Autonomous Drones in Agriculture

Standard Operating Protocols for Agrochemical Application in Field Crops

Striving for a Greener Tomorrow...

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Modernizing Agriculture

Farming in India is critical to global agricultural crop production and food security. Accounting for approximately 2.4% of the world's total arable land, 4.0 % of global water resources, India is the 2nd largest agricultural commodities producing country, feeding about 18% of the global population. In 2020, India's total crop production output was valued at USD 400 billion. Achievements at this scale, however, have come at a cost. According to the Food and Agriculture Organisation of the United Nations, the volume of crop protection products India consumes annually is on the rise and between 2010–11 and 2020–21, there has been a growth of 11.19% in the overall consumption of pesticides in the country, from 58,634 metric tonnes to 62,193 metric tonnes. The overuse of agrochemicals (pesticides, fungicides, herbicides and fertilisers) and irrigation has led to soil degradation and contamination of water bodies. Injudicious use of pesticides has led to problems of resistance, resurgence and residues. Non-target effects of exposure of humans and the environment to pesticide residues are a continuing concern. Rapid urbanisation and ageing farming population are also posing threats to the world's 2nd largest food producer. India's total population is estimated to have increased by 146 million over the past decade to reach 1.38 billion. The agriculture sector faces an increasing shortage of manpower owing to rural-urban migration and an ageing population. With asymmetrical labour supply and demand for crop output to sustain and grow India's agriculture production, the Indian government and domestic drone manufacturers are leveraging Fourth Industrial Revolution (4IR) technological tools and automation to address future agricultural challenges.

Drone Technology – An enabler of Smart Farming

DRONE (Dynamic Remotely Operated Navigation Equipment) or an unmanned aerial vehicle (UAV), is an aircraft that can fly and stay airborne without a human pilot on board, able to perform critical farm operations without risking a human's safety, and operating more cost effectively than equivalent manned systems. Based on the aerodynamic flight principles, drones are classified into two major types: (i) Fixed-wing and (ii) Multi-rotor. An aerial agrochemical (pesticide, fungicide, herbicide, defoliant etc.) spraying drone with basic components is shown in Fig. 1.

