00-21.40 per three leaves. The maximum percent, i.e. 84.85% reduction in white fly population was observed at 7 DAS in H1S1 treatment. In rice, BPH population was varied between 6.60–9.47 per hill followed by control 17.20 per hill. Maximum percent reduction in BPH population was observed 67.42% at 7 DAS in H3S1 treatment. In moong, reduction in whitefly population was varied between 4.87–5.80 per plant followed by control (7.00 per plant). After three days of spray, combination of flying heights (H1, H2 and H3) and forward speeds (S1, S2 and S3) were found to be significantly effective in dropping whitefly and BPH population. Increase in flying height and forward speed reduced percentage reduction of pests. Combination of flying heights H1 and H2 and forward speeds S1 and S2 treatments were found significantly effective in controlling pests in all three crops.

Keywords: Aerial spray, Bio-efficacy, Cotton, Moong, Rice, UAV spraying

Pests in crops significantly affect agricultural production and due to that world had to face about 30% of crop loss annually (Godfray *et al.* 2010). Therefore, it is prime objective to adopt an efficient crop protection technology which can effectively control pests for agricultural productivity and sustainability. Aerial spraying by unmanned aerial vehicle (UAV) is an emerging practice in many developed countries as well as developing country like India (Li *et al.* 2019). Indian farmers use conventional sprayers, which leads to excessive use of chemicals, less spray uniformity, low deposition, higher cost of spray operation and environment pollution (Rincón *et al.* 2017, Cao *et al.* 2017). The use of UAV for spraying pesticides can improve spray quality, timeliness, effectiveness and reduce labour cost (Zhou and He 2016).

Various researchers and scientists conducted field tests using UAVs. Field coverage of UAV was generally in the range of 4-10 ha/h which was 30 to 100 times more than manual spraying (Huang *et al.* 2009, Xinyu *et al.* 2014, Qin *et al.* 2014, Giles and Billing 2015, Meivel *et al.* 2016). According to He and Zhang (2014), the unmanned helicopter spraying system saved up to 50% pesticides and 90% water compared to high clearance crop sprayer. Increase in rotors speeds made more uniform droplet deposition (Xinyu *et al.* 2014, Ru *et al.* 2015, Qing *et al.* 2017). Through the application of UAV spraying system mechanical damage of crop can be prevented as compared to tractor operated sprayer and secondly spray application can be done in standing water in rice crop (Parmar 2019). Lou *et al.* (2018) found that the control of aphids and spider mites in cotton crop by using UAV sprayer was 64.0% and 61.3%, respectively. Qin *et al.* (2016) used small UAV to control brown plant hoppers (BPH) in rice and found insecticidal efficacy of 92–74% from 3–10 days after spraying insecticide. Keeping in view of above facts, an agricultural spraying system was developed for UAV and used for spraying pesticides in different crops (i.e. cotton, rice and moong) to study its efficacy in pest control.

MATERIALS AND METHODS

Unmanned Aerial Vehicle based spraying system: A vertical take-off and landing (VTOL) type of unmanned multicopter was selected for the study, which was powered by two Li-Po batteries. The octacopter UAV comprised

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Table 1 Different treatment combinations

Treatment	Flight height (m)	Forward speed (m s^{-1})
H1S1	0.55 (H1)	2.00 (S1)
H1S2		3.00 (S2)
H1S3		4.00 (S3)
H2S1	0.75 (H2)	2.00 (S1)
H2S2		3.00 (S2)
H2S3		4.00 (S3)
H3S1	1.00 (H3)	2.00 (S1)
H3S2		3.00 (S2)
H3S3		4.00 (S3)
Control	No spray application	

