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Performance Evaluation of Hexacopter UAV (ANGRAU-PUSHPAK) Spraying for Management of Chilli Aphids, *Myzus Persicae* (Sulz.)

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ABSTRACT

Unmanned aerial vehicle (UAV) sprayers have exceptional potential to revolutionize the Indian agriculture to ensure sustainable national food and nutritional security by efficiently performing the crop protection activities with precision in very short time. The present was study aimed at evaluating efficacy of UAV spraying in managing chilli aphids, *Myzus persicae.* The experiment was conducted at operational research project (ORP) site at Lam village of Guntur District, Andhra Pradesh during *kharif* 2021-22 and *kharif,* 2022-23 with restricted randomized block design (RRBD). The treatments imposed are based on the recommended doses of pesticides issued by Central Insecticide Board and Registration Committee (CIB and RC), Govt. of India for the evaluation. RRBD was imposed with five treatments and four replications with 100%, 75% and 50% RDP with UAV sprayer and 100% RDP with human backpack sprayer and a control plot with only water spraying with UAV sprayer for asserting the efficacy of UAV spraying when sprayed at low volume spraying (25 L per ha)) Pre and post spraying (5 days after spraying) data was collected. The first spray to control chilli aphids was carried out 54 DAT (Days after transplant) with Spirotetramat 15.3 % w/w OD with 100% RDP (T1), 75% RDP (T2), 50% RDP (T3) with drone and 100% RDP with human back pack sprayer (T4) and control (T5). The pre count was 34.5 – 36.25 per 10 cm twig and post count data reduced number of aphids per 10 cm twig from 34.5 to 18.75, 35.25 to 21.0, 35.5 to 21.5, 36.25 to 24.25, 34.75 to 35.25 acrds the treatments respectively with a percent reduction over control of 46.19, 40.86, 33.34 and 40.33 respectively in 2021 and 44.74, 37.09, 27.08, 35.03 respectively acards the treatments during 2022. The second spray was carried out at 61 DAT with Fipronil 5% SC. The pre and post spraying (5 days after spraying) data analysis revealed that in T1, T2, T3, T4 and T5 the percent reduction over control was 83.19, 78.58, 59.79 and 78.27, respectively during 2021 and 86.05%, 82.05%, 67.45%, 80.21% reduction over control respectively during 2022. The drone spray fluid volume of 25 L ha^{-1} was found efficient without affecting the bio-efficacy instead of 500 L.ha^{-1} used in human back pack spray technology. Drone spraying technology offers 95% reduction in water use for plant protection. The recommended doses for UAV spraying of Spirotetramat 15.3 % w/w OD is 120 ml $acre^{-1}$ and Fipronil 5% SC is 300 ml acre-^{1} to control aphids in chilli which saves 25% cost of plant protection for aphids in chilli.

Key Words: *Chilli, Hexacopter, Myzus persicae, Spirotetramat and UAV sprayer.*

Adoption of modern technologies in agriculture, especially unmanned aerial vehicles (UAV's) / drones has been a great boon to Indian agriculture to effectively and efficiently combat the problem of acute labour shortage to take up timely plant protection and other management activities. To ensure sustainable growth of agriculture produce and national food security, it is essential to standardize and upscale the technologies for precise use of factors of production of seed, irrigation, fertilizers, pesticides, labour and capital. Chemical control for insects, diseases and weeds is an important agricultural factors of production, which contributes to the largest share of cost of cultivation. Spraying technology by using unmanned aerial vehicle (UAV) has various advantages over traditional spraying for it being 10 times more field capacity, high spraying uniformity, good droplet deposition, time saving and zero drudgery and toxic exposure to the farmer (*Sambaiah et al.,* 2022).

