Article citation info:
Szymczyk S., Legutko S., Szulc T., Zawada M., Nijak M., Szychta M. 2022. Innovative Solutions in Crop Protection Technology. *Journal of Research and Applications in Agricultural Engineering* 67 (1): 15-20. https://doi.org/10.53502/YEMI2804

Łukasiewicz Poznań Institute of Technology

Journal of Research and Applications in Agricultural Engineering

Journal website: https://tech-rol.eu/

Innovative Solutions in Crop Protection Technology

Sebastian Szymczyk[a,b] * (https://orcid.org/0000-0002-0081-3111)
Stanisław Legutko[a] (https://orcid.org/0000-0001-8973-5035)
Tomasz Szulc[b] (https://orcid.org/0000-0001-5554-3836)
Michał Zawada[a,b] (https://orcid.org/0000-0002-2552-5984)
Mateusz Nijak[b]
Marek Szychta[b,c] (https://orcid.org/0000-0002-7877-1898)

[a] Poznan University of Technology, Poznan, Poland
[b] Łukasiewicz Research Network – Poznań Institute of Technology, Poznan, Poland
[c] Poznań University of Life Science, Poznan, Poland

Article info
Received: 24 May 2022
Accepted: 28 June 2022
Published: 30 August 2022

Keywords
protection technology
agricultural sprayers
agricultural machinery

The article presents a collection of the most interesting innovative solutions and trends that have recently appeared in plant protection technology. Particular attention was paid to the solution improving the efficiency of spraying and the possibility of spraying the fields without the direct participation of the farmer. It describes, among others, a drone and a mobile robot adapted to automatic spraying of fields and systems improving the quality of spraying by analyzing the image from cameras or monitoring the parameters of the liquid in the sprayer.

DOI: 10.53502/YEMI2804

1. Introduction

The European Union established a framework for joint action to achieve the sustainable use of pesticides in agricultural production in Directive 2009/128/EC. This was related, inter alia, to the abuse of, often unjustified, chemical plant protection products, which resulted in the emergence of new resistant pests and endangered the health of consumers in the case of pesticide residues in crops. As a result, Poland introduced the obligation to apply the principles of integrated pest management, i.e. a new approach to control pests [1-3].

Among agricultural machines, there must also be changes to adapt them to EU guidelines related to the sustainable use of plant protection products. Machine manufacturers in plant protection technology and research institutions are looking for new solutions to improve the effectiveness of pesticide coverage of plants with less consumption. This article is a collection of the most interesting solutions to improve the application of plant protection products that have recently appeared on global markets. The authors note a certain trend in plant protection technology related to the installation of a greater number of sensors and cameras to collect and analyse data, which contributes to the elimination of application errors or reducing the number of agents used.

* Corresponding author: sebastian.szymczyk@pit.lukasiewicz.gov.pl

The main criterion for selecting the described machines was the need to have by the manufacturers their commercial versions available and possible to use in the care of crops. Thus, the presented technologies have passed various stages of tests related to commercialization and are verified technologies. Another evaluation indicator was the fact that it stand out from the current spraying technologies and was compatible with the main ideas of precision farming with the elements of agriculture 4.0. The described solutions are a response to the challenges of modern agriculture and relate to solving staffing problems on farms and developing more ecological methods of cultivating crops as a consequence of the growing awareness of consumers of the produced food. This is directly related to the limitation of the amount of used pesticides. The machines mentioned in the article refer to this criterion.

2. Real-time monitoring of sprayer parameters

Changing weather conditions, such as wind direction and velocity, are one of the reasons for the deterioration of the quality of plant cover during spraying – a phenomenon known as plant protection agent drift. One of the countermeasures is to lower the boom towards the plants, which makes it necessary to increase the number of nozzles on the sprayer boom. Intelligent Ag has found that with the growing number of nozzles it is difficult for the farmer to visually inspect them, and with the use of low-flow nozzles, it is an additional difficulty to determine whether the pressure and flow are correct for each nozzle. When using, for example, herbicides, it is necessary to precisely and evenly covers the entire field so that the treatment is as effective as possible, and this is associated with the correct maintenance of the set pressure and flow throughout the treatment. Pressure drops in the sprayer supply lines may cause incorrect dosing and, consequently, the survival of weeds and their re-expansion [4–5].

