

Standard operating procedure for herbicide application in direct seeded rice using unmanned aerial vehicles

Vijayakumar S.^{1*} and Virender Kumar²

¹ICAR-Indian Institute of Rice Research, Hyderabad, Telangana 500 030

²International Rice Research Institute, Los Banos, Philippines 4031

The agricultural landscape is continually evolving, driven by the need for increased efficiency, resource optimisation, and environmental stewardship. In Direct Seeded Rice (DSR) cultivation, a water-saving and labour-efficient alternative to transplanted rice, effective weed management is paramount to securing high yields. The shift from manual or conventional spraying methods to Unmanned Aerial Vehicles (UAVs), commonly known as drones, represents a significant technological leap in this domain. This article contains details on the standard operating procedure for applying herbicides in DSR using UAV technology, covering the technical parameters and critical considerations for successful, precise, and safe application.

Keywords: Drone, Herbicide spraying, Precision agriculture, Spray height, Weed control

THE adoption of Direct Seeded Rice (DSR) offers significant advantages in water and labour savings. However, a major challenge in this cultivation method is its high vulnerability to weed infestation, primarily due to the absence of standing water during the initial growth stages. In transplanted rice, standing water naturally suppresses weeds. This condition is entirely absent in DSR. Consequently, weeds germinate simultaneously with the rice crops, competing aggressively for nutrients, space, and sunlight. While herbicides are indispensable for effective weed control in DSR, the success of this cultivation method hinges on the timing and precision of their application.

Conventional application methods like knapsack spraying are plagued by several critical drawbacks. These include the inconsistent coverage and heavy reliance on manual labour leading to operator fatigue, inconsistent walking speeds, and highly variable dosing across the field.

Furthermore, conventional sprayers require large volumes of water, making the operation significantly slower and more resource-intensive due to frequent refilling. Another major issue is the physical damage to the soil and plant stand caused by the movement of personnel. Human foot traffic creates paths that disturb soil topography, press seeds too deep into the soil, and inhibit germination through localised water-logging. The overall result is an uneven, suboptimal plant stand that promotes greater weed competition and leads to substantial yield loss.

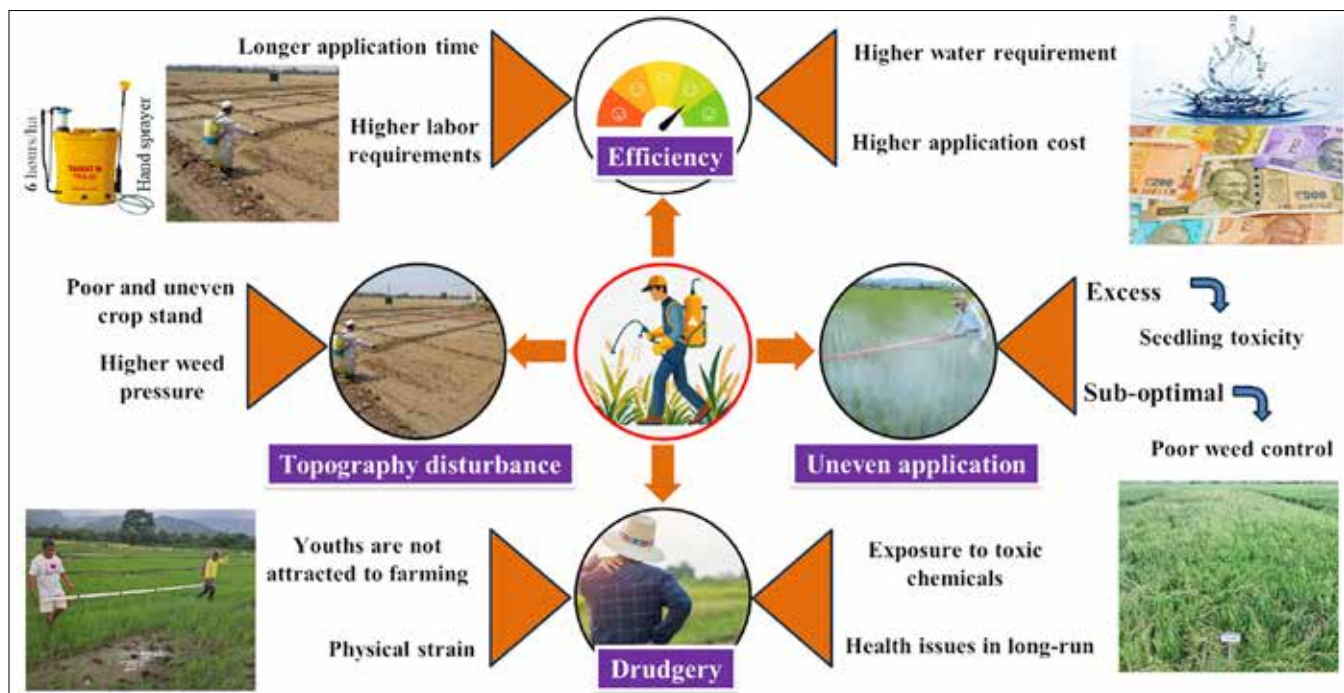
Crucially, manual spraying exposes farm labourers directly to herbicide chemicals, posing severe health risks even when personal protective equipment (PPE) is utilised. At the same time, the inherent lack of site-specific precision in conventional methods leads to significant chemical wastage, environmental contamination and damage to non-target organisms due to off-target drift. The necessity