Chilli (*Capsicum annum* L.) belongs to Solanaceae and center of origin of hot chilli is Mexico. It is important vegetable cum spice crop valued for its aroma, taste, flavor and pungency grown in all over world, India and Andhra Pradesh in particular. It contains numerous chemicals like steam volatile oils, fatty oils, capsaicinoids, carotenoids, vitamins, protein, fiber and mineral elements which have tonic and carminative action (*Bosland and Votava, 2012*). It is also an excellent source of Vitamins A, B, C (340 mg per 100 gram), E and P. Fresh green chilli has more vitamin A than carrots. In 2021-22, India has reached its pinnacle in world trade of chilli with 42% share followed by Bangladesh, Thailand and China etc. Andhra Pradesh is the largest producer of chilli with 38%, production with Guntur, Krishna, Prakasam and Kurnool are the major chilli growing districts and Guntur district alone contributes to cultivation in 70,000 ha and 15% of total production of chilli in India (*Sireesha et al., 2021*).

Although the crop has got great potential for export, ravages of insect pests and disease has drastically decreased its yield. Among all, sucking pests like *Myzus persicae*, *Thrips parvispinus*, *Aphis gossypii* and yellow mite are considered as major pests that attack chilli. After invasive thrips, aphids found to be devastating in both open and poly house conditions. Due to variation in agroclimatic regions, the nature and extent of damage caused by aphids vary in terms of degree and intensity. They suck the sap from leaves and shoots and the effected leaves turn yellow, wrinkled and distorted and exude honeydew on which fungus develops, rapidly multiply and yield get reduced by 20-30% besides spreading cucumber mosaic virus in chilli. Due to the continuous biotic stress of pests and diseases in chilli, farmers spray various chemicals using human backpack sprayers once in 4-5 days which demands for intensive labour input (*Pathipati et al., 2020)* and increases cost of cultivation and incapacitate the chilli ecosystem with untimely plant protection. Use of UAV is the best combating farm machine to counter act the 4-dimentsional problem of labour issue in India, i.e. in terms of quantity, quality, cost and accessibility. According to *Phang et al. (2014)*, UAV has greater benefits over terrestrial vehicles in terms of mobility and time efficiency. It is 40 times faster than the conventional backpack sprayer. Through the application of UAV based spraying system, mechanical damage of crop can be prevented as compared to tractor operated sprayer. In order to standardize UAV spraying in chilli for it's bio-efficacy, phytotoxicity, standard operational parameters for UAV spraying the present study was done in chilli ecosystem in Lam village, Guntur Dist, Andhra Pradesh.

MATERIAL AND METHODS

The present research was conducted in the experimental fields of Regional Agricultural Research station, Lam, ANGRAU during the year *kharif*, 2021 and *kharif*, 2022. In both the years, the data on parameters required for standardizing operational protocols and data on bio-efficacy, phytotoxicity and plant and yield parameters were recorded and used for the analysis.

Design of Plant Protection UAV for spraying

A Rotorcraft hexacopter UAV with 10 litre payload carrying capacity with all up weight of upto 24.8 kg was designed and standardized specifically for plant protection spraying in agricultural crops by Centre for APSARA (Andhra Pradesh Sensors and Smart Applications Research in Agriculture) of Acharya N G Ranga Agricultural University. The UAV built by ANGRAU with the specifications as mentioned in Table1, below designated as "ANGRAU-Pushpak-01", a model RPAS (Remotely Piloted Aircraft System). The registration approval pertaining to the "ANGRAU-Pushpak-01" was obtained based on guidelines issued by Directorate General of Civil Aviation (DGCA) for its usage in agricultural operations for research purpose. The specifications pertaining to technical parameters and payload data are detailed below (Table 1).

Standardization of spraying height, time, direction of spray, drift, ambient temperature, time taken for drone flight, spray fluid volume and uniformity of distribution of droplet deposition (vertical distribution) with ANGRAU Pushpak-01-UAV were done following the procedures given by DGCA, New Delhi.

Bio efficacy studies on *Myzus persicae* (Sulz.)