The solution to the problem presented above is the Recon SpraysenseTM product by Intelligent Ag, which increases the level of control of the nozzles by the farmer. The Recon SpraysenseTM is a specially designed flow and pressure sensor mounted upstream of each sprayer. The collected data from the sensor goes to the application on the tablet, where it is analyzed and displayed. During spraying, the farmer can control parameters such as flow velocity, pressure, and droplet size in real-time. Deviations from the norm are properly signalled. The view of the application and the sensor is shown in the photo below (Fig. 1). The application has a preloaded database of over 1100 nozzles. The product is compatible even with standard electronic valves [6, 7].

The advantage of the product shown above in plant protection technology is the greater control of the user over each sprayer, thanks to which the spraying can be more even. However, the disadvantages of such a solution certainly include the cost that should be incurred when equipping the sprayer with flow sensors.

Fig. 1. Recon SpraySense by Intelligent AG – view of real work with reading from the tablet[8]

3. The use of drones in plant protection technology

Drones are increasingly used in a precision farming systems – in particular, they act as devices for collecting data on yields, which are later used for field mapping. Data is collected by flying with cameras mounted over the cultivated field. Thanks to such readings, it is possible to create application maps, i.e. maps of the dose variation, e.g. of fertilizer, in different parts of the field. However, this requires appropriate analysis of the recorded image in dedicated programs. The creation of a separate group of these devices for spraying is also noticeable. The market for unmanned aerial vehicles used in agriculture is growing every year, and drone manufacturers are outdoing each other in designing new models and looking for industries in which they can be used. Unmanned aerial vehicles have become well-established in the field of agriculture, i.e. precision agriculture [9–12].

In 2021, DJI presented drones that, according to precision agriculture, can properly use application maps when spraying on farmlands. It presented two new models, the Agras T10 and the Agras T30. The rest of the article focuses on the largest Agras T30 model (Fig. 2). The drone is made mainly of carbon fiber elements, which ensures a relatively low weight while meeting the requirements of strength and stiffness. The design allows the drone to be folded and its dimensions reduced by 80%, which facilitates transport between fields. The electronics inside are closed in a sealed casing with IP67 protection. The control is possible manually using a dedicated remote control with a display or via the DJI Agriculture application, where it is possible to plan the route of the flight over the field fully automatically using GPS (Global Positioning System) + RTK (Real-Time Kinematic) positioning, which ensures positioning accuracy at the level of ± 10 cm. In addition, the drone is equipped with an omnidirectional radar to detect obstacles on the flight path and illuminators for night treatments [13].

The Agras T30 has two main services where it can use precision farming application maps. The first is the possibility of spraying plants with 16 nozzles mounted around the drone, which allow spraying up to 9 m wide. The maximum efficiency that can be obtained during spraying is, according to the manufacturer, theoretically even 16 ha·h-1. The nozzles are fed from a 30-liter tank mounted in the central part of the drone. The second service that the drone can provide is the spreading option, which can be activated within approx. 3 minutes. According to the manufacturer, it allows for spreading seeds and fertilizers with a range of up to 7 m and a theoretical efficiency of up to 1000 kg·h-1. The coverage area during the treatment is up to 28 ha·h-1 [13].

The advantage of the above-mentioned product in plant protection technology is the possibility of spraying from the air, especially in hard-to-reach or mountainous fields. Thanks to the possibility of spraying or fertilizing with the use of application maps, it allows to save material and thus maximize profits. An additional advantage is the lack of soil compaction, as in the case of using conventional sprayers. The wind generated by the drone's propellers can positively affect the quality of the plant protection treatment. The disadvantages include the cost of the purchase, which, according to dilectro.pl, can be up to PLN 110,000.00 (in words: one hundred ten thousand Polish zlotys). Additionally, a small tank and a small battery require frequent intervention by the operator.

Fig. 2. DJI Agras T30 drone during spraying [13]

4. Agriculture robot with a sprayer

The agricultural robot's market is developing significantly, which is confirmed by the report prepared by the BIS Research organization. It projects an increase from $ 1.9 billion in 2019 to $ 7.7 billion in 2025 in the agricultural robot's market. Manufacturers are arming them with more and more tools, replacing classic machines. It is no different in the case of plant protection technology. There are solutions on the market that allow for autonomous spraying of fields. One example of such a solution is the SwarmFarm robot [14].

