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Improving the process of plant protection mechanisation in grape growing

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Abstract. The study aimed to investigate the impact of modern vineyard cultivation technologies on reducing pesticide consumption and increasing yields. The study evaluated the effectiveness of using AgriSpray 5000 sprayers and DJI Agras T30 drones in agronomy, particularly in viticulture. The research methodology included an analysis of pesticide consumption and grape yields before and after the introduction of these technologies. For this purpose, a comparative analysis was carried out with traditional methods of processing, in particular by hand. The use of AgriSpray 5000 sprayers and DJI Agras T30 drones has reduced pesticide consumption by 30 and 25%, respectively, thanks to the precise distribution of solutions and the automation of field processing. The main results of the study showed that AgriSpray 5000 sprayers reduced the number of diseased grape plants by 40%, which led to a 15% increase in yield. At the same time, DJI Agras T30 drones reduced the number of diseased plants by 35% and increased yields by 12%. The integration of new technologies has reduced the overall cost of vineyard cultivation by 20%, in particular, due to lower pesticide and labour costs. The study findings show that the introduction of modern sprayers and drones significantly optimises vineyard processing, reduces costs and increases yields. The AgriSpray 5000 and DJI Agras T30 technologies provide a high level of precision in the application of agrochemicals, which has a positive impact on the environment

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and economic results. The results confirm the effectiveness of the latest technologies as an important tool for increasing the competitiveness of Ukrainian vineyards and improving product quality

Keywords: pesticides; sustainable development; irrigation; crop production; agriculture; diseases

INTRODUCTION

In modern viticulture, the mechanisation of plant protection processes is an important aspect of increasing the efficiency of agronomic practices and ensuring the sustainable development of the industry. Traditional methods of vineyard cultivation often require significant human resources and can be inefficient due to irregularity and incomplete coverage of cultivated areas. In this regard, there is a need to introduce new mechanised technologies that can ensure more accurate and cost-effective application of pesticides and other agrochemicals.

The research relevance is determined by the need to adapt modern technologies to improve the efficiency of vineyard protection. Due to global climate change and growing demands for environmentally friendly agronomic practices, traditional cultivation methods are becoming less effective and often do not meet modern standards. Mechanisation, including the latest spraying and monitoring systems, can ensure precision and efficiency in pesticide application while reducing environmental impact.

The problem of the study is the gap between traditional methods of plant protection and modern technological advances. While the latest systems show great potential, there are gaps in their integration and practical application. It is necessary to assess their impact on plant resistance to diseases, economic efficiency and the overall condition of vineyards, which will allow agronomists to better implement these technologies to achieve maximum results.

There are several important aspects of improving the process of plant protection mechanisation in grape growing that have already been studied by various authors. The issue of increasing the resistance of grapes to diseases such as black rot was addressed by Q. Kong *et al*. (2024), who found that UV irradiation could improve grape resistance by regulating the synthesis of phenolic compounds. At the same time, M. Karim *et al*. (2024) focused on improving the classification of grape leaf diseases using a lightweight convolutional neural network architecture, which showed potential for real-time disease diagnosis. P. Wang *et al*. (2021) proposed an improved grape leaf disease recognition methodology based on enhanced attention, which achieved high accuracy in disease detection.

A study conducted by K. Pandey & A. Chandak (2024) addressed deep-learning techniques used to detect grape diseases. This study not only confirms the relevance of the latest approaches in the mechanisation of plant protection but also emphasises the importance of introducing modern technologies into agronomic practice. Detecting diseases at early stages is critical to ensuring vineyard health and increasing yields, making these technologies extremely valuable to farmers. In addition, R. Patil & A. More (2023) conducted a detailed technical review of grape disease prediction methods using machine learning. Their study pointed out a wide range of technologies that can be integrated into the process of mechanising protection, including algorithms for data analysis and modelling, which allows for more accurate prediction of disease epidemics. This opens up new opportunities for agronomists to plan protection measures and optimise processing costs.