The bio-efficacy studies were conducted with drone (Figure 1) and human backpack sprayer with the two CIB &RC recommended insecticides to control aphids at different dosages (Table2). The spraying treatments were carried out at 54 DAT and

61 DAT with 7 days interval, when the peak population of *Myzus persicae* (Sulz.) appearance was observed. The recommended chemicals to control aphids were tested for their efficacy at 100%, 75% and 50 % recommended doses of pesticide (RDP) using drone, 100 % RDP with human back power sprayer and Control (Water Spraying with drone).

Chilli Armour-F1 hybrid was selected which is semi-erect and strong plant structure, resistance to Chilli leaf curl virus, fruit surface is semi wrinkled, fresh fruit starts from 45-50 days after transplant (DAT) and is suitable for fresh and dry purpose. The seedlings of 54 (DAS) days were transplanted in the field at a spacing of 75X 45 cm. The treatments were imposed from 54 DAT and 61 DAT. The crop was sown in the black cotton soils of Lam village of Guntur district which falls in Krisha Agro-climatic Zone of Andhra Pradesh. The crop was raised during *kharif* 2021-22 and 2022-23 and the data was recorded for the two years. The experiment was designed and laid in 5 acres with RRBD (Restricted randomized block design) with total 5 treatments and 4 replications. Treatments T1-100% RDP sprayed from 0.6 -1.0 m above crop canopy, T2-75% RDP sprayed from 0.6 -1.0 m above crop canopy, T3-50% RDP sprayed from 0.6 -1.0 m above crop canopy, T4-100% RDP sprayed with human back power sprayer and T5-Control (Water Spraying with drone). During the experimental period, all the recommended agronomical practices were followed for raising the crop and the scheduled plant protection treatments were imposed to control aphids, *Myzus persicae* (Sulz.) as per the recommendations and experimental protocols.

Treatment Details

The list of CIB & RC recommended insecticides and their dosages for control of *Myzus persicae* (Sulz.)which were sprayed using drone and human back pack sprayer are presented in Table 2.

Percentage reduction of aphids population over control (% ROC)

$$\% ROC = \left[1 - \frac{Post\ Treatment\ population\ in\ the\ treatment}{Pre - treatment\ population\ in\ the\ treatment}\right]$$

$$X \left[\frac{pre\ treatment\ population\ in\ the\ untreated\ check}{post\ treatment\ population\ in\ the\ untreated\ check}\right] X\ 100$$

Statistical Analysis: The data were transformed to " x+ 0.5 transformation before analysis and subjected to one way ANOVA using OP STAT software package. The treatments effect was compared by following Duncan's Multiple Range Test (DMRT) (*Gomez and Gomez, 1984*).

Phytotoxicity Studies

Observations for phytotoxicity were taken on 1, 3 and 5 days after the insecticide application for the specific parameters like chlorosis, necrosis, wilting, scorching, hyponasty and epinasty by using scale Table 3.

Overall health of the crop due to drone spraying

The overall health of the plant under UAV spraying and human back pack spraying technology was ascertained from the NDVI values. The NDVI values were also used to monitor the crop growth, health and to identify potential diseased parts in the fields. The NDVI readings were measured using Green Seeker™ handheld sensor which is easy to use optical sensor that instantly measures plant health and vigor. The sensor was held at 24-48" (60-120 cm) above the crop canopy and observed the average reading on the display. The higher the NDVI value the greater plants density and health.

RESULTS AND DISCUSSION

The results of the experiment conducted to control aphids in chilli through UAV spraying and human back pack sprayer equipment with recommended chemicals are presented as detailed below.

Standard Operating Procedures (SOPs)

The standard operating procedures (SOPs) (Table 4) for drone spraying in chilli crop using ANGRAU – PUSHPAK -01 (Figure 2) developed as the part of this experiment from vegetative stage to flowering stage were used for imposing the spraying treatments. At the time of operating the drone in field conditions of chilli crop, was is at flowering stage, *i.e.*at 54 DAT and 61 DAT, the plant heights were ranging from 42.0-45.1 cm at 54 & 61 DAT respectively.