of overcoming these limitations, coupled with the rising demand for timely and resource-efficient farming, calls for a fundamental technological transition. Unmanned Aerial Vehicles (UAVs) have emerged as the optimal alternative, providing a platform for precise, low-volume, and rapid herbicide application. Their inherent ability to navigate diverse terrains and deliver chemicals with high spatial accuracy makes them a promising platform for precision weed management in DSR.

Standard operating procedure for herbicide application using UAV

The efficacy and safety of UAV-based spraying depend critically on adhering to precise technical parameters. Deviation from these standards can compromise weed control and increase the risk of drift.

Optimum spray volume: The UAV system is characterised by Ultra-Low Volume (ULV) or Low Volume (LV) spraying. Therefore, ensuring the optimal spray volume



Major drawbacks of manual herbicide spraying

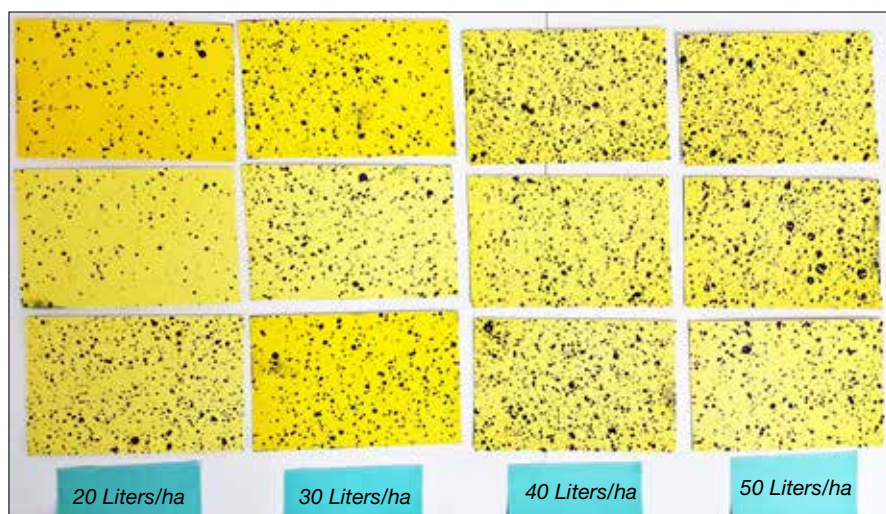
is critical, as a suboptimal volume can significantly compromise Weed Control Efficiency (WCE). For DSR, the optimal spray volume typically ranges from 30–45 L/ha. This represents a substantial reduction up to 9–13 fold less compared to the 400 L/ha, often required for conventional sprayers. This efficient LV application not only saves water and labour time (due to fewer refills) but also helps achieve higher droplet density and better penetration into the crop canopy, provided the droplet size is correctly optimised. The UAV system's pump automatically calibrate its flow rate to match the chosen volume, and

the spraying speed is then adjusted accordingly to maintain the desired application rate.

