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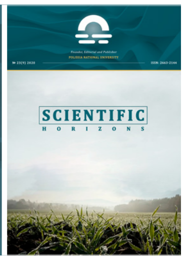

Development of a drone-based sowing technology for oilseed radish as a green manure crop

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Abstract. The aim of the study was to experimentally justify a drone-based surface sowing technology for oilseed radish as a green manure crop under the conditions of the Polissia region of Ukraine. The methodology included laboratory testing of seed quality, NDVI field monitoring, a field experiment with variable flight height, sowing rate and soil preparation type, as well as statistical assessment of variability and survival using ANOVA ($p \leq 0.05$). High physiological quality of the Raiduha seeds was confirmed (94.0% germination energy; 99.0% laboratory germination rate), which ensured stability of the initial plant stand. Spatial unevenness of sowing caused by aerodynamic seed drift was investigated; the coefficient of variation reached 68.3%, indicating pronounced asymmetry of the agrophytocenosis. The influence of two

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sowing rates (320 and 560 plants/m^2) and two flight heights (3 and 5 m) was analysed, establishing that the optimal combination consisted of a rate of 320 plants/m^2, a 5 m flight height and glyphosate-based soil preparation, which resulted in 13.4% viable plants. Herbicide application accelerated phenological development and reduced inter-species competition. A technological solution was analytically proposed in the form of drone-based cross-seeding to compensate for aerodynamic seed displacement and stabilise plant stand density. The practical value of the research lies in its applicability for developing a UAV-based sowing standard for green manure crops within precision farming and post-war agricultural rehabilitation programmes

Keywords: aerodynamic seed drift; agrophytocenosis density; phenological monitoring; precision agriculture; sowing variability; post-war agricultural recovery

INTRODUCTION

The intensification of digital technologies within agricultural production fundamentally transformed the principles of crop cultivation and field management, particularly in regions with complex terrain and degraded soils. The Polissia area of Ukraine remained one of the most challenging agroecological zones, characterised by excessive soil moisture, acidity, and geomorphological heterogeneity, which substantially limited the use of conventional sowing machinery. Under such conditions, the development of autonomous drone-based sowing technologies for green manure crops acquired strategic value for resource conservation, soil restoration, and post-war agricultural reconstruction. Oilseed radish has been identified in previous agronomic investigations as a biologically adaptive and technologically promising species for biomass accumulation and structural soil recovery, yet the problem of achieving its uniform distribution during drone-assisted sowing has remained insufficiently resolved at the scientific level.

The current global tendency towards precision agriculture stimulated an increased interest in using unmanned aerial vehicles for direct sowing, although the technological performance of spreading mechanisms and airflow stability did not always meet agronomic standards. Researchers noted that sowing efficiency significantly depended on the inateraction between seed weight and aerodynamic turbulence generated by the drone, which resulted in asymmetric distribution and formation of sparsely vegetated areas (Qi *et al.,* 2022). Similar conclusions were reached by X. Wang *et al.* (2024), who established that large-seeded crops demonstrated greater adaptability to aerial broadcasting; however, seed displacement increased exponentially with rising flight altitude and wind variability. Experimental work performed by M.N. Nordin *et al.* (2022) confirmed that airflow generated during drone trajectory shifts caused lateral drift of seeds even under moderate wind conditions, which reduced the accuracy of seed placement and complicated the prediction of final plant density.

Aerial seeding was also analysed from the perspective of seeding mechanism design. Field simulations conducted by W. Zhijun *et al.* (2023) demonstrated that auger-type spreading systems could ensure higher stability than centrifugal distribution, although their efficiency markedly declined when seeds demonstrated low thousand-seed weight. According to H. Li (2023), the technological reliability of sowing systems required precise calibration before each flight, while the absence of post-sowing incorporation into the soil remained the primary limiting factor for uniform germination. Other studies proposed the modification of existing drone seeders to counteract airflow distortion and improve the dispersion radius (Adithya *et al.,* 2024). However, the integration of these improvements into an agronomically viable sowing standard remained underdeveloped.