Bio-efficacy of chemicals sprayed with UAV

The results of the bioefficiacy study of Spirotetramat 15.31% w/w OD and Fipronil 5% SC sprayed with drone and human back pack sprayers revealed the following results.

Bio-efficacy of Spirotetramat 15.31% w/w OD

For the first spray with Spirotetramat 15.31% w/w OD at 54 DAT during 2021, the pre -treatment data of no. of aphids per 10 cm twig was within range of 34.5 – 36.25 and no significant difference was observed across all the treatments. Post-treatment i.e. five days after the application of Spirotetramat 15.31% w/w OD, aphid population decreased from 34.5 to 18.75, 35.25 to 21.0, 36.25 to 24.25, 35.5 to 21.5 and 34.75 to 35.25 aphids per 10 cm twig in T1, T2, T3, T4 and T5 respectively. It is revealed from the results that T1, T2 and T4 are on par (Table 5 & Table 6) in their bio-efficacy and followed by T3. Similar results were found during the 2^{nd} year experimentation i.e., 2022 and the pre-treatment data of no. of aphids per 10 cm twig was found within a range of 25.25 – 26.25 across all the treatments. Post-treatment i.e. five days after the application of Spirotetramat 15.31% w/w OD, aphid population was found decreased from 26.5 to 17.50, 25.25 to 18.75, 26.0 to 22.25, 26.25 to 20.25 and 26.25 to 31.25 aphids per 10 cm twig in T1, T2, T3, T4 and T5 respectively. It is revealed from the results that T1, T2 and T4 are on par in their bio-efficacy followed by T3. The percent reduction of aphids population over control (%ROC) after five days after spraying was 46.19%, 40.86%, 33.34% and 40.33 % for T1, T2, T3, T4 and T5. Untreated control plot continued to be more damaged by aphids with 35.25 aphids per 10 cm twig.

Bio-efficacy of Fipronil 5% SC

The second spray with Fipronil 5% SC after 7 days i.e. at 61 DAT after 1^{st} spray with Spirotetramat 15.31% w/w OD was carried out as the aphid population was still found above economic threshold level of 10-15 aphids per leaf or 20% infected per plant. The post-treatment data i.e. five days after the application of Fipronil 5% SC, aphid population was found decreased to 5.5, 7.0, 13.5, 7.25 and 32.75 aphids per 10 cm twig in T1, T2, T3, T4 and T5 respectively. It is revealed from the results that T1, T2 and T4 are on par (Table 5 & Table 6) in their bio-efficacy and followed by T3. Similar results were found during the 2^{nd} year experimentation i.e., 2022. The post-treatment data i.e. recorded at five days after the application of Fipronil 5% SC, the aphid population was found decreased to 4,5,9.25, 5.75 and 29.25 aphids per 10 cm twig in T1, T2, T3, T4 and T5 respectively. It revealed from the results that T1, T2 and T4 are on par in their bio-efficacy followed by T3. The percent reduction of aphids population over control (%ROC) after five days after spraying Fipronil 5% SC showed 86.05%, 82.05%, 67.45% and 80.21 % reduction for T1, T2, T3, T4 and T5. Untreated control plot continued to be more damaged by aphids with 29.25 aphids per 10 cm twig.

Overall health of the crop due to drone spraying

The overall health of the crop under specific treatment conditions with drone and human backpack sprayer were studied comparatively in order to ascertain whether changing from human back pack sprayer to drone and changing spray fluid volume from 500 L ha^{-1} to 25 L ha^{-1} lead to any ill-effects on plant growth and it's chlorophyll content. This is indirectly ascertained using NDVI index (Table 9) and the results revealed that the growth of the plant was not affected due to either changing the machine or reducing the spray fluid volume from 500 L ha^{-1} to 25 L ha^{-1}. The results are presented in table 9.