P. Sindhu & G. Indirani (2022) also demonstrated the effectiveness of using optimisers and deep neural networks to classify grape diseases. This shows the great potential for integrating the latest technologies into agronomic practices, which can significantly improve the accuracy and speed of disease detection. The use of such innovative solutions can not only increase the effectiveness of plant protection but also reduce the environmental impact of the agricultural sector, ensuring the sustainable development of viticulture.

Despite these achievements, there are gaps in the development of integrated systems for mechanised protection, in particular combinations of biocontrol agents and chemical fungicides, as reported by L. Ons *et al*. (2020). Z.S. Asgarian *et al*. (2024) investigated the effect of calcium and zinc spraying on berry quality during storage, which highlights the importance of integrating new protection methods into the growing process. The study by X. Zhou *et al*. (2024) showed that new quantitative indices of grape quality can improve the assessment of quality parameters. Thus, the main gaps in research relate to the integration of new technologies and mechanisation methods to improve the sustainability and quality of grapes.

This study focused on improving the process of mechanisation of plant protection in grape growing by introducing new models of sprayers, drones for agronomy and monitoring systems. Study goals include:

1. Evaluate the effectiveness of new mechanised systems for vineyard cultivation.

2. Determine the impact of new technologies on plant health and protection against diseases and pests.

3. Develop recommendations for optimising plant protection processes based on the results obtained.

MATERIALS AND METHODS

The study was conducted from May 2024 to September 2024 in the vineyards of the Vinogradnaya Gora farm, which is located in the southern region of Ukraine. A vineyard area of 10 hectares was selected for the experiments, which was used to obtain representative data on the impact of new mechanical systems on various aspects of cultivation. The sample included a variety of grape varieties (Arcadia 1995, Bianca 2007, Perseus 2020, Kishmish 2007, Kobzar 2009, Iskorka 2015, Isabella 2017, Aromatic 2009) that were subject to treatment with new mechanical protection systems, which was used to assess their effectiveness in different conditions. The study also included an analysis of the impact of mechanisation on crop quality and plant resistance to diseases. Robotic sprayers (AgriSpray 5000 – the United States of America); drones for agronomy (DJI Agras T30 – China); innovative sensors for plant monitoring (AquaSpy 9000 – Germany); precision farming systems for data monitoring and analysis (Trimble Ag Leader 360 – the United States) were used in the study.

An experimental methodology was used to assess the effectiveness of new sprayers and drones by comparing their performance with traditional methods of cultivation. The analytical methodology was used for the analysis of the collected data to determine the level of pesticide consumption reduction and improvement of the grapes' condition. Technical specifications of sprayewrs: AgriSpray 5000 (USA) – tank volume: 500 litres; processing range: up to 12 metres; weight: 1,200 kg; Global Positioning System (GPS) for precise application. DJI Agras T30 drones (China) – tank capacity: 30 litres; maximum treatment area per charge: 40 hectares; automatic control and programming of routes; a camera for monitoring the condition of plants.

All experiments and data collection were carried out under the supervision of the agronomic service of the Vinogradna Gora farm, using the farm's developed methods and processing protocols. The study complies with ethical standards and adheres to the Convention "On Biological Diversity" (1992). Regulation of the European Parliament and of the Council No. 1107/2009 (2009), which regulates the conditions and procedures for the registration and use of pesticides in the European Union, was taken into account. Chemicals for plant protection: Systemic fungicide "Kuproksat" (Active ingredient: Kuproksat; intended for control of fungal diseases on grapes (Israel)); Insecticide "Keltis" (Active ingredient: Lambda-cyhalothrin; intended for control of insect pests in vineyards (France)).