The question of seed germination and subsequent resilience under surface broadcasting was examined in several studies. It was found that independently of sowing uniformity, high seed physiological quality, particularly germination energy, had a decisive influence on the early stages of organogenesis (Tsytsiura, 2024a). Laboratory investigations into oilseed radish germination under surface conditions demonstrated that rapid water absorption and metabolic activation were essential for successful emergence without conventional soil embedding. Nonetheless, uneven seed distribution and intensified intra-species competition, especially at high sowing rates, remained a limiting factor for green manure efficiency (Stroud *et al.,* 2017). These observations raised the need to adapt seeding algorithms to crop-specific biological features rather than relying solely on standardised rates used in conventional agriculture.

An increasingly relevant research direction concerned the interaction between drone-assisted sowing and soil preparation technologies. The combined application of green manure sowing and herbicide-based treatment was reported to improve weed suppression and enhance plant survival during early development stages (Helander *et al.*, 2019). According to Y. Tsytsiura (2024b), oilseed radish contributed to the restoration of organic matter content and improved phosphorus mobilisation, which increased its agronomic value for organic crop rotations. Ukrainian research also confirmed the suitability of this species for restoring structural integrity in light loam soils of Polissia, although sowing outcomes depended heavily on climatic stability and moisture retention capacity.

UAV-based monitoring methods provided further advancement of this technological approach. Remote sensing and NDVI mapping were increasingly used to evaluate sowing uniformity and assess the effectiveness of alternative sowing strategies (Vavlas *et al.,* 2024). D. Reddy *et al.* (2025) demonstrated that UAV-based multispectral imaging enabled precise detection of vegetation gaps and facilitated corrective assessment of sowing efficiency. Such methods were considered to be particularly valuable in unstable climatic conditions and agronomic zones with spatially heterogeneous soil cover.

The reviewed literature indicated that drone-assisted sowing could be successfully applied for green manure crops, provided that aerodynamic constraints, sowing rates, and crop biological characteristics were appropriately synchronised. However, the absence of an experimentally validated technological standard for oilseed radish sowing from UAVs remained a critical research gap that limited large-scale implementation in post-war agricultural recovery programmes. The aim of the study was to determine technological parameters that ensured uniform surface sowing of oilseed radish from drones in unprepared soil conditions of the Polissia region of Ukraine, with a view to developing an agronomically justified framework for its practical application in green manure farming.

MATERIALS AND METHODS

The study aimed at developing a drone-based technology for sowing green manure crops was conducted over a two-year period at the research field of Polissia National University, located near the village of Velyka Horbasha, Cherniakhiv Territorial Community, Zhytomyr District, Zhytomyr Region (50°26'17" N, 28°41'38" E). The soil cover of the experimental site is represented by grey forest light loam soils, characterised by low humus content, insufficient levels of essential nutrients, and increased acidity. Prior to the establishment of the experiment, a soil agrochemical survey was conducted, with samples taken from depths of 0-10 cm, 10-20 cm, and 20-30 cm to determine pH, humus content, and available forms of nitrogen, phosphorus, and potassium. These measurements were necessary to establish the initial agrochemical background that could influence the germination, growth, and development of oilseed radish.

The object of the study was the oilseed radish variety Raiduha, developed by the V.Ya. Yuriev Institute of Plant Production of the National Academy of Agrarian Sciences of Ukraine. This annual, cold-season crop is characterised by rapid accumulation of green biomass and a well-developed root system that contributes to improving the structural and physical properties of the soil. Its seeds contain 40-46% oil, rich in omega-3 fatty acids and antioxidants. In conventional agriculture, the recommended seeding rate ranges from 16 to 22 kg/ha. However, in this study, increased seeding rates were applied due to the specific requirements of drone-based sowing. The research was conducted in three stages. At the preparatory stage, laboratory assessment of the seed material was performed (germination rate and germination energy testing), an experimental design was developed, and the study plot was selected and delineated. The main stage involved testing two field preparation approaches: glyphosate-based and glyphosate-free technologies (Fig. 1).