CONCLUSION

UAV spraying to control chilli aphids was found effective and efficient in managing the pests and utilizing the pesticide substance delivery and deposition when compared to human backpack spraying. In UAV spraying, aerodynamic forces of the drone induces additional kinetic energy to the vertically downward moving spray fluid droplets, thus causing decreased drift, increased penetration and deposition on the on-target surfaces. UAV spraying also offers an opportunity to reduce 25% of RDP of Spirotetramat 15.31% w/w OD and Fipronil 5% SC without compromising on the bio-efficacy. The spray fluid volume of 25 L ha^{-1} for drone spraying was found to be technically feasible instead of 500 l ha^{-1} used for human back pack knapsack sprayers, which offers reduction in use of precious water resource for spraying by 95%, without affecting the bio-efficacy and without causing phytotoxicity on the crop. The aphid population was effectively controlled both at 100% RDP and 75% RDP sprayed with UAV and offers an

Table 1. Technical parameters of Model Remotely Piloted Aircraft System (MRPAS) "ANGRAU-PUSHPAK-01" for Plant Protection research

SI. No.	Classification		Parameters
1.	Official Designation	:	ANGRAU – PUSHPAK-01 series Agricultural drone
2.	Size (mm)	:	1495 mm X 1308 mm X 500 mm (Arms unfolded with motor and without propellers)
3.	Category of drone	:	Rotorcraft
4.	Sub-Category	;	Model Remotely Piloted Aircraft System
5.	Class of the Drone	:	Small - All up weight (AUW) of 24.8kg
6.	Motors Type and Specification	:	BLDC (Brushless Direct Current) with 180 KV rating; Input Current: 80A; IPX7
7.	Maximum Thrust of each Motor	:	12kg/Axis (48V, Sea Level)
8.	Battery Specification	:	16000 mAh capacity with charging C rating 1C and discharging C rating of 15 C and Burst Discharge rating of 30C; 6S1P; 22.2 V and 355.2 Wh
9.	Spray width	:	2.8 m
10.	Pay Load capacity	:	10-12 kg or Litres
11.	Field Capacity	:	2.5 ha/hr
12.	Spray system	:	Hydraulic
13.	Flight mode	:	Autonomous
14.	Navigation System	:	GNSS
15.	Forward speed of the UAV	:	5.5 m/s
16.	Nozzle type		Flat fan (VP 110015)
17.	Number of nozzles	:	4 Numbers
18.	Nozzle flow rate	:	0.42 to 0.45 lpm
19.	Spraying direction	:	Vertically down
20.	Spray angle	:	110 degrees
21.	Spray fluid volume	:	25 L ha^{-1} (Low volume and high concentration)
22.	Radio communication frequency	:	2.40 GHz - 2.4833 GHz

Figure 1. UAV spraying of recommended insecticides for bio-efficacy and phytotoxicity studies

Table 2. Details of the chemicals sprayed using UAV to control *Myzus persicae* (Sulz.).

Treatment No.	Spirotetramat 15.3 % w/w OD, ml/acre	Fipronil 5% SC, ml/acre
Dates of Sowing (DAS)	25.07.2021 & 01.08.2022	
Date of Transplanting (DAT)	17.09.2021 & 25.09.2022	
Treatment Imposed on	10.11.2021 & 16.11.2022 (108 DAS/54 DAT)	(17.11.2021 & 23.11.2022) (115 DAS / 61 DAT)
T1	160	400
T2	120	300
T3	80	200
T4	160	400
T5	Only Water	Only Water

Table 3. Grading scale for phytotoxicity measurement

Score	Phytotoxicity (%)	Score	Phytotoxicity (%)
0	No phytotoxicity	6	51 – 60
1	0 – 10	7	61 – 70
2	11 – 20	8	71 – 80
3	21 – 30	9	81 – 90
4	31 – 40	10	91 – 100
5	41 – 50	--	--

opportunity to save 25% of the pesticide. All the insecticides applied have effectively managed the aphid population. High efficacy was observed at five days after each spray.