Optimum spray height: The height of the UAV above the crop canopy is the critical factor influencing spray deposition and drift. For optimal spray deposition with minimal off-target movement, the UAV should be maintained at a constant height of 1.5–2.0 m above the top of the rice canopy. The rotor downwash plays a crucial role in this process, creating a characteristic known 'vortex effect'. Flying too low increases turbulence from the rotor wash which can push the spray out laterally, causing uneven

deposition. Conversely, flying too high dramatically increases the risk of spray drift due to greater exposure to wind currents. At the 1.5–2.0 m spray height, this downwash efficiently pushes the fine droplets downward, ensuring effective canopy penetration and herbicide deposition on target weeds. It is important to note that this optimal height is typically ideal for UAVs with a payload of around 20 kg. If the UAV has a higher payload, the rotor generates a stronger vortex effect, and consequently, the optimal operational height must be slightly increased to 2.0–2.5 m to maintain the desired deposition pattern and coverage uniformity.

Optimum flight speed: Flight speed directly dictates the actual application rate, making its consistency vital for proper dosing. A consistent flight speed between 3–6 m/sec (approximately 10.8–21.6 km/h) is typically recommended. Slower operational speeds may lead to over-application of the herbicide causing phytotoxicity, while faster speeds can result in under-application or insufficient canopy penetration. It is important to note that modern agricultural UAV systems are equipped to automatically adjust their flight speed based on the required spray



Spray droplet deposition and distribution under different UAV spray volumes



Herbicide spraying in direct seeded rice using unmanned aerial vehicle

volume per unit area that is pre-set by the operator. This automation ensures a consistent and accurate application rate throughout the mission.

Optimum spray time: The time of herbicide spray significantly affects both spray drift and the opportunity time (duration for which a droplet remains on the leaf surface for absorption before evaporating). The best window for application is generally the early morning (before 8:00 AM) or the late afternoon/early evening (after 4:00 PM). These periods are ideal because they are naturally characterised by lower air temperatures, higher relative humidity, and, most importantly, lower wind speeds. These atmospheric conditions are crucial for minimising the evaporation of the spray droplets and reducing the potential for drift. Furthermore, the higher humidity levels during these periods slow droplet evaporation extending the opportunity time, thus facilitating better herbicide absorption. Conversely, spraying must be avoided during the hottest parts of the day, as high temperatures and low humidity accelerate droplet evaporation, drastically reducing efficacy and increasing drift risk.

Optimum wind speed: Wind is the primary driver of spray drift. Operational safety and efficacy rely on strict adherence to wind speed limits. Herbicide application should only be performed when

the wind speed is below 3 m/sec (approx. 10.8 km/h). Application must be suspended if wind speed exceeds it. Continuous monitoring of wind speed and direction using an anemometer is mandatory before and during the operation.

Optimum droplet size: Droplet size is a critical physical parameter that balances the need for effective coverage with the necessity of minimising drift, and it is quantified by the Volume Median Diameter (VMD), measured in micrometers (μm). For herbicides applied via UAV, a medium droplet spectrum is generally targeted, with a VMD typically around 250 μm . While fine droplets ($\text{VMD} < 100 \mu\text{m}$) offer excellent coverage, they are highly susceptible to drift and evaporation and must therefore be avoided. Conversely, coarse droplets ($\text{VMD} > 300 \mu\text{m}$) have a low drift potential but provide insufficient coverage due to too few droplets per unit area. The

required VMD is determined by the specific nozzle type, pressure, and flow rate used by the UAV system. Consequently, specialised anti-drift nozzles or centrifugal atomisers are preferred for UAV applications because they offer superior control over VMD, ensuring the consistent production of the desired droplet size.

