
# Spreading Performance of a UAV for Cover Crop (Cereal Rye) Seeding at Varying Application Rates and Flight Speeds

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***Abstract.***

*With the increased use of UAVs for pesticide applications in agriculture, there is growing interest in their use for applying dry solid materials, especially for seeding cover crops. However, limited information currently exists on the application performance of UAVs for broadcasting cover crop seed and the effects of different operational parameters. Therefore, studies were conducted to assess the spreading performance of a DJI Agras T25 UAV under varying application rates (22.4, 33.6, 44.8, 56.1 & 67.3 kg/ha) and flight speeds (6, 7, 8, 9, & 10 m/s) when applying cereal rye. Before any field testing, static experiments were conducted to determine the material flow rate (kg/min) and compare it with the manufacturer's internal calibration process. The field testing involved capturing the material dispensed by the UAV, using pans arranged in a single line perpendicular to the flight path, and assessing the single-pass spread patterns across different application rates and flight speeds. The simulated overlap spread patterns were generated to assess the mean applied rate and distribution uniformity (using the coefficient of variation, CV) of cereal rye within the swath. Results showed that the actual flow rate differed from the rate suggested by the manufacturer's internal calibration. Due to this discrepancy, the mean rate applied by the UAV was considerably lower than the target rate, indicating significant under-application. The single-pass spread patterns suggested leftward skewness, with a peak and heavy material deposition toward the left of the swath. The simulated overlap spread patterns showed an increase in the mean applied rate with increasing rate, but no effect of flight speed on the applied rate across the swath. The CV values ranged from 21% to 39% across the application rates and flight speeds, indicating a considerable variability in cereal rye distribution within the swath. However, there was no significant effect of application rate or flight speed on spread uniformity. The results of the study suggested that UAVs can be used to apply cover crop seed, but proper calibration procedures to verify the applied rate and spread uniformity, as well as the selection of optimal parameters, must be followed for effective applications.*

***Keywords.***

*Unmanned Aerial Vehicles, Cover Crop Seeding, Application Performance, Spread Uniformity, Applied Rate, Flight Speed*

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Recently, the use of Unmanned Aerial Vehicles (UAVs) in agriculture has increased rapidly in the United States, with over 4.1 million hectares treated by UAVs in 2024 (ASDC, 2024). Most of these applications involve the use of agrochemicals in agricultural fields or crops. However, most modern UAV platforms also include an interchangeable dry spreading system for broadcasting solid materials such as cover crop seed and small granular fertilizers. Cereal rye (*Secale cereale*) is amongst the most widely used cover crops in the United States (Sever, 2023) due to its numerous benefits, such as excellent winter hardiness, weed suppression, and residue persistence (Rorick & Kladivko, 2017). In 2023, over 890,000 hectares of cereal rye were planted in the United States (USDA, 2024). Cereal rye is also used in various cover crop mixtures, often seeded with other small grains, legumes, and brassicas. With increased use of UAVs for cover crop seeding, investigating their spreading performance, especially application rate and distribution uniformity, is much needed to inform effective utilization of this technology. Therefore, a study was conducted to evaluate the application performance of a UAS for cover crop seeding. The specific objectives of this study were to (1) evaluate the application rate (metering) accuracy of a UAS when applying cereal rye at different target rates and flight speeds, and (2) assess the distribution uniformity across the swath for cereal rye applied with a UAS at different rates and flight speeds.

A commercially available UAV, DJI Agras T25 (SZ DJI Technology Co., Shenzhen, China), was used in this study (Figure 1a). Static testing was conducted to determine the actual flow rate (kg min$^{-1}$) of cereal rye at different hopper gate openings (%) to generate a flow rate curve and compare it with the manufacturer-generated calibration. Field tests were conducted at the E.V. Smith Research Center in Shorter, AL, USA on a flat, open, and uncropped site. The application area selected for testing within the field was approximately 150 m long and 30 m wide. The first set of experiments involved applying cereal rye at rates of 22.4, 33.6, 44.8, 56.0, and 67.3 kg ha$^{-1}$ with the UAV, while keeping the other parameters, including flight speed, height, and spinner disc speed, fixed. Similarly, the second experiment involved applying cereal rye at flight speeds of 6, 7, 8, 9, and 10 m s$^{-1}$ with a fixed application rate, height, and spinner disc speed. All field tests for assessing the distribution uniformity of cereal rye were conducted following the procedures outlined in the ASABE standard S386.2 “Calibration and distribution pattern testing of agricultural aerial application equipment”. A total of 29 pans, spaced evenly at 0.61 m intervals from the center of one pan to the next, were placed in a single line within the application area (Figure 1b). This arrangement of pans was perpendicular to the flight path and was directly centered under the UAV pass. During each test, the UAV performed a single pass over the collection pans with the desired application parameters preset in the controller and broadcast the material within the application area. The collected material was recorded and converted to an applied rate, in kilograms per hectare, for each pan location. Further, single-pass and overlap simulated distribution patterns were generated from the applied rate at each pan location. To analyze and compare the spread patterns, the applied rate (kg ha$^{-1}$) and coefficient of variation (CV, %) were calculated and subjected to analysis of variance using an alpha level of 0.05.