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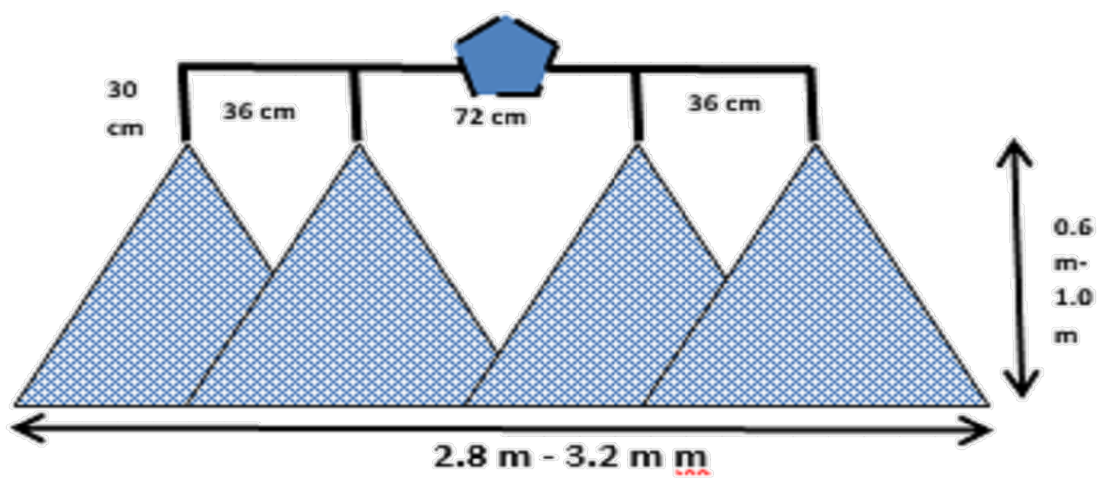
Table 4 SOP's of drone spraying in Chilli

Sl.No.	UAV Spraying Parameter / Condition	SOP's	Results Observed
A.	**Standardised parameters for UAV and spraying system**		
1.	Weight of the Drone	Small Category – 24.8 to 26.8 kg for spraying	The plants did not lodge, leaves, flowers and fruits did not drop
2.	Spray Fluid Volume	25 L ha^{-1} or 10 L $acre^{-1}$(Low Volume Spraying)	This volume is arrived based on relative reduction of the droplet size (100 -250 µm) from the conventional technology (300 - 750 µm) and phytotoxicity studies.
3.	Nozzle Type & Specifications	Flat Fan & VP 110015	Manufacturer specifications
4.	Droplet size of the Nozzle	100-250 µm	Through water sensitive paper studies
5.	Discharge of each nozzle	0.42 to 0.45 lpm	Measured through Discharge test
6.	No. of Nozzles in Hexacopter	4 Nozzles	
7.	Arrangement of Nozzles	Beneath the rotors and strictly avoid boom arrangement to avoid formation of vertices which cause non-uniform spraying.	
8.	Spacing, vertical distance and arrangement of 4 nozzles on the drone. (Under 5 Kmph wind speed and 35^0C- static condition at 0.6-1.0 m height above crop canopy).	• Beneath the rotors at 30 cm from the arms axis. • Distance between nozzles from each other on either side at 36 cm. • The nozzle flow fan should be vertically downwards without any obliqueness. The noz zles should be adjusted accordingly. • All the nozzle tips must be aligned to be in horizontally parallel	