RESULTS

The AgriSpray 5000 sprayer and the DJI Agras T30 drone are innovative solutions for modern agriculture that focus on increasing the efficiency of crop processing and reducing the negative impact on the environment. The AgriSpray 5000 is a sprayer equipped with a GPS navigation and mapping system that ensures precise positioning and uniform coverage of the field, avoiding re-treatment and skipping parts of the field, which reduces pesticide consumption. The system automatically adjusts the spraying height and solution flow to ensure optimum plant coverage. It also includes pressure regulators and nozzles with variable droplet sizes for even applications. The precise distribution of pesticides reduces the total amount of pesticide used and minimises water and soil contamination. The intuitive automatic control system and mobile monitoring apps ensure ease of use.

The DJI Agras T30 is a drone equipped with an advanced automated control system that can be used to plan routes and spray with high accuracy. Sensors and mapping technologies ensure precise positioning and control of the spraying process. The DJI Agras T30 can cover up to 40 hectares on a single battery charge, which significantly reduces the need for manual labour. It can also be used to operate in hard-to-reach areas, increasing overall efficiency. By precisely managing pesticide and fertiliser consumption, the drone helps to avoid excessive amounts of solutions and reduces the likelihood of soil and water pollution. Both solutions provide significant benefits in crop production, particularly through high precision and automation, which reduces costs and minimises negative environmental impact. Table 1 illustrates a comparison of the costs of cultivating fields using the latest methods, showing that the use of drones can achieve significant cost savings due to their high productivity and accuracy.

Table 1. *Impact of new technologies on pesticide consumption*

Technology	Pesticide consumption before implementation	Pesticide consumption after implementation	Reduction (%)
AgriSpray 5000	100 litres/ha	70 litres/ha	30
DJI Agras T30	100 litres/ha	75 litres/ha	25

Source: *compiled by the authors*

The use of AgriSpray 5000 sprayers significantly reduced the number of diseased grape plants – by 40% (Table 2). This is the result of precise pesticide application using advanced solution distribution systems, which ensures uniform coverage of each plant and eliminates problems associated with uneven protection.

Table 2. *The number of diseased plants before and after applying the latest technologies*

Technology	Number of diseased plants before treatment (per 10 ha)	Number of diseased plants after treatment (per 10 ha)	Reducing the number of diseased plants
AgriSpray 5000	2,000	1,200	-40%
DJI Agras T30	2,000	1,300	-35%

Source: *compiled by the authors*

Among fungal diseases such as powdery mildew and grey rot, a significant reduction in their manifestations was observed due to precision spraying, which reduces the number of affected berries, which is important for maintaining crop quality. The reduction in the number of diseased plants has had a positive impact on the overall condition of the vineyards. The plants had healthier leaves, and less yellowing and stunting, which contributed to their normal growth and development. After the introduction of AgriSpray 5000, an increase in grape yields of 15% was noted. This is due to the increased health of grape plants and a reduction in the number of dead berries due to diseases, which leads to an increase in the number of productive shoots.

DJI Agras T30 drones demonstrated a significant reduction in the number of diseased plants by 35% due to the introduction of automated control and precise programming of processing routes. This state-of-the-art technology solution effectively covered even hard-to-reach areas of vineyards that are traditionally difficult to cultivate. Due to the high speed and accuracy of spraying, drones have been able to significantly reduce the occurrence of dangerous diseases such as oidium and mildew. This, in turn, led to a reduction in overall yield losses and improved berry quality, which is an important factor for growers. The introduction of drones for vineyard treatment not only had a positive impact on the overall condition of the plants, but also provided better and more even coverage of the pesticide, which significantly reduced the risk of disease, increasing plant viability and, consequently, their productivity. Thus, drone technology is becoming an integral part of modern agricultural production, contributing to the efficiency and quality of grape growing (Fig. 1).