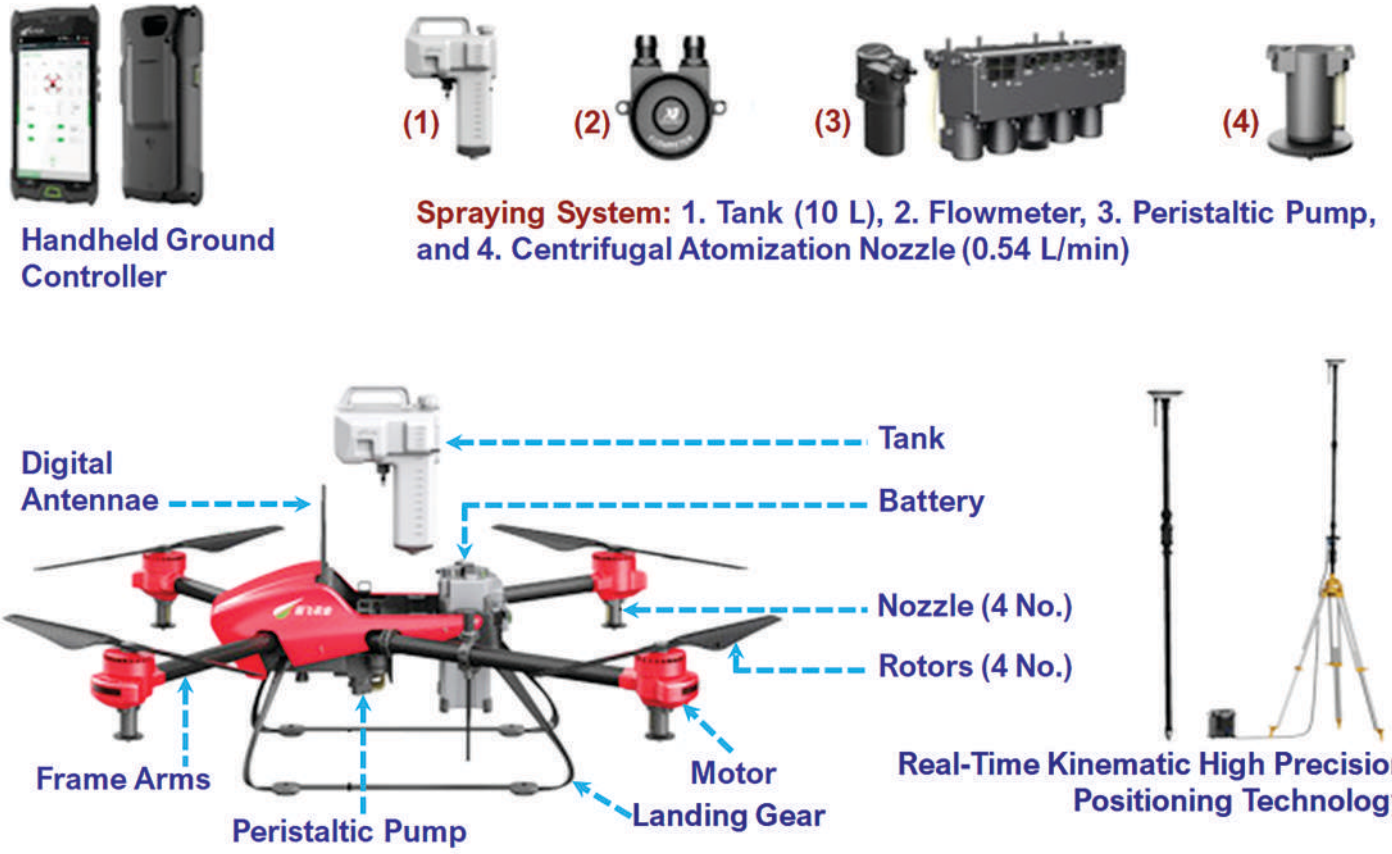


Fig. 1. A spraying UAV (quadcoptor) with basic components

India – Drone Spray Initiatives

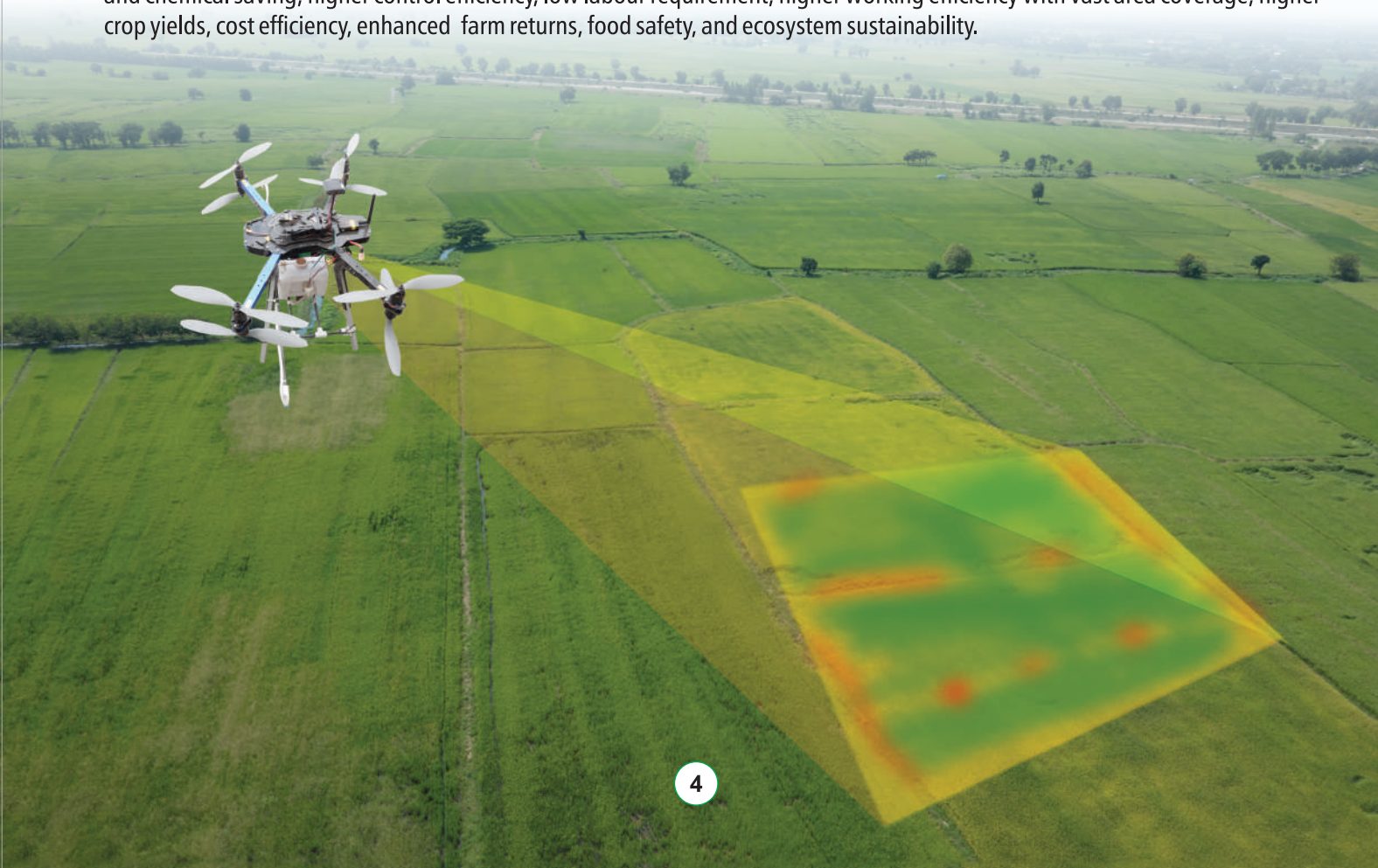
To remove all unnecessary operational and entry barriers and to create a strong drone ecosystem in the country and to make India a global hub for drones by 2030, Government of India has taken up several initiatives, as follows.