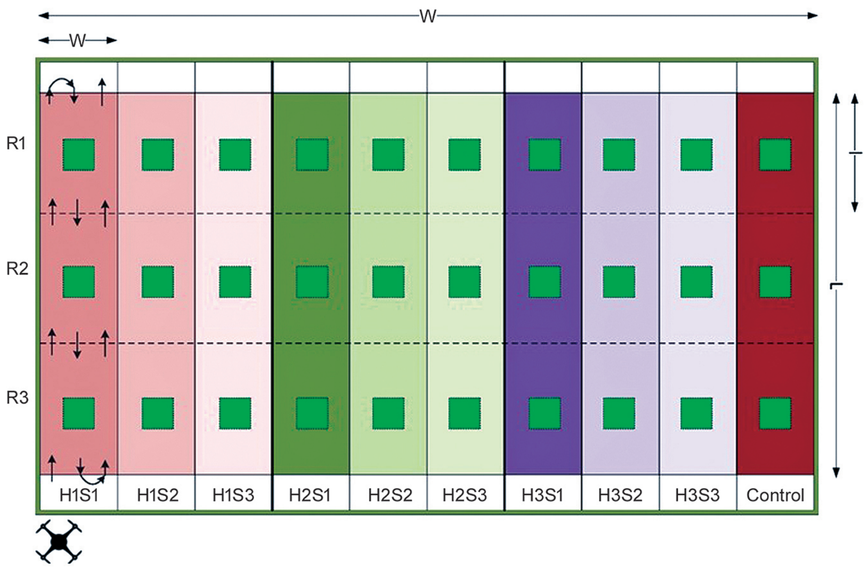
of several components like airframe, propulsion system, command and control system. Fuselage, landing gear, and arms belong to the airframe. Battery, motor, electronic speed controller (ESC), and propellers belong to the propulsion system. Radio-controlled (RC) transmitter and receiver, flight controller unit, global position system (GPS) receiver, a ground control station (GCS), and radio telemetry belong to the command and control system. The agricultural spraying system for unmanned aerial vehicle was developed by Parmar (2019) at the Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana (2019). The spraying system consisted of a 10 litre capacity tank, a 12V DC diaphragm pressure pump, transparent water hoses, six hollow cone nozzles having orifice size 925 µm, and electronic control valve. Nozzles were fitted vertically downward at 620 mm spacing. The pump was operated at the pressure of 0.39 MPa and average discharge of single nozzle was 0.206 L/min. The pump flow rate was constant irrespective of forward speed of the UAV.

Experimental design: The experiment was conducted at research farm of the Department of Farm Machinery and Power Engineering during *kharif* and *rabi* 2019. Three different flight heights and three different forward speeds of the UAV based sprayer were selected for the study (Table 1). Nine combinations of treatments were replicated thrice (Fig 1). One untreated control plot was provided to compare the performance of developed agricultural spraying system for UAV. The experimental layout was split-plot design, and treatments were not randomized within blocks due to a straight flight path of UAV spraying system. Qin *et al.* (2016) also conducted experiments in the similar way without treatment randomization. Each block was covered by three flight paths, and a buffer zone was kept in between treatments to avoid experimental error. The detailed field layout has been shown in Fig 1.

Crop and field preparation for experiment: Field was prepared and cotton variety RCH-773 was sown using pneumatic planter at spacing of 675 mm × 750 mm. Bt-cotton is highly susceptible sucking pests, viz. whitefly, jassid, mealybug, thrips and aphid. For the study in cotton, target pest was whitefly. Spray application was done referring the Economic Threshold Level (ETL). ETL level was six adults per leaf in the upper canopy of the plant or when honey dew appeared on 50% of the plants.

Rice variety PR 121 was grown for the study. Transplanting was done by mate type paddy transplanter at spacing of 300 mm × 120 mm. In rice, main target pest was brown plant hopper. BPH is sucking pests mostly found during the months from July to October. The ETL level in this case was minimum 5 plant hoppers BPH per hill. Sowing of moong ML-2056 was done by raised bed former seed drill (Fig 1). In this crop the target pest was whitefly.

Bio-efficacy: Five plants were selected randomly in each plot. The randomly selected plants were from central area of the plot and they were tied with tags for easy identification. The number of insects was counted on each plant before spray and it was further counted on 1st, 3rd, 5th and 7th days after spraying. The insecticide was used as per the recommended dose and spray schedule. To control whitefly in cotton, polo 50% WP (diafenthiuron) @ 200 g/acre was applied. Confidor 17.80% SL (imidacloprid) @ 40 ml/acre was applied in the rice field using UAV spraying system to control



Parameter	Cotton	Rice	Moong
Total length of field (L), m	60	65	45
Total width of field (W), m	75	60	45
The total area of the experimental field, m^2	4500	3900	2025
Length of each test plot (l), m	20	20	15
Width of each test plot (w), m	7.5	6.5	4.5
Area of each test plot, m^2	150	130	67.5

Fig 1 Experimental layout and treatments for cotton, rice and moong.