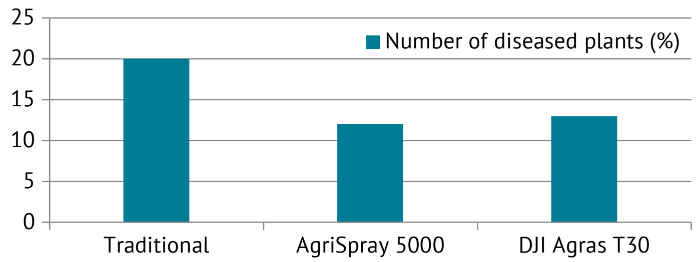

Figure 1. *Reducing the number of diseased plants using new systems*

Source: *compiled by the authors*

The cost analysis carried out as part of the study showed that the introduction of the latest vineyard cultivation technologies does indeed lead to a significant reduction in overall costs. In particular, the integration of the AgriSpray 5000 sprayer system in combination with DJI Agras T30 drones has reduced vineyard processing costs by an impressive 20% compared to traditional methods (Table 3).

Table 3. *Comparison of costs before and after implementing new methods*

Processing method	Total costs (thousand UAH/ha)	Difference (%)
Traditional	8	-
AgriSpray 5000	6.4	-20
DJI Agras T30	6.5	-18.75

Source: compiled by the authors

This positive result not only illustrates the reduction in pesticide costs but also indicates a reduction in labour costs, as process automation reduces the need for manual labour. The use of drones and modern sprayers has significantly reduced the time required to process vineyards, which has increased overall production efficiency. Thus, the introduction of these technologies is not only cost-effective but also helps to optimise agronomic processes in viticulture.

Traditional vineyard management methods used for many years often involved manual labour to apply pesticides and fertilisers. This process was not only labour-intensive but also required significant effort on the part of the workers, leading to fatigue and reduced efficiency. Manual application of pesticides was time-consuming, which increased the overall cost of vineyard management. The high labour costs in this situation were a serious challenge for growers, as they had to spend significant financial resources on hiring labour.

Manual application of pesticides did not always guarantee the accuracy and uniformity of the solution distribution. The conventional sprayers used in such cases were less accurate, resulting in uneven coverage of the plants. This caused pesticide overspending, as some areas were overtreated while others were left insufficiently protected. Such shortcomings required additional treatments, which further increased the costs and time required to care for the vineyards. As a result, traditional treatments were not only economically unprofitable but also less effective in ensuring vineyard health and productivity.

The AgriSpray 5000 sprayer has become an important tool for farmers as it ensures accurate and efficient application of pesticides. This has not only improved the quality of crop treatment but also reduced the cost of using chemical plant protection products. The high accuracy and uniform distribution of the solution led to a 30% reduction in pesticide costs. As a result, farmers were able to significantly optimise their costs while maintaining the effectiveness of their crops.

DJI Agras T30 drones, in turn, provided automated control and precise programming of processing routes, which significantly optimised field processing. This has reduced labour costs, as drones can perform tasks with high productivity without the need for many employees. Pesticide costs have also been reduced by 25% due to the high accuracy of processing and the ability to access hard-to-reach areas that previously required significant effort and resources to process.

The introduction of modern technologies, such as AgriSpray 5000 and DJI Agras T30, has allowed farmers to significantly reduce the cost of vineyard cultivation. This has a direct impact on reducing overall production costs, which, in turn, increases the competitiveness of products on the market. Thus, the use of these innovative solutions contributes not only to cost savings but also to the overall efficiency of agricultural production. This included savings on pesticides, reduced labour requirements and reduced processing time.

Experimental data obtained as a result of the research shows that the latest technologies introduced in viticulture have a significant positive impact on grape yields. In particular, the use of the innovative AgriSpray 5000 equipment has led to an impressive 15% increase in yields (Fig. 2). This demonstrates the effectiveness of this device in optimising crop processing, which in turn helps to improve the quality and quantity of the harvest.