B.	**Standard Flight parameters**						
9.	Optimal flight height (above crop canopy), Optimal drone forward speed and corresponding width of spray coverage	Sl. No.	Item	Drone Flight Height, m above crop canopy	Width of Spraying, m	Forward Speed of UAV, m/s	Arrived by studying the iterative operations to match 10 L delivery with speeds, widths and corresponding heights of spraying with no crop damage and with 10 -15% drift losses
		1.	Vegetative stage to Before Flowering stage	0.6-1.0	2.8	5.5	
		2.	From flowering stage onwards	1.0-1.5	3.2	4.5	
10.	Recommended diurnal Schedule of drone spraying	8-11 A.M. & 3.00 P.M. to 6.00 P.M. (Avoid Rainy periods)				Arrived based on the wind speeds & prevailing temperatures and corresponding spray coverage	
11.	Optimum wind speeds recommended	3-10 kmph wind speeds are good for insecticides, fungicides and foliar nutrients, PGR, PGI's etc. and for herbicides, <5 kmph wind speeds are recommended with reduced flight height.					
12.	Drone flight direction for spraying	The direction of drone travel must be parallel to the longest side of the field. During exigencies, if wind speeds >10 kmph are prevailing, direction of drone travel must be parallel to the direction of the wind.					
13.	Drift	0.5-1.5 m effective drift on either side at 5 -10 kmph wind speeds and temperature of about 35 -40 ^{0}C is found.					
14.	Optimal ambient temperature envelope	35-40 ^{0}C. Drone spraying above 40 ^{0}C results in excessive vapour drift causes low bio -efficacy achieved due to poor deposition.					
15.	Time for Drone spraying	1. Net Time of 15 min. ha^{-1} and 2. Gross Time of 24.71 min. ha^{-1} (Including chemical filling, nozzle checking, battery replacement an d pilot instructions to the farmers).					
16.	Field Capacity of recommended 10L payload spraying drone	2.43 ha hr^{-1}					

Table 5 Bio-efficacy of insecticides on *Myzus persicae* during *kharif* 2021

Treatment details	*Number of Myzus persicae* population per 10 cm twig.						
	Spirotetramat 15.3 % w/w OD				Fipronil 5% SC		
	Pre treatment	3 DAS	5 DAS	ROC %	3 DAS	5 DAS	ROC%
T1	34.5	21.75	18.75	46.19	13.0	5.5	83.19
T2	35.25	23.5	21.0	40.86	14.0	7.0	78.58
T3	36.25	27.5	24.25	33.34	18.25	13.5	59.79
T4	35.5	23.5	21.5	40.33	14.5	7.25	78.27
T5	34.75	35.25	35.25	0.00	34.00	32.75	0.00
CD	N/A	3.09	2.315	--	3.60	2.94	--
CV (%)	7.75	7.57	5.17	--	10.21	10.81	--

Table 6 Bio-efficacy of insecticides *Myzus persicae* during *kharif* 2022

Treatment details	*Number of Myzus persicae* population per / 10 cm twig.						
	Spinetoram 11.7% SC				Fipronil 5% SC		
	Pre treatment	3 DAS	5 DAS	ROC%	3 DAS	5 DAS	ROC%
T1	26.5	20.50	17.5	44.74	9.25	4.0	86.05
T2	25.25	20.25	18.75	37.09	12.0	5.0	82.05
T3	26.00	23.25	22.25	27.08	15.75	9.25	67.45
T4	26.25	21.00	20.25	35.03	13.25	5.75	80.21
T5	26.25	30.75	31.25	0.00	29.25	29.25	0.00
CD	N/A	3.09	2.31		3.60	2.94	
CV (%)	7.75	7.57	5.17		10.21	10.81	

Figure 2. ANGRAU-PUSHPAK 01: An UAV standardized for agricultural spraying

Table 7. Phytotoxicity in Chilli with spraying of Spirotetramat 15.31% w/w OD

Treatments	Dosage / ha			Equipment for Application	Yellowing (DAA*)			Stunting (DAA)			Necrosis (DAA)			Epinasty (DAA)			Hyponasty (DAA)			Wilting (DAA)			Scorching (DAA)		
	a.i. (g)	Formulation (ml ha^{-1})	Water volume L ha^{-1}		1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
T1	60	400	25	10 L Pay load Drone	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	45	300	25		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	30	200	25		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	60	400	200	Human Back pack Sprayer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	Water		25	10 L Pay load Drone		0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0