- Release of Unmanned Aircraft System (Drone) Rules, 2021 by Ministry of Civil Aviation on 12th March 2021 with an aim to strike a balance between safety and operatability of UAVs.
- To address the strategic, tactical and operational uses of drone technology Production Linked Incentive Scheme (PLI) was launched on 16th September 2021for manufacturers of drone and drone components.
- Ministry of Civil Aviation (MoCA) launched a colour-coded and interactive Drone Airspace Map of India on 24th September 2021, that would allow civilians to operate drones with provision of no drone flight permission up to 400 feet in green zones, and up to 200 feet in the area between 8 and 12 km from the airport perimeter.
- UAS Traffic Management Policy Framework for national Unmanned Aircraft System (UAS) notified on 24th October 2021, allows both private and public service providers to manage drone traffic in the country.
- Release of Standard Operating Protocols (SOPs) by Ministry of Agriculture & Farmers Welfare on 21st December 2021 for spraying of agrochemicals (pesticides, fungicides, herbicides etc.) using drones to accelerate mechanization in crop protection with an aim to increase efficiency and efficacy of applied agrochemicals for pest control.
- A business-friendly, Single-Window Digital Sky Platform launched by Aviation Ministry on 26th January 2022.
- Issue of notification for ban of import of foreign drones from 9th February 2022 by the Director General of Foreign Trade, Government of India.
- Issue of Gazette notification on Drone (Amendment) Rules 2022 by Ministry of Civil Aviation on 11th February 2022
- Issue of interim approval for registered pesticides, fungicides and plant growth regulators on 18th April 2022 by MoA & FW for commercial use through drones for two years.
- Organising a National Conference on "Promoting Kisan Drones: Issues, Challenges and the Way Ahead" on 2nd May 2022 by the Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmer Welfare, Government of India.
- No pilot licence required for micro drones (for non-commercial use), nano drones and for R&D organisations under State Agricultural Universities and Indian Council of Agricultural Research.
- No requirement of certificate of airworthiness, unique identification number, prior permission and remote pilot licence for R&D entities.