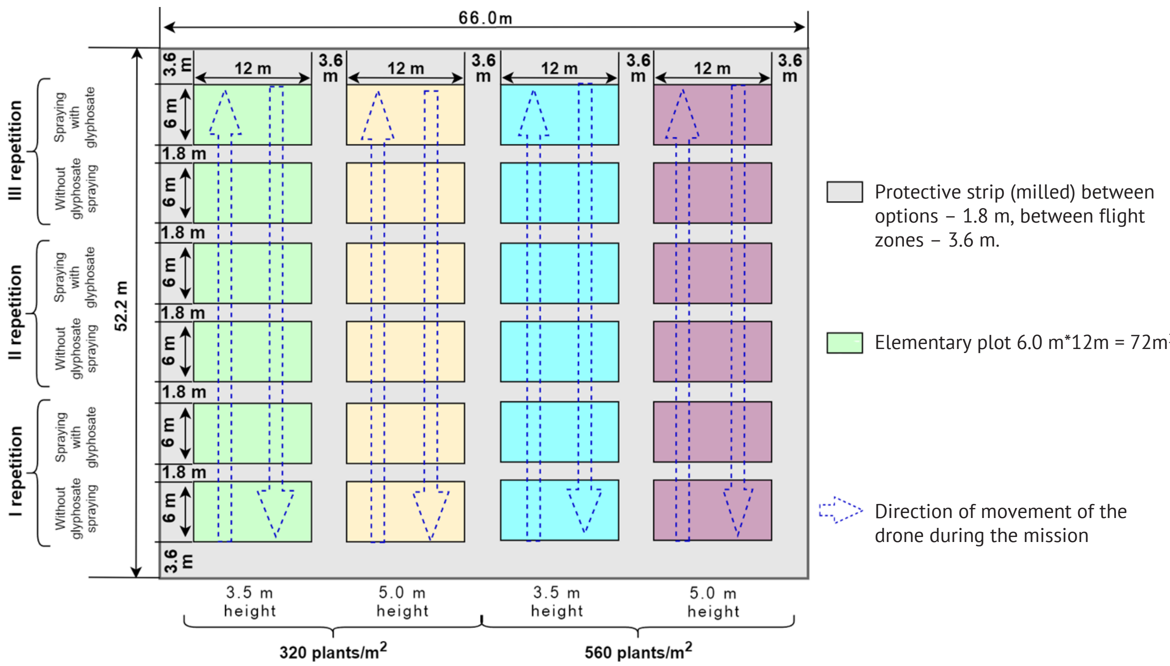

***Figure 1**. Experimental scheme*

***Source:** developed by the authors*

Herbicide application was carried out using an MC A22 (Multicopter LLC, Ukraine) drone at a rate of 2 l/ha, with a working solution rate of 7.5 l/ha, a flight altitude of 4 m, and a flight speed of 8 m/s under wind conditions of 2 m/s and a wind direction of A338°. Spraying was conducted in two passes in mission mode, with drone flight directions of A73° and A253°. Moderate lateral drift of the herbicide was recorded; however, it did not affect the geometric layout of the experimental plots.

Sowing of oilseed radish was performed with an XAG P100 Pro drone in three replications using two seeding rates: 320 plants/m^2 (62 kg/ha) and 560 plants/m^2 (76 kg/ha). Prior to each flight, calibration of the seeding mechanism was carried out. Sowing took place under favorable weather conditions: air temperature +22.6°C, relative humidity 60%, and wind speed 1.1 m/s, which ensured uniform seed distribution. Each experimental plot was sown in two passes in mission mode with flight directions of A295° and A115°, under a wind direction of A163°. Only minimal lateral seed drift was observed, and it did not affect the geometric accuracy of the sowing pattern. For spatial referencing of the results, preliminary NDVI mapping of the study area was conducted using Sentinel-2 satellite imagery in the ArcGIS Pro environment (ESRI), confirming the homogeneity of the site in terms of soil productivity. During monitoring, the proportion of areas with NDVI < 0.35 was determined as an indicator of insufficient seedling density, which made it possible to identify potential areas of uneven development of the agrophytocenosis. Ground control points were established using a Hi-Target V30Plus RTK GNSS receiver to synchronise field observations with aerial imagery.