Fig 2 View of spraying in cotton using developed spraying system for UAV.

brown plant hopper. Similarly, in moong rogor 30% EC (dimethoate) @ 250ml/acre was applied to control whitefly (Fig 2).

The percent reduction in number of insects was calculated according to methods prescribed by Qin *et al.* (2016):

$$R = \frac{IB - IA}{IB} \times 100\% \qquad (1)$$

where R, percent reduction in number of insects; IB, number of live insects before spray; IA, number of live insects after spray.

The data collected from the research experiments was statically analyzed using IMB SPSS 22.0 software to compute the analysis of variance (ANOVA) and to compare mean values at 5% level of significance so as to understand the effect of flying height and forward speed to control pests in cotton, rice and moong.

RESULTS AND DISCUSSION

Bio-efficacy in cotton: At one day after spray (1 DAS), combination of flying heights H1 and H2 and forward speeds S1 and S2 were found significantly effective in the reduction of whitefly population at a 5% level of significance. Whitefly population varied between 19.60– 21.40 per three leaves (Table 2). Similar trends were observed at 3 DAS. Combination of flying height H1 and H2 and forward speed S1 and S2 treatments were found to be significantly effective in the reduction of the whitefly population which varied between 12.67–15.80 per three leaves followed by H3S1, H3S3 and H3S2 treatments, which were 20.07, 19.87 and 16.80 per three leaves, respectively. Although treatments under this study for cotton crop were found better in comparison to control. At 7 DAS whitefly population was significantly lower in case of H1S1, H1S2, H1S3, H2S1, H2S2 and H2S3 which were 6.00, 7.87, 8.13, 6.60, 6.80 and 7.33 per three leaves, respectively. At 10 DAS, whitefly population increased as compared to 7 DAS in all treatments. Although treatments under this study for cotton crop were found better in comparison to control.

It is evident from the observed data that ~~at~~ the lower flying height and slow forward speed were more effective to control whitefly. Increasing flying height and forward speed reduced percentage reduction in whitefly population. The reduction (84.85%) in white fly population was observed at 7 DAS in H1S1 treatment. Similar results were observed by Lou *et al.* (2018) to control whitefly in cotton. For better pest control desired droplet size should be between 50–300 µm (Song *et al.* 2007). Developed system generated 208.61 µm droplet size which is in the range of optimum for pest control. It was concluded from the results that UAV based sprayer was more effective to control whitefly in cotton due to its spray uniformity.

Bio-efficacy in rice: At 1 DAS, combination of flying height H1, H2 and H3 and forward speed S1, S2 and S3 treatments were found to be effective in reducing the BPH population which varied between 6.60–9.47 per hill, whereas in control field, it was 17.20 per hill (Table 2). At 3 DAS, combination of flying heights (H1, H2 and H3) and forward speeds (S1, S2 and S3) treatments were found to be effective in reducing the BPH population. It varied from 5.87 to 8.13 per hill, whereas in control it was 19.47 per hill. At 7 DAS BPH population was significantly lower in H1S1, H1S2, H1S3, H2S1, H2S2, H2S3, H3S1, H3S2 and H3S3 which were 5.80, 5.50, 5.53, 6.33, 6.33, 5.73, 4.80, 5.00 and 5.73 per hill, respectively. At 10 DAS, BPH population increased in all treatments. Although treatments under this study for rice crop were found better in comparison to control. Maximum reduction (67.42%) in BPH population was observed at 7 DAS in H3S1 treatment. Similar results were observed by Qin *et al.* (2016) to control BPH in rice.