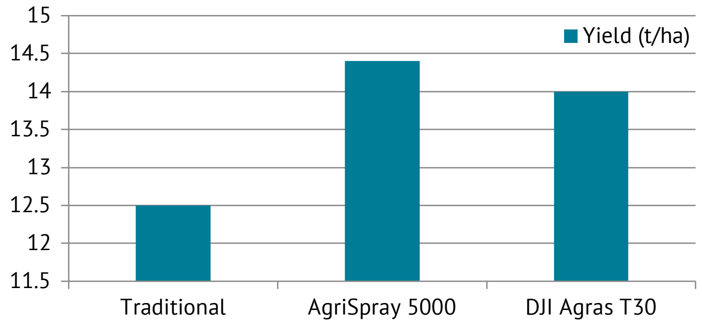

Figure 2. *Changes in grape yields by different cultivation methods*
Source: *compiled by the authors*

In addition, the use of drones for monitoring and processing vineyards also proved to be effective, as yields increased by 12%. The use of drones allows for high accuracy in the distribution of fertilisers and plant protection products, which significantly reduces losses and increases the overall productivity of vineyards. These results confirm that the integration of modern technologies into agriculture is an important step towards achieving sustainable development and increasing the efficiency of the agricultural sector (Table 4).

Table 4. *Influence of the latest technologies on the yield of different grape varieties*

Grape variety	Processing method	Yield before treatment	Yield after treatment	Difference (%)
Arcadia	AgriSpray 5000	80 t/ha	94 t/ha	+18%
	DJI Agras T30	80 t/ha	90 t/ha	+13%
Bianca	AgriSpray 5000	75 t/ha	85 t/ha	+14%
	DJI Agras T30	75 t/ha	82 t/ha	+10%
Perseus	AgriSpray 5000	70 t/ha	81 t/ha	+16%
	DJI Agras T30	70 t/ha	78 t/ha	+11%
Kishmish	AgriSpray 5000	85 t/ha	95 t/ha	+12%
	DJI Agras T30	85 t/ha	93 t/ha	+9%
Kobzar	AgriSpray 5000	90 t/ha	103 t/ha	+15%
	DJI Agras T30	90 t/ha	101 t/ha	+12%
Iskorka	AgriSpray 5000	78 t/ha	89 t/ha	+14%
	DJI Agras T30	78 t/ha	86 t/ha	+10%
Isabella	AgriSpray 5000	82 t/ha	95 t/ha	+16%
	DJI Agras T30	82 t/ha	91 t/ha	+11%
Aromatic	AgriSpray 5000	77 t/ha	87 t/ha	+13%
	DJI Agras T30	77 t/ha	84 t/ha	+9%

Source: *compiled by the authors*

The introduction of modern mechanised systems in the field of crop protection is an important step towards optimising agronomic processes, as it will significantly reduce the cost of crop processing. This, in turn, will increase the overall effectiveness of crop protection, which has been confirmed by numerous studies and practical trials. All the results obtained in the course of research show that new technologies not only reduce the cost of pesticide use but also significantly improve the condition of plants, which has a positive impact on their health and development. In addition, the introduction of such systems helps to increase yields, which is an important factor in ensuring food security. This confirms the validity of the hypothesis and demonstrates the high efficiency of the implemented mechanised systems, which can become the basis for further development of the agricultural sector. Based on the results obtained, which indicate the significant potential of new technologies, it is recommended to implement innovative solutions to reduce costs and increase the efficiency of vineyard processing. Among such technologies, it is worth highlighting the use of robotic sprayers and drones that can ensure the accuracy and speed of agronomic tasks, including spraying plants and monitoring the condition of the crop.

Farmers should account for the long-term economic benefits of investing in new technologies that not only reduce processing costs but also significantly increase labour productivity. Investing in automation and digitalisation of processes can lead to a significant reduction in labour costs, which is an important aspect in the current market environment. This helps to reduce the cost of crop protection products, as new technologies allow for more precise and efficient application of agrochemicals, which not only reduces costs but also has a positive impact on the environment. In addition, the introduction of modern technologies can significantly improve the quality of products, which undoubtedly opens new opportunities for sales and increased competitiveness in the market. Strategic investment in innovation can be a key success factor for farms in the future.