Phenological observations included the assessment of field emergence, plant stand density, and plant development at the cotyledon stage; the first and second true leaf stages; the 3-4 leaf stage; bud formation; flowering; and green biomass accumulation. Weed infestation levels and pest damage were also recorded. The final stage of the study involved mathematical and statistical processing of the collected data, comparative analysis of the experimental treatments, and formulation of conclusions. The duration of each phenological phase was recorded in days after sowing, followed by a comparison between the variants with herbicide treatment and the control plots for quantitative assessment of plant growth rates. To compare survival rates and variability, it was used the ANOVA criterion with a significance threshold of $p \leqslant 0.05$, which ensured the reliability of the calculated differences between the experimental variants. During the analysis of sowing variability, an additional technological approach was formulated – cross-seeding, which was not included in the initial experimental scheme but was proposed as an empirically justified recommendation. The authors adhered to the standards of the Convention on Biological Diversity (1992).

RESULTS AND DISCUSSION

As part of the preparatory stage, a laboratory assessment of the seed quality of the oilseed radish variety Raiduha was conducted, as this parameter is critical for the implementation of drone-based sowing technology. Unlike conventional mechanical seed drills, drone sowing does not incorporate seeds into the soil; instead, they remain on the soil surface, where they are exposed to fluctuations in temperature and moisture, biodegradation processes, and the risk of bird predation. Consequently, the success of germination under such conditions largely depends on the intrinsic physiological potential of the seeds, particularly their germination energy and laboratory germination rate. For this reason, the evaluation of seed quality served as one of the fundamental tasks of the study.

The laboratory experiment ($n = 3$) demonstrated that the oilseed radish seeds possessed high biometric quality (Table 1). The mean germination energy was 94.0%, while laboratory germination rate reached 99.0%. These values exceed the minimum standard requirements for green manure crop seed material (at least 85% germination rate), which justifies the use of calculated seeding rates without adjusting for potential losses. The high germination energy indicates rapid water uptake by the germ and active development of the sprout. These factors are particularly important when seeds are deposited on the soil surface during UAV-based sowing. High laboratory germination rate, in turn, ensures stability of the initial plant stand, which is a key determinant of productivity in green manure farming.

***Table 1**. Seed quality indicators of the oilseed radish variety Raiduha according to laboratory testing ($n = 3$), %*

Indicator	Replication			Mean
	I	II	III	
Germination energy	94	96	92	94.0
Germination rate	98	100	98	99.0

***Source:** developed by the authors*

The high physiological quality of the seeds made it possible to avoid artificially increasing the seeding rate, which is commonly practiced in direct surface broadcasting. This allowed to evaluate the influence of strictly technological factors (drone flight altitude, number of passes, and seeding rate) without confounding them with biological losses of the seed material. The next stage of the study involved assessing the uniformity of seed distribution on the soil surface, as this parameter is considered crucial for establishing a homogeneous agro-phytocenosis. Within the experiment, the distribution of seeds dropped from the drone was analysed at two flight altitudes (3 and 5 m) and under different seeding rates, which made it possible to determine the impact of aerodynamic factors on sowing accuracy. Uniformity was evaluated by establishing 1 m^2 control plots where the actual number of seeds per unit area was counted; the coefficient of variation was then calculated as a measure of distribution stability. Thus, the laboratory results confirmed the suitability of the selected oilseed radish variety for this type of experiment and substantiated the feasibility of proceeding to the field stage using drone-based sowing technology. This provided scientific validity for the subsequent field observations in terms of the crop's physiological potential.

The results of the field experiments (Table 2) revealed substantial unevenness in the distribution of oilseed radish seeds during drone-based sowing. This unevenness was reflected not only in variations in plant density within the seeded strip but also in a considerable drift of seeds beyond the boundaries of the control plots. In particular, lateral displacement of seeds was observed in the direction corresponding to the drone's flight path. Such an effect is typical for surface broadcasting of lightweight seeds, even under minor airflow conditions. Spatial analysis of plant density showed that at a drone flight altitude of 3 m and a seeding rate of 320 plants/m^2, the actual emergence averaged 283 plants/m^2 (88.5% of the intended rate). When the flight altitude was increased to 5 m, this value decreased to 279 plants/m^2 (87.1%), indicating a loss of distribution accuracy with increasing sowing height. A similar trend was recorded at the higher seeding rate of 560 plants/m^2: the actual density ranged from 440 to 458 plants/m^2 (78.6-81.7%), indicating a substantial deviation from the target plant density.