Benefits of Agrochemical Spray by Drones

- Suitability to diverse agri-horticultural crops and cropping systems and speciality crops such as tea, coffee, oil palm and cardamom crops.
- Provide viable cost-effective option on smallholder fragmented, irregular, complex steep slopes, hill-sides and mountain terrains
- Precise application of agrochemicals, higher penetration and droplet deposition ability.
- Higher control efficiency (4.3 to 15%) owing to improved spray coverage, droplet density and droplet deposition uniformity on the target crop.
- Higher field capacity i.e., area coverage per unit time (13 to 18 times higher than conventional manual spraying by knapsack sprayer) depending on the crop.
- Saving (20 to 93%) in agrochemical (pesticide, fungicide and herbicide) use rates.
- Improved pesticide use efficiency (12.6 to 45.3%) due to higher total deposition on target crop and less ground losses.
- Enables most economical, rapid, efficient and effective application of agrochemicals in short span of time for crop pest and pathogen control, allowing for speedy responses to sudden pest outbreaks.
- Improved pesticide resistance management.
- Meagre water use (92 to 95% lower) for agrochemical spraying relative to conventional knapsack and boom sprayer.
- Reduced risk of health hazard owing to 2 – 3 orders of magnitude less dermal exposure of applicators to pesticides and lower postural discomfort.
- Drones proved a useful, faster, cheaper and more effective substitute for labourers in farming (3 – 4 times higher labour productivity) for performing operations such as spraying of agrochemicals (pesticides, fungicides, herbicides etc).
- Development of certified spraying professionals providing customized application services to farmers, thereby creating new skilled employment and entrepreneurship potential in rural India.
- Finally produce higher crop yields (3.7 to 22.5%), cost effectiveness, enhanced farm returns, negligible pesticide residues, food safety, and ecosystem sustainability.

In summary UAVs help in precise detection of pest and pathogen infestation in cropped fields, allow to respond rapidly and timely, enable effective and efficient spraying of agrochemicals (pesticide, fungicide and herbicide) on target crop, using appropriate drone type under preferred weather conditions, maintaining optimum UAV flight height, flight speed, swath width and spray volume to produce desired droplet size and uniform droplet deposition contributing to higher pesticide use efficiency and chemical saving, higher control efficiency, low labour requirement, higher working efficiency with vast area coverage, higher crop yields, cost efficiency, enhanced farm returns, food safety, and ecosystem sustainability.



Standard Drone Aerial Spray Protocols For Crop Protection in Rice

Particulars	Standard Operating Protocol
Location	Rice Research Centre, ARI, Rajendranagar, Hyderabad.
Agri-Startup Partner	Marut Dronetech Private Limited, Hyderabad
1) Drone Spray Parameters	
Drone model	AGRICOPTOR AG365 with UIN – UA00132S1EX and HEPICOPTOR with UIN – UA000GU
Nozzle type	XR 11002VP (Extended range – Flat fan)
Number of nozzles	Four
Optimum flight height above crop canopy	2.5 m
Optimum flight speed	2.8 – 4.4 m/sec
Spray Volume ● At maximum tillering stage ● After maximum tillering stage	 25 liters/ha 40 liters/ha
Optimum time of spray	6.00 – 9.00 AM and 3.00 – 6.00 PM
2) Pests and Pesticide Formulations	
Stem borer at panicle initiation to booting stage	Chlorantraniliprole 18.5 SC @ 150 ml/ha Acephate 50 +Imidacloprid 1.8 SP @ 750 g/ha
Brown plant hopper at reproductive stage	Triflumezopyrim10 SC @ 240 ml/ha Pymetrozine 50 WG @ 300 g/ha Dinotefuran 20 SG @ 200 g/ha
3) Diseases and Fungicides Formulations	
Grain discolouration At 25% flowering stage	Tebuconazole 25+Trifloxystrobin 50 (75 WG) @ 200 g/ha Propiconazole 25 EC @ 500 ml/ha Azoxystrobin 18.2 +Difenoconazole 11.4 SC @ 500 ml/ha