**Figure 1. (a) DJI Agras T25 UAV with the dry spreading system and (b) collection pans placed within the application area and perpendicular to the UAV pass for assessing the distribution uniformity of cereal rye across the swath.**

The flow rate curve generated from data collected during static testing showed a non-linear relationship between the material flow rate (kg min$^{-1}$) and the hopper gate opening (%). The manufacturer-generated calibration curve differed from the actual flow-rate curve, which appears to show a linear relationship between flow rate and gate opening, especially for gate openings between 20% and 100%. These differences in flow rates highlight the inadequacy of the manufacturer's calibration procedure in accurately representing the actual flow rate from the hopper and would likely result in significant errors during the application of cereal rye with the UAV. Considering these results, similar calibration issues can also be expected for other cover crop seeds or mixtures, as the main issue lies in the calibration approach (using only three to four measurements) used by the manufacturer, which fails to account for and depict the non-linear (or quadratic) relationship between the hopper gate opening and material flow rate.

The single-pass spread patterns showed a peak indicating heavy material deposition to the left, between -1.0 and -2.0 m within the swath, which is a typical characteristic of single-disc broadcast systems. The total mass (i.e., the total amount of cereal rye deposited within the swath) increased significantly with increasing target rate, as expected due to higher flow rate (kg min$^{-1}$) as the rate (kg ha$^{-1}$) increased (Table 1). In contrast, the total mass was similar across the different flight speeds, indicating that the same amount of cereal rye was deposited within the swath regardless of an increase in the flight speed from 6 m s$^{-1}$ (60% of the maximum speed) to 10 m s$^{-1}$ (maximum speed). The maximum single-pass spread swath ranged from 11.9 to 13.6 m across different rates and flight speeds. The data also confirmed the leftward skew observed in the single-pass patterns, with 51% to 64% of cereal rye (by mass) deposited on the left side of the swath and 33% to 40% on the right. The overlap spread pattern analysis showed that the mean rate was considerably lower than the target rate, ranging from 33.9% to 44.3% across different application rates and flight speeds. For distribution uniformity, the CV values ranged from 21% to 39% across different rates and speeds. The statistical analysis indicated that neither application rate nor flight speed had a significant effect on the distribution uniformity of cereal rye within the swath. Most UAV applications occur at maximum flight speed to increase field efficiency. The results obtained here suggested that applications at lower flight speeds did not improve the uniformity of cereal rye distribution within the swath. Overall, the results suggest that UAVs can be an effective tool for applying cover crop seed, but proper calibration and selection of optimal parameters are important for achieving desired application performance and efficient operations.

**Table 1. Summary Statistics for the single-pass and simulated overlap spread patterns for cereal rye applied with the UAV at different application rates and flight speeds.**

| Test | Target Rate (kg ha$^{-1}$) | Flight Speed (m s$^{-1}$) | Single-Pass Spread Pattern[a] | | | Overlap Pattern[a] | |
|---|---|---|---|---|---|---|---|
| | | | Total Mass (kg x 10$^{-3}$) | Maximum Swath (m) | Skewness % (L/R) | Mean Rate (kg ha-1) | CV (%) |
| 1 | 22.4 | 10 | 3.7 a | 12.2 b | 56/37 ab | 13.7 e | 30 |
| | 33.6 | 10 | 5.8 b | 12.9 ab | 59/34 ab | 20.8 d | 30 |
| | 44.8 | 10 | 7.9 c | 13.6 a | 57/35 ab | 27.3 c | 27 |
| | 56.0 | 10 | 8.7 d | 12.7 ab | 51/40 b | 31.2 b | 21 |
| | 67.3 | 10 | 11.3 e | 12.0 b | 60/33 a | 41.0 a | 33 |
| 2 | 44.8 | 6 | 8.1 A | 12.8 A | 54/39 A | 29.1 A | 22 |
| | 44.8 | 7 | 8.2 A | 12.2 A | 56/37 A | 29.5 A | 22 |
| | 44.8 | 8 | 8.0 A | 11.7 A | 64/29 B | 28.8 A | 39 |
| | 44.8 | 9 | 8.2 A | 12.1 A | 60/33 AB | 28.9 A | 33 |
| | 44.8 | 10 | 8.0 A | 11.9 A | 59/35 AB | 29.6 A | 32 |

[a] Values followed by the same letters within each column and for each test are not significantly different from each other (*p>0.05*).

## References


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