***Table 2**. Distribution of winter rape and oilseed radish seeds across the plot depending on the drone's flight trajectory (average values)*

Projected plant density, plants/m^2	Seed sowing height, m	Distance from the drone's flight line, m			Weighted mean number of sown seeds, pcs/m^2	% of the planned seeding rate
		0	1.5	3		
		Number of seeds, pcs/m^2				
320	3	304	404	142	283	88.5
	5	316	352	168	279	87.1
560	3	522	680	118	440	78.6
	5	557	554	262	458	81.7

***Source:** developed by the authors*

These deviations can be explained by the aerodynamic behavior of the seeds, as oilseed radish has a lower thousand-seed weight compared with traditional cereal or legume crops. This increases its susceptibility to horizontal displacement under the influence of airflow, particularly within the vertical vortex zones that form behind the drone. These findings support the hypothesis that drone-based sowing of crops with low seed weight is associated with an elevated risk of sowing asymmetry and the formation of both densely populated and sparsely populated zones within a single technological pass. Analysis of the obtained results indicates that cross-seeding, where the drone performs two perpendicular passes using half of the standard seeding rate each time, may be a practical solution for improving sowing uniformity. This approach helps equalise plant density across the field, reduces localised competition for nutrients and moisture, and enhances the overall quality of the agro-phytocenosis. Additionally, cross-seeding has the potential to minimise lateral seed drift by offsetting sowing asymmetry from opposite flight directions. From the perspective of green manure farming, uniformity of sowing is of critical importance, as the homogeneity of plant cover directly determines the crop's capacity to accumulate green biomass, its phytosanitary effectiveness, and its ability to suppress weed growth. Thus, the results confirm the need for technological adaptation of agricultural drones for sowing small-seeded crops through improvements to seed-dispersion algorithms and modifications to flight-pattern design. Such advancements would ensure more stable biometric parameters and enable the formation of an agronomically justified plant density for green manure cover in the context of organic production.

The next stage of the research involved field monitoring of the growth and development of oilseed radish throughout the entire vegetation period in order to determine the influence of soil-preparation technology, seeding rate, and drone flight altitude on the formation of a stable plant stand density. The duration of each phenological phase was recorded in days after sowing, allowing quantitative comparison between herbicide-treated plots and control variants to assess the tempo of organogenesis. The emergence of the first true leaf pair occurred on average after 11.3 days in herbicide-treated plots and after 14.8 days in control variants, confirming different developmental dynamics depending on soil preparation. Post-emergence plant survival is one of the key indicators of sowing effectiveness, as the actual plant density determines the crop's ability to realise its green-manure potential through biomass accumulation and weed suppression.

As shown by the results presented in Table 3, the highest field germination and seedling survival rates were recorded in the cases that included pre-application of glyphosate and a projected density of 320 plants/m^2. In this case, sowing from a height of 5 m resulted in an average of 42.9 plants/m^2, which corresponds to 13.4% of the sown seeds. When sowing was carried out from a height of 3 m, the survival rate was slightly lower – 37.7 plants/m^2, or 11.8%; yet it remained substantially higher than in the plots without herbicide application. The use of glyphosate reduced competitive pressure from the weed component, thereby creating more favorable conditions for oilseed radish growth during emergence and early development.