Standard Drone Aerial Spray Protocols For Crop Protection in Rice

Particulars	Standard Operating Protocol
4) Risk to crops and Environment	
Phytotoxicity	No crop damage observed at tested concentrations to Chlorantraniliprole 18.5 SC, Tebuconazole 25+Trifloxystrobin 50 (75WG) and Propiconazole 25 EC alone or Pesticide combinations of (Mancozeb 50 +Carbendazim 25 WP) + (Acephate 50 + Imidacloprid 1.8 SP)y, Chlorantraniliprole 18.5 SC + (Picoxystrobin 7 + Propiconazole 12 EC), Cartap hydrochloride 50 SP + (Mancozeb 50 + Carbendazim 25 WS), Chlorantraniliprole 18.5 SC + (Flupyroxad 62.5 + Epoxiconazole 62.5 EC) and Chlorantraniliprole 18.5 SC + (Azoxystrobin 18.2 + Difenoconazole 11.4 SC)
Impact on beneficial fauna	Safe for Coccinellids, Spiders and Mirid bugs
Pesticide residues	Chlorantraniliprole 18.5 SC and Tebuconazole 25 +Trifloxystrobin 50 (75 WG) not detected in soil and grain
5) Efficiency indices	
Control Efficiency ● Drone Spray ● Knapsack Spray	 81.8 to 94.8% 71.7 to 82.8%
Field Capacity ● Drone Spray ● Knapsack Spray	 8 ha/day (20.0 acres/day) 2 ha/day (5.0 acres/day)
Water Saving by drones over Knapsack Spray	92.0 to 95.0%
Labour Productivity ● Drone Spray ● Knapsack Spray	 4.0 ha/labour day (10.0 acres/labour day) 1.0 ha/labour day (2.5 acres/labour day)
Saving in time by Drone Spray over Knapsack Spray	75%
Yield improvement by Drone Spray over Knapsack Spray	8.5 to 21.0%

Standard Drone Aerial Spray Protocols For Crop Protection in Cotton

Particulars	Standard Operating Protocol
Location	Regional Agricultural Research Station, Warangal.
Agri-Startup Partner	Marut Dronetech Private Limited, Hyderabad
1) Drone Spray Parameters	
Drone model	AGRICOPTOR AG365 with UIN – UA00132S1EX and HEPICOPTOR with UIN – UA000GU
Nozzle type	XR 11002VP (Extended range - Flat fan)
Number of nozzles	Four
Optimum flight height	2.0 m above crop canopy
Optimum flight speed	2.7 m/sec
Spray Volume	40 L/ha
Optimum time of spray	6.00 – 9.00 AM and 3.00 – 6.00 PM
2) Pests and Pesticide Formulations	
Sucking Pests: Aphids, Jassids, Thrips and White flies	Flonicamid 50 SG @ 150 g/ha
Pink bollworm	Spinetoram 11.7 SC @ 450 ml/ha
3) Diseases and Fungicide Formulations	
Leaf spot diseases	Tebuconazole 50 + Trifloxystrobin 25 (75 WG) @ 300 g/ha
Grey mildew	Metiram 55 + Pyraclostrobin 5 (60 WG) @ 1500 g/ha
4) Risk to Crops and Environment	
Phytotoxicity	No crop damage observed at tested concentrations to Flonicamid 50 SG, Spinetoram 11.7 SC, Monocrotophos 36 SL, Profenophos 50 EC, Acephate 75 SP, Diafenthiuron 50 WP, Fipronil 5 SC, Imidacloprid 17.8 SL, Acetamiprid 20 SP, Carbendazim 50 WP, Propiconazole 25 EC, Kresoxim methyl 44.3 SC or their combinations viz., Chlorpyriphos 50 + Cypermethrin 5 EC, Tebuconazole 50 + Trifloxystrobin 25 WG, Metiram 55 + Pyraclostrobin 5 (60 WG), Carbendazim 12 + Mancozeb 63 WP, Azoxystrobin 18.2 + Difenoconazole 11.4 SC
Impact on beneficial fauna	Safe for Coccinellids & Spiders
Pesticide residues	Not applicable
5) Efficiency Indices	
Control Efficiency ● Drone Spray ● Knapsack Spray	 36.0 to 40.0% 15.0 to 20.0%
Field Capacity ● Drone Spray ● Knapsack Spray	 8.0 ha/day (20.0 acres/day) 2.0 ha/day (5.0 acres/day)
Water Saving by drones over Knapsack Spray	92.0%
Labour Productivity ● Drone Spray ● Knapsack Spray	 4.0 ha/labour day (10.0 acres/labour day) 1.0 ha/labour day (2.5 acres/labour day)
Saving in time by Drone Spray over Knapsack Spray	75%
Yield improvement by Drone Spray over Knapsack Spray	11.7 to 22.5%