The SwarmFarm robot in Juliet version (Fig. 3) performs herbicide spraying automatically. It moves along a designated route using GPS navigation, in the event of going beyond the designated area, the robot will turn off the drives thanks to the installed geo-blockade. When programming the robot's route, it is possible to mark permanent obstacles, thanks to which the route will be planned in such a way as to avoid a collision. In addition, the robot is equipped with a 3D camera that detects obstacles and allows to analyse the shape of the terrain, e.g., hills, to react in the event of unexpected restrictions. Other elements ensuring the safety of the robot are bumpers, which disengage the drive under pressure, causing the vehicle to stop immediately. The robot is powered by a diesel engine with a 60-liter fuel tank, which is enough for 18 hours of operation.

The Julia robot in the tool part is equipped with an 8-meter beam with 40 spraying nozzles evenly distributed. The nozzles are supplied from a 600-liter tank, the filling level of which is controlled, and in the absence of refrigerant, the robot goes to the docking station to refill the liquid. To reduce the number of pesticides used, the robot is equipped with WEEDIT cameras that scan a 1-meter-wide strip, locating weeds and activating the appropriate nozzle directly above them - selective spraying. The velocity of the robot depends on the level of weed infestation in the field, and in the event of high weed infestation, the SwarmHive robot management software can allocate an additional robot to assist. SwarmHive monitors the weather conditions in the field thanks to cooperation with local weather stations, in the event of exceeding the values necessary for safe spraying, the robot can be turned off until the atmospheric conditions improve. Additionally, SwarmHive can record field conditions in real-time. The operator can control and monitor the robot using an iPad [15–18].

One of the greatest advantages of using robots is that farmer do not need to be actively involved in the spraying process. The advantages also include the possibility of continuous spraying with breaks for refilling the tanks. The disadvantages of autonomous spraying systems include the low availability of these devices, the price, and the high technical advancement of the machines, which make servicing and operation difficult for farmers.

Fig. 3. SwarmFarm Julia field robot with mounted sprayer [17]

5. Vision systems in sprayers

The "From farm to fork" strategy adopted by the European Commission envisages reducing the number of pesticides used by 50% by 2030. Limiting the use of plant protection products or a more radical cessation of their use may have a negative impact on the size and quality of the crop, which will have negative economic effects on farms. One of the solutions is to use new application technologies so that it occurs selectively in places where it is required while maintaining the recommended dose. The cooperation of three industry giants: Amazon, Bosch, and BASF Digital Farming contributed to the creation of the modern UX 5201 Smart Sprayer (Fig. 4) [19].

The machine was created based on a trailed sprayer by Amazone, to which Bosch cameras were mounted. The image from the cameras is transferred in real-time to BASF components, where it is saved, and actions are taken in accordance with the application strategy and economic threshold. The main task of the entire system is to recognize and locate the weed for herbicide application. The recognition process itself takes milliseconds, which enables effective application even at speeds of up to 12 km·h^{-1}. The process of accurate application is possible thanks to the use of nozzles with a spacing of 25 cm and dose control using the PWM signal. The sprayer beam is additionally equipped with active LED lighting, which ensures appropriate working conditions at night and reduces the formation of shadows on sunny days [20–22].

The advantage of using cameras along with image analysis is a significant reduction in the use of herbicides in the case of weed detection and spot application in relation to the overall spraying of the field. The disadvantages include, unfortunately, the high purchase price of a sprayer equipped with cameras compared to an ordinary sprayer.

Fig. 4. Amazone sprayer with Bosch cameras and BASF software [22]

6. Conclusion

Plant protection is an indispensable element in modern agricultural production. The growing prices of chemicals needed for spraying and the restrictions introduced by the European Union on the use of plant protection products have resulted in the development of new techniques for selective and precise spraying. The aim is to dose as precisely as possible in the minimum amounts of agents used in places where it is required while maintaining effectiveness. In addition, there is a visible trend in the development of drones and autonomous robots that require farmers only to supervise the work. It is also a response to the increasingly noticeable problem of the shortage of skilled workers on farms.

The presented machines are an indication for the reader in which direction the plant protection technology is developing. The presented machines, due to the high precision requirements and the use of modern sensors, are characterized by a high price, making them less accessible to small and medium-sized farms. Further development of the techniques of selective application of plant protection products, adapted to the needs of smaller farms representing a large market share, should be expected. Table 1 summarizes the innovations described in the article.