***Table 3**. Effect of soil preparation technology, seeding rate, and drone sowing height on the residual number of oilseed radish plants, pcs/m^2*

Case (cultivation technology)	Projected plant density, plants/m^2	Seed sowing height, m	Mean across replications, pcs/m^2			Case mean	Coefficient of variation, %	Plant survival per 1 m^2, %
			0	1.5	3			
Without glyphosate	320	3	30	33	49	37.15 ± 9.79	26.34	11.61
		5	28	32	31	30.21 ± 10.27	34.01	9.44
	560	3	10	11	15	12.15 ± 8.3	68.30	2.17
		5	17	12	17	15.16 ± 5.05	33.32	2.71
Glyphosate treatment	320	3	35	36	42	37.73 ± 6.85	18.14	11.79
		5	40	42	46	42.94 ± 14.94	34.79	13.42
	560	3	39	53	56	49.42 ± 10.98	22.21	8.83
		5	36	30	35	33.8 ± 7.88	23.33	6.04

***Source:** developed by the authors*

The cases with an increased seeding rate (560 plants/m^2) exhibited notably lower plant survival – only 2.2-9.4%. This outcome is due not so much to the biological characteristics of the crop as to intensified competition among seedlings and their uneven distribution on the soil surface. The high coefficient of variation (up to 68.3%) in this case further confirms that excessive stand density combined with surface seed placement led to the loss of a portion of the plants during the early stages of organogenesis. The presented data indicate that the most technologically justified approach is the combination of glyphosate-based soil preparation with a drone-applied seeding rate of 320 plants/m^2, as this provides an optimal balance between biological productivity and the uniformity of the green manure cover. Achieving an optimal plant stand density is a critical factor for successful green manuring, since the quantitative stability of the plant population determines the effectiveness of biomass accumulation, soil enrichment with organic matter, and the phytosanitary improvement of the agroecosystem.

The discussion required a comparison of the obtained experimental results with current research trends in UAV-based sowing of green manure and cover crops. It was found that the detected spatial variability of sowing corresponded to similar patterns reported in earlier studies, although distinct differences were associated with the biological properties of oilseed radish and the agroclimatic conditions of Polissia. According to B. Berner (2020), effective drone-assisted sowing was achievable only under minimal wind influence, whereas in this experiment the coefficient of variation reached 68.3%, exceeding the author's findings due to the lower thousand-seed weight of the Raiduha cultivar. Comparable aerodynamics-related constraints were reported by H. Liu *et al.* (2023), who demonstrated that flight stability and seed displacement were strongly dependent on UAV construction and airflow.

Cross-seeding emerged as a solution to compensate for airflow-induced drift and intraspecific competition. This aligned with the findings of S. Zhang *et al.* (2022), who achieved reductions in seed losses by adjusting speed and drop parameters during sowing. In contrast, H. Zhou *et al.* (2024) emphasised the potential of centrifugal distribution systems to ensure more stable seed trajectories, suggesting possible engineering modifications for green manure crops. Similar adaptive approaches were observed in forestry regeneration, where UAV-assisted sowing relied on topography-sensitive algorithms (Mohan *et al.,* 2021), reinforcing the relevance of spatial variability monitoring found in this study. Survival dynamics were consistent with agronomic research on cover crops. J.S. Cavadini and E.J. Kladivko (2025) confirmed that excessive sowing density induced strong intraspecific competition, closely matching the observed reduction to 2.2-9.4% survival under higher seeding rates. The adaptive potential of oilseed radish was further supported by H. Hereshko *et al.* (2021), who classified it as a biologically resilient crop with high suitability for sustainable farming.

A prominent direction in modern research involved digital assessment and post-sowing density estimation.

A deep learning approach using RGB imagery was developed by T. Luu *et al.* (2025), providing methodological opportunities to automate evaluation of agrophytocenosis structure. Comparable principles were applied in reforestation activities, where UAVs were controlled via observer-based algorithms for optimal placement accuracy (Istiak *et al.,* 2023; Muñoz *et al.,* 2025). Moreover, NDVI-based monitoring was validated as an effective post-seeding assessment tool, aligning with recommendations made by Y. Han (2024), which mirrored the approach implemented in this experiment.