Standard Drone Aerial Spray Protocols For Crop Protection in Redgram

Particulars	Standard Operating Protocol
Location	Agricultural Research Station, Tandur, Vikarabad Dist.
Agri-Startup Partner	Marut Dronetech Private Limited, Hyderabad
1) Drone Spray Parameters	
Drone model	AGRICOPTOR AG365 with UIN – UA00132S1EX and HEPICOPTOR with UIN – UA000GU
Nozzle type	XR 11002VP (Extended range - Flat fan)
Number of nozzles	Four
Optimum flight height	2.0 m above the crop canopy
Optimum flight speed	4.0 – 5.0 m/sec
Spray Volume	40 L/ha
Optimum time of spray	6.00 – 9.00 AM and 3.00 – 6.00 PM
2) Pests and Pesticide Formulations	
Gram Pod borer and Spotted pod borer	Emamectin Benzoate 5 SG @ 200 g/ha Chlorantraniliprole 18.5 SC @ 150 ml/ha Flonicamid 50 SG @ 150 g/ha
3) Diseases and Fungicide Formulations	
Alternaria leaf spot	Metiram 55 + Pyraclostrobin 5 (60 WG) @ 1500 g/ha
4) Risk to Crops and Environment	
Phytotoxicity	No crop damage observed at tested concentrations to Monocrotophos 36 SL, Chlorpyrifos 20 EC, Quinalphos 25 EC, Chlorantraniliprole 18.5 SC, Flubendiamide 39.35 SC, Indoxacarb 14.50 SC, Emamectin Benzoate 5 SG, Spinosad 45 SC, Novaluron 5.25 + Indoxacarb 4.50 SC, Metiram 55 + Pyraclostrobin 5 (60 WG) and Chlorantraniliprole 9.30 + Lambda-cyhalothrin 4.6 ZC
Impact on beneficial fauna	Safe for Coccinellids and Spiders
Pesticide residues	Both Chlorantraniliprole 18.5 SC and Emamectin Benzoate 5 SG not detected in soil and seeds
5) Efficiency Indices	
Control Efficiency ● Drone Spray ● Knapsack Spray	 71.8 to 100.0% 74.2 to 94.7%
Field Capacity ● Drone Spray ● Knapsack Spray	 7.2 ha/day (18.0 acres/day) 1.5 ha/day (3.75 acres/day)
Water Saving by drones over Knapsack Spray	92.0%
Labour Productivity ● Drone Spray ● Knapsack Spray	 3.6 ha/labour day (9.0 acres/labour day) 0.75 ha/labour day (1.9 acres/labour day)
Saving in time by Drone Spray over Knapsack Spray	79%
Yield improvement by Drone Spray over Knapsack Spray	15.9 to 18.5%