Bio-efficacy in moong: At 1 DAS, combination of flying height H1, H2 and H3 and forward speed S1, S2 and S3 treatments were found to be significantly effective in reducing the whitefly population which varied from 4.87 to 5.80 per plant, whereas in control it was 7.00 per plant (Table 2). At 3 DAS, combination of flying heights (H1, H2 and H3) and forward speeds (S1, S2 and S3) treatments were found to be more effective in reducing the whitefly population which varied between from 3.60 to 4.73 per plant. In control it was 7.53 per plant, although treatments under this study for moong crop were found better in comparison to control. At 7 DAS whitefly population was significantly low in H1S1, H1S2, H1S3, H2S1, H2S2, H2S3, H3S1, H3S2 and H3S3 which were 5.20, 4.67, 4.80, 5.47, 5.73, 5.20, 5.27, 5.47 and 5.67 per plant, respectively. At 10 DAS, whitefly population increased in all treatments, although treatments under this study for moong crop were found better in comparison to control.

It was observed that lower flying heights (H1 and H2) and slow forward speeds (S1 and S2) were more effective to control whitefly in moong. Increasing flying height and forward speed reduces percentage reduction of whitefly population. However, the maximum reduction (44.33%) in BPH population was observed at 3 DAS in H1S2 treatment. It was concluded from the results that UAV based pesticide sprayer was more effective to control whitefly in moong due to its uniformity and optimum droplet size. It is evident from the results for all three crops (i.e. cotton, rice and moong) at 3 DAS and 7 DAS all treatments effectively reduced the targeted pests. Even though these three crops having different type of canopy, the developed agricultural spraying