These results can serve as a basis for further research and practical application in the field of viticulture, contributing to the development of innovative approaches and increasing the competitiveness of Ukrainian winemakers in the international market. The introduction of new technologies will allow Ukrainian producers not only to maintain but also to increase their market share, responding to the growing demands of consumers for quality and environmental friendliness of products.

DISCUSSION

A detailed study of the resilience of European wine regions to climate change was conducted by S. Tscholl *et al.* (2024), who focused on the importance of adapting technologies to new, changing conditions. In their work, they emphasised that climate change can have a significant impact on wine production, so winemakers should take steps to adapt their technologies. The results of the current study support their conclusions, demonstrating that improved spraying technologies can be effectively adapted to increase the resilience of vineyards to the negative impacts of climate change, which in turn can contribute to the sustainability of wine production in the face of global warming.

S. Mehretie *et al.* (2024) developed an innovative ultrasonic sensor that allows predicting the quality of grape bunches at different stages of maturity. This approach is revolutionary in the field of grape quality assessment, as it provides more accurate data on the condition of the product. These findings support the current study, confirming that new technologies can significantly improve grape quality through more accurate monitoring, which in turn can increase the competitiveness of wineries in the market. A study conducted by J.Y. Park *et al*. (2023) focused on the impact of plant growth regulators and bunch thinning on the quality of Shine Muscat grapes. This study found that the use of mechanisation in agronomy can significantly contribute to the optimisation of plant processing, which in turn leads to an increase in grape quality. This emphasises the importance of using modern technologies in viticulture to achieve high standards of product quality.

The significant effect of growth regulators and bunch thinning on the overall productivity of grapes was investigated by S. Choi *et al*. (2023). The findings confirm that these factors are crucial for achieving optimal yield quality and quantity. The conclusions of this study indicate that the introduction of improved mechanisation in the cultivation processes can significantly improve control over product quality, which in turn contributes to the competitiveness of viticulture farms in the market. M. Li *et al*. (2024) assessed the current state of plant protection mechanisation technologies in China and identified an urgent need to improve these technologies to increase the efficiency of crop treatment. These results confirm the importance of innovation, as they demonstrate the positive impact of new technologies on reducing pesticide consumption, which in turn contributes to improved vineyard protection.

The introduction of agrochemical technologies in viticulture was studied by D.G. Bhalekar *et al*. (2024a), who emphasise the importance of the safety and efficiency of the spraying process. The results of their work also confirm the conclusions about the need to improve technologies to ensure not only high efficiency but also safety for the environment and human health. Research by O. Nefti *et al*. (2024) focused on the possibility of partial pesticide phase-out in viticulture. They found that the latest technologies being introduced into the industry could provide such an alternative. The findings support their conclusions, demonstrating that advanced spraying can reduce pesticide use without negatively impacting grape quality, which is an important consideration for producers and consumers. Thus, these studies highlight the importance of integrating new technologies into viticulture practices to achieve sustainable development in the agricultural sector.

A. Bjørnåvold *et al*. (2022) conducted an in-depth study analysing the reasons why France is not achieving its goals in reducing pesticide use. Scholars addressed the socio-economic bargaining power of farmers, which often becomes an obstacle to the implementation of new environmental practices. The findings indicate the positive impact of new technologies that can significantly reduce pesticide costs, which in turn can be useful in overcoming such problems in agriculture. This study emphasised the importance of integrating innovative technologies into the agricultural sector to achieve sustainable development.

The mechanical removal of leaves was studied by B. Hed & M. Centinari (2024), which is an important aspect of improving the control of bunch rot. This study confirms the basic idea that new technologies are effective in reducing pesticide use. The authors note that mechanical technologies not only increase the efficiency of plant processing but also significantly reduce the need for chemical plant protection products. This discovery is important for agronomists and farmers, as the introduction of such technologies can contribute to environmentally friendly agriculture and improve product quality. E. Fouillet *et al*. (2024) demonstrated that reducing the use of pesticides not only does not reduce yields but also does not affect labour intensity, which is an important aspect of the agricultural sector. The study also confirms that the introduction of improved technologies can significantly reduce pesticide costs without compromising overall crop productivity. This opens new opportunities for sustainable development of agricultural production, as reducing the chemical burden on the ecosystem is an important task.