Regulatory framework for agricultural drone operations in India

To ensure safety and legal compliance in Indian airspace, all UAV-based herbicide applications must strictly adhere to the guidelines set by the Directorate General of Civil Aviation (DGCA) under the Ministry of Civil Aviation, Government of India. Farmers, custom hiring centers, and extension workers must fulfill the following mandatory requirements before deploying agricultural drones.

Remote pilot certificate: Operating an agricultural drone requires a valid Remote Pilot Certificate (RPC). The operator must be at least 18 years old, have cleared Class 10th, and must successfully completed institutional theoretical and practical flight training from a DGCA-approved Remote Pilot Training Organisation (RPTO).

Drone categorisation and type certification: Most agricultural spraying drones fall under the "Small" category (2–25 kg total weight including payload). To operate legally, the drone model must hold a valid Type Certificate (TC) issued by the DGCA, certifying that the aircraft meets rigid national manufacturing and safety quality check standards.

Table 1. Economic and operational efficiency comparison

Parameter	Manual knapsack spraying	UAV/Drone spraying
Operational capacity	1.5–2.0 acres/worker/day	25–40 acres/day
Labour requirement	High	Low (Requires only 1 certified pilot + 1 helper)
Water consumption	400 L/ha	30–45 L/ha
Application speed	~0.08 ha/h	~3.0–4.0 ha/h
Spraying cost	~ ₹800–1,000/acre	₹400–500/acre

Note: Manual spraying has almost negligible initial capital cost, its long-term operational expenses accumulate rapidly due to rising seasonal wages and input wastage. Conversely, UAV application achieves a lower per-acre cost over large-scale or custom-hired fields by optimising resource use efficiency.

Unique identification number:

Just like a motor vehicle registration plate, every individual agricultural drone must be registered on the government's official DigitalSky Platform to obtain a Unique Identification Number (UIN). This UIN must be physically printed or engraved onto the chassis of the drone.

Third-party liability insurance:

Under current guidelines, it is illegal to operate a commercial or agricultural drone without a valid third-party liability insurance policy. This covers any unforeseen financial liabilities arising from accidental bodily injury or public/private property damage caused by the drone during field operations.

Airspace zone compliance:

Before every flight, pilots must verify the zone classification via the interactive DigitalSky airspace map. While operations up to 400 feet (120 m) in Green Zones require no prior flight permission, any

agricultural spraying falling within a restricted Yellow or Red Zone (such as areas near airport perimeters or military installations) requires mandatory digital clearance prior to take off.

Extension note: Operating an unregistered agricultural drone or flying without a valid DGCA remote pilot certificate is a punishable offense under the Drone Rules, which can lead to administrative grounding of equipment and structural monetary penalties up to ₹1 Lakh.

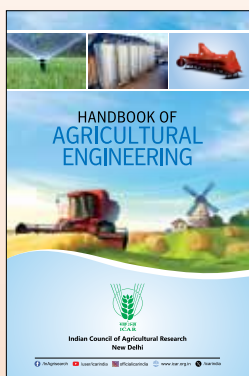
SUMMARY

The transition from conventional spraying to UAVs represents a pivotal advancement in the weed management strategy for DSR. By adhering to a rigorous SOP that meticulously controls technical parameters, specifically, maintaining an optimum spray volume of 30–45 L/ha, a consistent flight height of 1.5–2.0 m above the

canopy, a steady flight speed of 3–6 m/sec, and strictly operating within a wind speed window of 2–3 m/sec, farmers can achieve superior application efficiency. The UAVs fundamentally overcome limitations of conventional methods. They drastically reduce water usage, eliminate damage to topography, enhance worker safety by minimising chemical exposure, and, most importantly, deliver unparalleled precision in targeting weeds. By embracing the procedure outlined in this article and avoiding the pitfalls of improper operation, the agricultural sector can unlock the full potential of UAV technology, ensuring sustainable, cost-effective, and highly efficacious weed control in DSR, thereby securing higher yields and promoting environmental integrity.

*Corresponding author email: vijitnau@gmail.com

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