Tab. 1. Table of innovations contained in the article

No.	Company	Product	Description
1.	Intelligent Ag	Recon SpraysenseTM	Real-time monitoring of sprayer parameters
2.	DJI	Agras T30	Spray drone
3.	SwarmFarm	Juliet	Spraying robot
4.	Amazon, Bosch, and BASF Digital Farming	Smart Sprayer	Vision systems in sprayers

Acknowledgements

The article was created as part of the implementation of the Implementation Doctorate program of the Ministry of Education and Science in the years 2022–2026 (Agreement No. DWD/5/0016/2021).

References

[1] Mucha S. 2021. Integrowana ochrona roślin. Ministerstwo Rolnictwa i Rozwoju Wsi. https://www.gov.pl/web/rolnictwo/integrowana-ochrona-roslin

[2] DYREKTYWA PARLAMENTU EUROPEJSKIEGO I RADY 2009/128/WE z dnia 21 października 2009 r. ustanawiająca ramy wspólnotowego działania na rzecz zrównoważonego stosowania pestycydów. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:309:0071:0086:pl:PDF

[3] Korbas M., Mrówczyński M., Węgorek P., Kierzek R., Tratwal A., Danielewicz J., Roik K. 2022. *Kodeks dobrej praktyki ochrony roślin*. Poznań.

[4] Wiadomości Rolnicze Polska: Zwiększyć skuteczność oprysku, 2020. https://wrp.pl/zwiekszyc-skutecznosc-oprysku/

[5] Press Release: Intelligent Ag Launches Recon Spraysense™, 2021. https://intelligentag.com/press-release-intelligent-ag-launches-recon-spraysense/
[6] Claver H. 2021. Monitoring real-time flow and pressure of spray nozzles. Future Farming. https://www.futurefarming.com/crop-solutions/weed-pest-control/monitoring-real-time-flow-and-pressure-of-spray-nozzles/
[7] Intelligent Ag Launches Recon Spraysense™ Vital Technology for Sprayers, 2021. https://www.prnewswire.com/news-releases/intelligent-ag-launches-recon-spraysense-301408071.html
[8] Recon SpraySense firmy Intelligent AG. https://intelligentag.com/spraysense/
[9] Kwestarz P. 2021. Rynek bezzałogowych statków powietrznych, czyli dronów, ma przed sobą dobre perspektywy, a rozwojowi sprzyja normalizacja przepisów. *Strefa Inwestorów*. https://strefainwestorow.pl/artykuly/analizy/20210906/rynek-dronow-na-swiecie
[10] Berner B. 2016. Wykorzystanie dronów w rolnictwie precyzyjnym. *Technika Rolnicza Ogrodnicza Leśna* 3: 19-21.
[11] Mogili U., Deepak B. 2018. Review on Application of Drone Systems in Precision Agriculture. *Procedia Computer Science* 133: 502-509.
[12] Meola A. 2021. Precision agriculture in 2021: The future of farming is using drones and sensors for efficient mapping and spraying. *Businness Insider.* https://www.businessinsider.com/agricultural-drones-precision-mapping-spraying?IR=T
[13] https://www.dji.com/pl/t30
[14] https://www.dllgroup.com/en/blogs/blogsoverview/The-High-Tech-Revolution-in-Agriculture-Trends-in-Robotics
[15] Leggatt J. 2017. SwarmFarm: Exciting times in agriculture for robotic company. *The Weekly Times*. https://www.weeklytimesnow.com.au/machine/crop-gear/swarmfarm-exciting-times-in-agriculture-for-robotic-company/news-story/8f5872d26de9852b202f2f1784679aea
[16] Cindy B. 2017. SwarmFarm: Targeting small weeds all year. *Weed Smart.* https://www.weedsmart.org.au/content/swarmfarm-targeting-small-weeds-all-year/
[17] https://www.swarmfarm.com/
[18] Regional entrepreneur reinventing agriculture with robotic innovation. Queensland Goverment, 2020. https://advance.qld.gov.au/whats-happening/stories-about-innovation/regional-entrepreneur-reinventing-agricul-ture-robotic-innovation
[19] https://www.consilium.europa.eu/pl/policies/from-farm-to-fork/
[20] https://www.bosch.com/research/know-how/success-stories/smart-spraying-precision-herbicide-application-on-weeds/
[21] https://amazone.net/en/service-support/for-the-press/press-releases/press-review-2019/smartsprayer-joint-project-45720
[22] Justin R. 2021. Amazone, Bosche and BASF reduce herbicide use by 90% with new sprayer technology. *Agriland.* https://www.agriland.co.uk/farming-news/amazone-bosche-and-basf-reduce-herbicide-use-by-90-with-new-sprayer-technology/