The development of a combined effector for bunch removal was carried out by S. Sui *et al*. (2024), which also confirms the effectiveness of mechanical technologies in viticulture. This study demonstrates that the mechanisation of processes can significantly reduce the need for manual labour and increase the efficiency of vineyard processing. The introduction of such innovative solutions not only optimises work processes but also contributes to the economic efficiency of production, which is critical in today's competitive agricultural market. A. Le Roux (2024) addressed in detail the issue of improving equipment for spraying crops by recycling excess solution through modifying the airflow. The research provides strong evidence that the introduction of such innovations can significantly increase the efficiency of spraying processes, reducing the cost of crop protection products and improving their uniform distribution. This opens new opportunities for optimising agricultural production and increasing yields.

L.S. de Oliveira *et al*. (2024) focused on the use of aerial spraying for mildew control in vineyards using an unmanned aerial vehicle (UAV). The results of this work confirm that UAV technology can be extremely effective in the vineyard treatment process, ensuring the accuracy and speed of application of protective agents. This can reduce the risks associated with traditional spraying methods and increase overall viticulture productivity. F. Ahmad *et al*. (2020) also studied the effectiveness of using UAVs for spraying rice fields, finding a positive impact of such systems on the uniform distribution of the spray. The results show that UAV technologies can not only be effective in vineyards but can also be successfully applied in other agricultural sectors. This highlights the potential of drone technology to transform traditional agriculture by providing more efficient solutions for crop protection and agricultural resource management.

The water consumption and drift of fungicides used for mildew control in grapes were studied by B. Bajagić *et al*. (2022). This work provided important data that support the conclusions about the need to optimise pesticide and water consumption. This study emphasises the importance of rational use of resources in viticulture, which can significantly reduce costs and increase the effectiveness of plant disease control. F.K. Carvalho *et al*. (2020) studied the problems associated with the use of aircraft and drones for crop spraying. Their study analysed the technical and practical challenges that arise when using these modern technologies. The results confirm their findings regarding the difficulties faced by agronomists and farmers seeking to incorporate UAVs into their field operations and highlight the need for further improvements in these methods. C. Michael *et al*. (2022) evaluated the effectiveness of low-volume spraying in vineyards, which is consistent with the results of this paper. Their study demonstrates that the use of low-volume spraying technologies can significantly reduce the cost of pesticides, as well as reduce the risk of their negative impact on the environment. These results confirm the importance of introducing innovative vineyard management practices to increase productivity and sustainability.

The use of UAVs for crop spraying was studied by J.O. Silva Neto *et al*. (2021), focusing on their ability to reduce pesticide use and improve accuracy. Their findings support their conclusions about the effectiveness of unmanned technologies, indicating that the use of UAVs can not only reduce processing costs but also reduce the negative impact on the environment through more precise application of chemicals. G. Wang *et al*. (2020) investigated the effectiveness of low-volume pesticide application in rice fields, focusing on reducing water consumption and increasing yields. The results of the study support these findings, demonstrating a similar positive effect in vineyards, where the use of low-volume spraying leads to improved crop quality and reduced risk of plant diseases. D.G. Bhalekar *et al*. (2024b) optimised the configuration of spraying systems, focusing on improving fluid distribution mechanisms and reducing losses during treatment. These results support their findings that pneumatic spraying systems are more efficient than traditional methods, providing more uniform coverage of plants and increasing overall treatment efficiency. Overall, the results of the study confirm that the integration of new technologies into vineyard protection mechanisation can significantly increase efficiency and reduce pesticide consumption. They are also consistent with research showing the positive impact of new technologies on grape quality and processing efficiency.