*DAA – Days after application

Table 8 Phytotoxicity in Chilli with spraying of Fipronil 5% SC

Treatments	Dosage / ha			Equipment for Application	Yellowing (DAA*)			Stunting (DAA)			Necrosis (DAA)			Epinasty (DAA)			Hyponasty (DAA)			Wilting (DAA)			Scorching (DAA)		
	a.i. (g)	Formulation (ml ha^{-1})	Water volume L ha^{-1}		1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
T1	50	1000	25	10 L Pay load Drone	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	37.5	750	25		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	25	500	25		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	50	1000	500	Human Back pack Sprayer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	Water		25	10 L Pay load Drone		0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0

*DAA – Days after application

Table 9 Average NDVI Values in Chilli before and after spraying with drone and human backpack sprayer

Treatments	Average NDVI values / m^2							
	Spirotetramat 15.3 % w/w OD, ml/acre				Fipronil 5% SC, ml/acre			
	Kharif, 2021-22		*kharif*, 2022-23		*Kharif*, 2021-22		*kharif*, 2022-23	
	Before Spraying	After Spraying	Before Spraying	After Spraying	Before Spraying	After Spraying	Before Spraying	After Spraying
T1	0.71	0.73	0.69	0.72	0.74	0.75	0.72	0.74
T2	0.70	0.72	0.68	0.70	0.73	0.75	0.70	0.71
T3	0.63	0.64	0.57	0.55	0.62	0.60	0.55	0.53
T4	0.70	0.72	0.68	0.69	0.72	0.73	0.70	0.71
T5	0.44	0.34	0.34	0.30	0.33	0.30	0.30	0.28

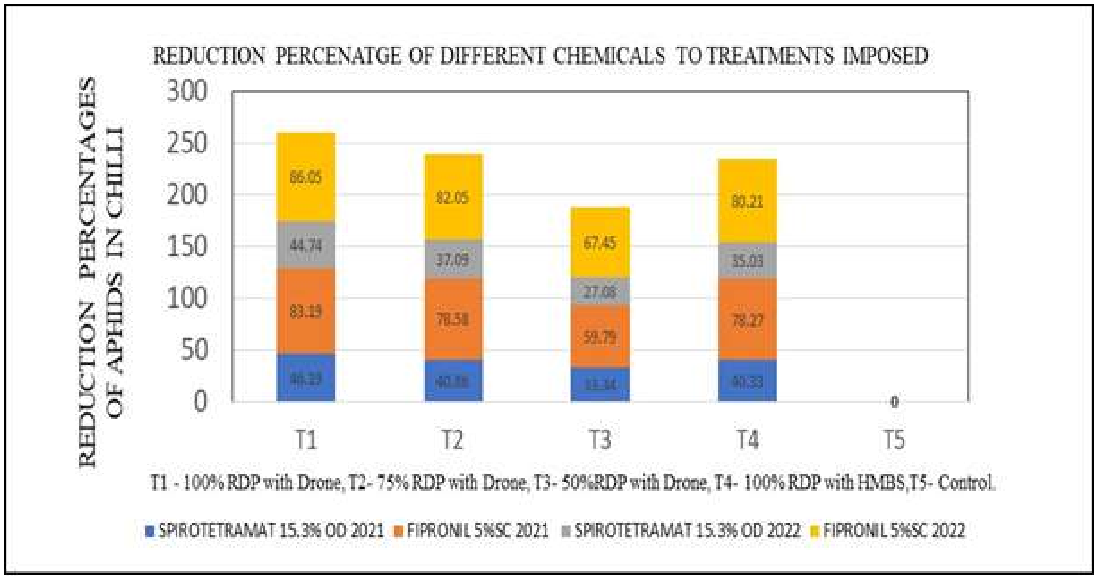


Figure 3. Bio-efficacy of insecticides against *Myzus persicae* (Sulz.) under field conditions using Drone in *kharif* , 2021 and 2022

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