A recent review by R. Guebsi *et al.* (2024) outlined major challenges in precision agriculture using UAVs, particularly regarding uneven distribution on irregular terrain. In comparison, the results of this study demonstrated that seed mass rather than topography was the primary limiting factor, indicating the necessity of biological adaptation in UAV-sowing protocols. Consequently, cross-seeding was analytically proposed as a potential baseline strategy for managing spatial variability. The comparison with international studies demonstrated that UAV-based sowing of oilseed radish was consistent with broader scientific trends yet revealed species-specific constraints shaped by seed mass and airflow dynamics. Existing research confirmed both the agronomic potential of the crop and the feasibility of drone-assisted sowing; however, it underscored the need for technological refinement and spatial correction strategies. The analytical justification of cross-seeding indicated a promising direction for optimising agrophytocenosis structure and integrating oilseed radish into precision farming systems.

CONCLUSIONS

The findings demonstrated that the high physiological quality of the Raiduha oilseed radish seeds, confirmed by laboratory indicators of 94.0% germination energy and 99.0% laboratory germination rate, provided a reliable biological foundation for testing surface drone-based sowing. The field experiment indicated that the principal limitation of this technology was the uneven spatial distribution of seeds, caused by the low thousand-seed weight and the influence of the drone's aerodynamic airflow. The coefficient of variation reached 68.3%, confirming the formation of asymmetric zones of seed accumulation and depletion within a single technological pass, which intensified intraspecific competition and reduced plant survival during early ontogenesis.

The combination of glyphosate-based soil preparation and a seeding rate of 320 plants/m^2 yielded the most stable agrophytocenosis, resulting in an average of 42.9 surviving plants/m^2 at a 5 m flight height, equivalent to 13.4% of the sown seeds. In control plots without herbicide treatment, survival remained comparatively high at 11.6%, which indicated a strong adaptive potential of the crop under surface sowing conditions. However, an increased seeding rate of 560 plants/m^2 led to a marked reduction in survival to 2.2-9.4%, confirming the negative effect of excessive stand density when uniformity was not ensured. A technologically grounded solution was analytically proposed in the form of cross-seeding, based on spatial variability analysis, with the aim of counteracting airflow-induced seed displacement and levelling intra-row competition. This approach was considered promising for enhancing sowing uniformity and strengthening the agroecological value of green manure crops within precision farming systems. Further research should focus on experimental validation of cross-seeding efficiency under varied flight parameters and climatic risk scenarios.

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CONFLICT OF INTEREST

None.

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Розробка технології посіву олійної редьки з дрону як сидеральної культури

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Анотація. Метою дослідження було експериментальне обґрунтування технології поверхневого посіву редьки олійної дроном як сидеральної культури в умовах Полісся України. Методологія включала лабораторний аналіз посівних якостей насіння, NDVI-моніторинг ділянки, польовий експеримент із варіюванням висоти польоту, норми висіву та типу підготовки ґрунту, а також статистичну оцінку варіабельності та виживання рослин за критерієм ANOVA ($p \leqslant 0{,}05$). Було встановлено, що насіння сорту Raiduha мало високі біометричні показники (94,0 % енергії проростання; 99,0 % лабораторної схожості), що забезпечувало стабільність початкового агрофітоценозу. Було досліджено просторову нерівномірність посіву, спричинену аеродинамічним зносом дрібного насіння; коефіцієнт варіації сягав 68,3 %, що зумовлювало утворення асиметричних зон загущення та прорідження. Було проаналізовано вплив двох висот польоту (3 і 5 м) та двох норм висіву (320 і 560 рослин м^2) на виживання рослин, було встановлено, що оптимальна комбінація включала норму 320 рослин/м^2, висоту польоту 5 м та гербіцидну підготовку, де формувалося 13,4 % життєздатних рослин. Було узагальнено, що гербіцидна обробка прискорювала проходження фенологічних фаз і знижувала міжвидову конкуренцію. Було аналітично запропоновано технологічне рішення – перехресний (cross-seeding) посів дроном як спосіб компенсації аеродинамічного зносу та вирівнювання густоти агрофітоценозу. Практична цінність дослідження полягає у можливості використання отриманих результатів під час формування стандарту посіву сидеральних культур з БПЛА в системах точного землеробства та післявоєнного агровідновлення

Ключові слова: аеродинамічний знос насіння; густота агрофітоценозу; фенологічний моніторинг; точне землеробство; варіабельність посіву; післявоєнне агровідновлення