Standard Drone Aerial Spray Protocols For Crop Protection in Soybean

Particulars	Standard Operating Protocol
Location	Regional Agricultural Research Station, Polasa, Jagtial.
Agri-Startup Partner	Marut Dronetech Private Limited, Hyderabad
1) Drone Spray Parameters	
Drone model	AGRICOPTOR AG365 with UIN – UA00132S1EX and HEPICOPTOR with UIN – UA000GU
Nozzle type	XR 11002VP (Extended range - Flat fan)
Number of nozzles	Four
Optimum flight height	2.0 m
Optimum flight speed	3.0 m/s
Spray Volume	35 L/ha
Optimum time of spray	6.00 – 9.00 AM and 3.00 – 6.00 PM
2) Pests and Pesticide Formulations	
Leaf eating caterpillar	Chlorantraniliprole 18.5 SC @ 150 ml/ha
3) Diseases and Fungicide Formulations	
Anthracnose	Carbendazim 12 + Mancozeb 63 WP @ 1250 g/ha
4) Risk to Crops and Environment	
Phytotoxicity	No crop damage observed at tested concentrations to Chlorantraniliprole 18.5 SC and Carbendazim 12 + Mancozeb 63 WP
Impact on beneficial fauna	Safe for Coccinellids
Pesticide residues	Not verified
5) Efficiency Indices	
Control Efficiency ● Drone Spray ● Knapsack Spray	 63.6 to 76.1% 62.9 to 70.1%
Field Capacity ● Drone Spray ● Knapsack Spray	 8.0 ha/day (20.0 acres/day) 2.0 ha/day (5.0 acres/day)
Water Saving by drones over Knapsack Spray	93.0%
Labour Productivity ● Drone Spray ● Knapsack Spray	 4.0 ha/labour day (10.0 acres/labour day) 1.0 ha/labour day (2.5 acres/labour day)
Saving in time by Drone Spray over Knapsack Spray	75%
Yield improvement by Drone Spray over Knapsack Spray	3.7 to 6.6%

Standard Drone Aerial Spray Protocols For Crop Protection in Groundnut

Particulars	Standard Operating Protocol
Location	Regional Agricultural Research Station, Palem, Nagarkurnool Dist.
Agri-Startup Partner	Marut Dronetech Private Limited, Hyderabad
1) Drone Spray Parameters	
Drone model	AGRICOPTOR AG365 with UIN – UA00132S1EX and HEPICOPTOR with UIN – UA000GU
Nozzle type	XR 11002VP (Extended range - Flat fan)
Number of nozzles	Four
Optimum flight height	2.0 m
Optimum flight speed	2.7 m/s
Spray Volume	40 L/ha
Optimum time of spray	6.00 – 9.00 AM and 3.00 – 6.00 PM
2) Pests and Pesticide Formulations	
Spodoptera	Chloratraniliprole 18.5 SC 150 ml/ha
Leafhopper	Thiamethoxam 25 WG 250 g/ha
3) Diseases and Fungicide Formulations	
Leaf spots	Tebuconazole 25.9 EC 500 ml/ha
4) Risk to Crops and Environment	
Phytotoxicity	No crop damage observed at tested concentrations to Chlorantraniliprole 18.5 SC, Tebuconazole 25.9 EC, Thiamethoxam 25 WG and Chlorantraniliprole 18.5 SC+ Tebuconazole 25.9 EC
Impact on beneficial fauna	Safe for Coccinellids
Pesticide residues	Chlorantraniliprole 18.5 SC not detected in soil and pods
5) Efficiency Indices	
Control Efficiency ● Drone Spray ● Knapsack Spray	 100% 85.0 to 92.7%
Field Capacity ● Drone Spray ● Knapsack Spray	 8.0 ha/day (20.0 acres/day) 2.0 ha/day (5.0 acres/day)
Water Saving by drones over Knapsack Spray	92.0%
Labour Productivity ● Drone Spray ● Knapsack Spray	 4.0 ha/labour day (10.0 acres/labour day) 1.0 ha/labour day (2.5 acres/labour day)
Saving in time by Drone Spray over Knapsack Spray	75%
Yield improvement by Drone Spray over Knapsack Spray	8.5 to 9.6%