CONCLUSIONS

The study confirmed the effectiveness of the introduction of AgriSpray 5000 sprayers and DJI Agras T30 drones in vineyards, which led to a reduction in pesticide consumption and an increase in yields. Specifically, the use of sprayers reduced pesticide consumption by 30% and increased yields by 15%. Drones, in turn, reduced costs by 25% and increased yields by 12%. Qualitative indicators include a 40% reduction in plant disease with sprayers and 35% with drones, indicating improved plant health and reduced disease. The results of research confirm that the introduction of modern viticulture technologies can significantly improve the efficiency of vineyard cultivation. This is achieved through process optimisation, which reduces pesticide costs and significantly increases yields. The use of innovative methods, such as precision farming, automation and plant health monitoring, opens new opportunities for agronomists. In addition, these technologies have a significant potential to reduce the negative impact on the environment, as the reduced use of chemicals helps to preserve ecosystems and improve soil quality. Thus, the integration of modern technologies not only increases the economic efficiency of production but also contributes to the sustainable development of the agricultural sector.

To further improve agricultural outcomes, especially in the context of drones and sprayers, there is a need to focus on improving the technologies that ensure their effectiveness. This includes improving the precision of pesticide application, which is critical to reducing pesticide losses to the environment and minimising negative impacts on beneficial organisms. It is necessary to adapt these technologies to different types of vegetation and specific climatic conditions to ensure optimal treatment results. Longer and more detailed field trials are also recommended to assess the long-term impacts of drone and sprayer use on soil quality and ecosystem integrity. This includes monitoring changes in biodiversity, vegetation and overall ecosystem health, which will help identify possible negative impacts and develop recommendations to avoid them. Thus, the integration of new technologies into agriculture should be accompanied by a comprehensive analysis and assessment of environmental aspects, which will ensure the sustainable development of the agricultural sector. Limitations of the study include the limited number of surveyed sites and the potential impact of unforeseen weather conditions that could affect the accuracy of the results.

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CONFLICT OF INTEREST

None.

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Анотація. Метою роботи було дослідити вплив сучасних технологій обробки виноградників на зменшення витрат пестицидів та підвищення врожайності. Під час дослідження оцінено ефективність використання обприскувачів «AgriSpray 5000» та дронів «DJI Agras T30» в агрономії, зокрема у виноградарстві. Методологія дослідження включала аналіз витрат пестицидів і врожайності винограду до і після впровадження зазначених технологій. Для цього було проведено порівняльний аналіз з традиційними методами обробки, зокрема вручну. Застосування обприскувачів «AgriSpray 5000» та дронів «DJI Agras T30» дозволило зменшити витрати пестицидів на 30 % і 25 % відповідно, завдяки точному розподілу розчинів і автоматизації обробки полів. Основні результати дослідження показали, що обприскувачі «AgriSpray 5000» зменшили кількість хворих виноградних рослин на 40 %, що привело до збільшення врожайності на 15 %. Водночас, дрони «DJI Agras T30» забезпечили зменшення кількості хворих рослин на 35 % і підвищили врожайність на 12 %. Інтеграція нових технологій дозволила зменшити загальні витрати на обробку виноградників на 20 %, зокрема завдяки зниженню витрат на пестициди та робочу силу. Висновки дослідження свідчать про те, що впровадження сучасних обприскувачів і дронів суттєво оптимізує процеси обробки виноградників, знижує витрати та підвищує їхню врожайність. Технології «AgriSpray 5000» і «DJIAgras T30» забезпечують високий рівень точності у застосуванні агрохімікатів, що має позитивний вплив на екологічну ситуацію та економічні результати. Результати підтверджують ефективність новітніх технологій як важливого інструмента для підвищення конкурентоспроможності виноградних господарств в Україні та покращення якості продукції

Ключові слова: пестициди; сталий розвиток; зрошення; рослинництво; сільське господарство; хвороби