Table 2 Effect of treatments on bio-efficacy against pests in various crops

Treat-ment	Cotton					Rice					Moong				
	No. of whitefly adults/3 leaves					No. of BPH adults/hill					No. of whitefly population/plant				
	BS	1 DAS	3 DAS	7 DAS	10 DAS	BS	1 DAS	3 DAS	7 DAS	10 DAS	BS	1 DAS	3 DAS	7 DAS	10 DAS
H1S1	39.60 [6.29] a	20.20 [4.49] a (48.99)	15.53 [3.94]a (60.77)	6.00 [2.45] a (84.85)	8.00 [2.83] a (79.80)	13.87 [3.72]a	7.33 [2.71] a (47.12)	6.80 [2.61] a (50.96)	5.80 [2.41] a (58.17)	8.53 [2.92] a (38.46)	6.87 [2.62] a	5.73 [2.39] a (16.50)	3.93 [1.98] a (42.72)	5.20 [2.28] b (24.27)	5.73 [2.39] b (16.50)
H1S2	38.53 [6.21] a	19.60 [4.43]a (49.13)	14.67 [3.83]a (61.94)	7.87 [2.81] a (79.58)	9.73 [3.12] a (74.74)	14.93 [3.86]a	7.70 [2.77] a (48.44)	6.67 [2.58] a (55.36)	5.50 [2.35] a (63.17)	8.07 [2.84] a (45.98)	6.47 [2.54] a	5.50 [2.35] a (14.95)	3.60 [1.90] a (44.33)	4.67 [2.16] a (27.84)	5.40 [2.32] a (16.49)
H1S3	39.87 [6.31]a	19.00 [4.36]a (52.34)	13.93 [3.73]a (65.05)	8.13 [2.85] a (79.60)	9.73 [3.12] a (75.59)	14.27 [3.78]a	7.93 [2.82] a (44.39)	6.67 [2.58] a (53.27)	5.53 [2.35] a (61.21)	8.40 [2.90] a (41.12)	6.13 [2.48] a	5.40 [2.32] a (11.96)	4.00 [2.00] a (34.78)	4.80 [2.19] a (21.74)	5.40 [2.32] a (11.96)
H2S1	39.87 [6.31]a	21.40 [4.63]a (46.32)	15.80 [3.97]a (60.37)	6.60 [2.57] a (83.44)	8.47 [2.91] a (78.76)	14.73 [3.84]a	8.07 [2.84] a (45.25)	7.13 [2.67] a (51.58)	6.33 [2.52] a (57.01)	8.80 [2.97] a (40.27)	6.53 [2.56] a	5.73 [2.39] a (12.24)	4.73 [2.17] a (27.55)	5.47 [2.34] b (16.33)	5.73 [2.39] b (12.24)
H2S2	42.60 [6.53]a	19.87 [4.46]a (53.39)	12.67 [3.56]a (70.27)	6.80 [2.61] a (84.04)	9.40 [3.07] a (77.93)	15.13 [3.89]a	9.47 [3.08] a (37.44)	8.13 [2.85] b (46.26)	6.33 [2.52] a (58.15)	8.47 [2.91] a (44.05)	6.33 [2.52] a	5.40 [2.32] a (14.74)	4.47 [2.11] a (29.47)	5.73 [2.39] b (9.47)	5.87 [2.42] b (7.37)
H2S3	38.00 [6.16]a	19.80 [4.45]a (47.89)	13.27 [3.64]a (65.09)	7.33 [2.71] a (80.70)	9.40 [3.07] a (75.26)	14.93 [3.86]a	8.33 [2.89] a (44.20)	7.13 [2.67] a (52.23)	5.73 [2.39] a (61.61)	8.33 [2.89] a (44.20)	7.47 [2.73] a	5.73 [2.39] a (23.21)	4.40 [2.10] a (41.07)	5.20 [2.28] b (30.36)	5.47 [2.34] a (26.79)
H3S1	40.00 [6.32]a	27.60 [5.25]b (31.00)	20.07 [4.48]b (49.83)	12.87 [3.59]b (67.83)	15.80 [3.97]b (60.50)	14.73 [3.84]a	8.07 [2.84] a (45.25)	6.07 [2.46] a (58.82)	4.80 [2.19] a (67.42)	7.87 [2.81] a (46.61)	6.07 [2.46] a	4.87 [2.21] a (19.78)	4.47 [2.11] a (26.37)	5.27 [2.30] b (13.19)	5.93 [2.44] b (2.20)
H3S2	39.73 [6.30]a	23.33 [4.83]b (41.28)	16.80 [4.10]b (57.72)	12.20 [3.49]b (69.30)	13.80 [3.71]b (65.27)	13.60 [3.69]a	6.60 [2.57] b (51.47)	5.87 [2.42] a (56.86)	5.00 [2.24] a (63.24)	8.60 [2.93] a (36.76)	6.73 [2.59] a	5.40 [2.32] a (19.80)	4.40 [2.10] a (34.65)	5.47 [2.34] b (18.81)	5.87 [2.42] b (12.87)
H3S3	39.47 [6.28]a	23.87 [4.89]b (39.53)	19.87 [4.46]b (49.66)	16.13 [4.02]b (59.12)	18.00 [4.24]b (54.39)	14.60 [3.82]a	7.93 [2.82] a (45.66)	6.93 [2.63] a (52.51)	5.73 [2.39] a (60.73)	7.70 [2.77] a (47.26)	6.80 [2.61] a	5.80 [2.41] a (14.71)	4.73 [2.17] a (30.39)	5.67 [2.38] b (16.67)	6.20 [2.49] b (8.82)
Control	41.20 [6.42]a	45.40[6.74] c	48.87[6.99] c	55.13[7.42] c	57.70[7.60] c	15.53 [3.94]a	17.20[4.15] c	19.47[4.41] c	21.27[4.61] b	23.27[4.82] b	6.60 [2.61] a	7.00 [2.65] b	7.53 [2.74] b	7.80 [2.79] c	8.53 [2.92] c
CD (0.05)	0.10	0.72	1.01	1.49	1.43	0.08	0.44	0.58	0.71	0.62	0.08	0.11	0.23	0.08	0.18
CV	0.02	0.15	0.24	0.43	0.38	0.02	0.15	0.21	0.28	0.20	0.03	0.05	0.11	0.03	0.07

BS, Before spray, DAS: Days after spray; Those in [] are square root transformed values and () are per cent reduction over control; Mean values in the same column showing similar alphabets are at par at P<0.05 by Tukey's B method.

system for UAV it effectively reduced the pests as compared to control. Increasing flying height and forward speed reduced percentage reduction of pests. All the treatments under the study were found better in comparison to control. The flying heights (0.55 m and 0.75) and speeds (2 m/s and 3 m/s) for aerial spraying were found to be better for effective pest control.

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