Standard Drone Aerial Spray Protocols For Crop Protection in Sesame

Particulars	Standard Operating Protocol
Location	Regional Agricultural Research Station, Polasa, Jagtial.
Agri-Startup Partner	Marut Dronetech Private Limited, Hyderabad
1) Drone Spray Parameters	
Drone model	AGRICOPTOR AG365 with UIN – UA00132S1EX and HEPICOPTOR with UIN – UA000GU
Nozzle type	XR 11002VP (Extended range - Flat fan)
Number of nozzles	Four
Optimum flight height	2.0 m
Optimum flight speed	2.7 m/s
Spray Volume	40 L/ha
Optimum time of spray	6.00 – 9.00 AM and 3.00 – 6.00 PM
2) Pests and Pesticide Formulations	
Leaf Webber and Capsule Borer	Chlorantraniliprole 18.5 SC @ 150 ml/ha
3) Diseases and Fungicide Formulations	
Powdery mildew	Myclobutanil 10 WP @ 500 g/ha
4) Risk to Crops and Environment	
Phytotoxicity	No crop damage observed at tested concentrations to Acephate 75 SP, Chlorpyriphos 20 EC, Chlorantraniliprole 18.5 SC, Profenophos 50 EC and Myclobutanil 10 WP
Impact on beneficial fauna	Safe for Coccinellids
Pesticide residues	Myclobutanil 10 WP not detected in soil and seeds
5) Efficiency Indices	
Control Efficiency ● Drone Spray ● Knapsack Spray	 81.1 to 88.8% 77.7 to 83.4%
Field Capacity ● Drone Spray ● Knapsack Spray	 8.0 ha/day (19.7 acres/day) 2.0 ha/day (5.0 acres/day)
Water Saving by drones over Knapsack Spray	92.0%
Labour Productivity ● Drone Spray ● Knapsack Spray	 4.0 ha/labour day (10.0 acres/labour day) 1.0 ha/labour day (2.5 acres/labour day)
Saving in time by Drone Spray over Knapsack Spray	75%
Yield improvement by Drone Spray over Knapsack Spray	11.2 to 12.2%

Standard Drone Aerial Spray Protocols For Crop Protection in Safflower

Particulars	Standard Operating Protocol
Location	Agricultural Research Station, Tandur, Vikarabad Dist.
Agri-Startup Partner	Marut Dronetech Private Limited, Hyderabad
1) Drone Spray Parameters	
Drone model	AGRICOPTOR AG365 with UIN – UA00132S1EX and HEPICOPTOR with UIN – UA000GU
Nozzle type	XR 11002VP (Extended range - Flat fan)
Number of nozzles	Four
Optimum flight height	2.0 m above crop canopy
Optimum flight speed	4.0 – 5.0 m/sec
Spray Volume	40 L/ha
Optimum time of spray	6.00 – 9.00 AM and 3.00 – 6.00 PM
2) Pests and Pesticide Formulations	
Gram podborer	Emamectin Benzoate 5 SG 200 g/ha Chloranthraniliprole18.5 SC @ 150 ml/ha
Aphids	Imidacloprid 17.8 SL @ 200 ml/ha Thiamethoxam 25 WG @ 125 g/ha
3) Risk to Crops and Environment	
Phytotoxicity	No crop damage observed at tested concentrations to Chlorantraniliprole-18.5 SC, Emamectin Benzoate 5 SG, Imidacloprid 17.8 SL and Thiamethoxam 25 WG
Impact on beneficial fauna	Safe for Coccinellids and Spiders
Pesticide residues	Not verified
4) Efficiency Indices	
Control Efficiency ● Drone Spray ● Knapsack Spray	 100% 92.7 to 93.9%
Field Capacity ● Drone Spray ● Knapsack Spray	 7.2 ha/day (17.8 acres/day) 1.5 ha/day (3.75 acres/day)
Water Saving by drones over Knapsack Spray	92.0%
Labour Productivity ● Drone Spray ● Knapsack Spray	 3.6 ha/labour day (9.0 acres/labour day) 0.75 ha/labour day (1.9 acres/labour day)
Saving in time by Drone Spray over Knapsack Spray	79%
Yield improvement by Drone Spray over Knapsack Spray	16.5 to 17.4%

Drone Project Launching : Dr. B. Janardhan Reddy, APC & Secretary, Govt. of Telangana, Sri Jeyesh Ranjan, Principal Secretary (IT, E & C), Govt. of Telangana & Dr. V. Praveen Rao, Vice Chancellor, PJTSAU, Rajendranagar.

Witnessing Drone Demonstration : Dr. G.R. Chintala, Charman, NABARD, Dr. V. Praveen Rao, Vice Chancellor, PJTSAU, Rajendranagar & Sri Y,K. Rao, CGM, NABARD, Telangana.

Visit of NABARD Chairman

Visit of World Economic Forum team

Visit of Gujarat Team

Brainstorming Session on Drone use in Agriculture

Citation:
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