[1.]Remus Marius OPRESCU, [1.]Florin NENCIU, [1.]Iulian VOICEA, [1.]Dan CUJBESCU,
[1.]Cătălin PERSU, [2.]Maria–Diana BĂRCAN, [3.]Nino MARICA

EMERGING AGRICULTURAL EQUIPMENT USING ARTIFICIAL INTELLIGENCE AND SPECTROSCOPY FOR THE AGRICULTURAL SYSTEMS OF THE FUTURE

[1.]INMA Bucharest / ROMANIA;
[2.]Agricultural Research – Development Station Secuieni / ROMANIA;
[3.]Research and Development Station for Fisheries Nucet / ROMANIA

Abstract: Ecological agriculture advocates for sustainable, diversified, and harmonious production systems to mitigate crop and environmental contamination. Ecological plant cultivation, which abstains from the use of harmful conventional substances, has been a prominent focus in economically advanced nations for many decades. Ecological agriculture emerged as a counterbalance to intensive, conventional (industrialized) farming practices that prioritize maximizing output by employing large quantities of fertilizers and energy–intensive production enhancers, all aimed at sustaining agricultural production for a continuously expanding, mainly urban population. Agricultural robots have emerged as a response to farmers' needs for automating repetitive, time–consuming tasks, enabling them to focus on improving production quality and increasing yields. While we commonly refer to them as robots, these devices come in various forms with varying degrees of mobility. They include unmanned aerial vehicles (UAVs) or drones, milking robots, automatic harvesting systems, autonomous tractors, unmanned ground vehicles (UGVs) used in nurseries or greenhouses, sorting and packing robots, and weed control systems. The paper explores various equipment employed for mechanical weed control in ecological agriculture.
Keywords: agricultural production, emerging agricultural robots, weed control, organic farming

INTRODUCTION

Considering the rapid growth of the population, modern agriculture used excessive mechanization and chemical products, and the consequences were the degradation and pollution of the soil, as well as a low quality of food (tasteless food, health risks). In this context, it is necessary to find innovative solutions for the following needs: maintaining a high yield, creating healthier productions and environmentally friendly crops and capitalizing on local agricultural land (*Vladut et al., 2023*).

Sustainable agriculture must not only address environmental concerns but also ensure profitability for its longevity. One key approach to achieving this is cost reduction. Farmers can work towards cost reduction by enhancing the efficiency of farming techniques.

Agricultural robots have emerged as a response to farmers' needs for automating repetitive, time–consuming tasks, enabling them to focus on improving production quality and increasing yields. While we commonly refer to them as robots, these devices come in various forms with varying degrees of mobility. They include unmanned aerial vehicles (UAVs) or drones, milking robots, automatic harvesting systems, autonomous tractors, unmanned ground vehicles (UGVs) used in nurseries or greenhouses, sorting and packing robots, and weed control systems. At present, milking robots and drones dominate this market, but other intelligent systems are poised to take the lead in the near future.

Weeds are among the major causes of crop yield loss, compared to any other categories of agricultural pests (*Tillett et al. 2022*). They are also responsible for a large part of the production costs. Weed control in an environmentally safe practice, that is often considered a challenge, and can be achieved by several means, of which cultural and mechanical methods are the most common, since easily accessible to smallholder farmers. However, these methods have proven to be expensive as they are laborious and time intensive operations and are also risk exposing the soil to erosion and damaging.

In contemporary agricultural production, chemical herbicides continue to hold a significant role in weed management (*Home et al. 2022*) due to their higher effectiveness. However, their usage often raises concerns related to public health, environmental pollution, and the emergence of herbicide–resistant weed species. Future strategies for weed management should seek innovative solutions to minimize the environmental and toxicological impacts associated with these systems and address the development of herbicide–resistant weed species (*Astrand et al. 2022*).

Mechanical weed control, one of the oldest weed management methods, involves the physical removal of weeds using mechanical equipment before or during the crop's growing season. Effective management of tillage practices plays a crucial role in mechanical weed control. The choice of various tillage systems can significantly influence the competitive dynamics between crops and weeds (*Slaughter et al. 2022; Nenciu et al. 2022; Mircea et al. 2020*).

Agriculture around the world, faces many challenges both presently and, even more significantly, in the future: limited natural resources, including non–renewable energy sources (oil, natural gas, coal) with rising prices for them· worsening economic conditions for the activities of farmers due to the unfair increase in the prices of industrial inputs and agricultural products· ensuring food security at the local, regional and global level in the conditions of a higher population density· biodiversity loss, including genetic loss both on the soil surface and, especially, in soil (*Chen et al. 2022*).

In recent years, organic agriculture has gained attention not only from researchers but also from the broader community, encompassing consumers and farmers. This interdisciplinary field, influenced by agriculture and environmental conservation, has evolved its own terminology, resulting in the development of a distinct language.

Ecological agriculture embodies a farming system dedicated to the preservation and improvement of productive ecological systems, without resorting to synthetic chemicals. This approach amalgamates traditional knowledge with scientific progress across diverse agronomic domains. A fundamental objective of ecological agriculture is the protection of the biosphere and the planet's resources.

The principles of ecological agriculture are based on the maximum utilization of local resources and the minimization of economic and ecological risks. Organic agriculture is not a "do–nothing" type of agriculture, without fertilization and without treatments. The ecological production method differs from the conventional one in that it avoids the use of chemical fertilizers and pesticides. The fundamental rule of organic farming is that natural inputs are allowed while synthetic ones are prohibited (*https://www.industrialautomationindia.in/*).

Conventional agriculture has determined the decrease in the content of organic matter in the soil and the accumulation of toxic compounds. In ecological practice, soil fertility and health are maintained by biological methods, such as: crop rotation, manual work, weeding, composting, mulching. Using organic fertilizers increases and maintains the percentage of soil organic matter (*Mariș et al. 2022*).

Starting from these realities, obtaining raw material and quality processing products, unpolluted – without the use of genetically modified organisms, the use of synthetic fertilizers and pesticides, stimulators and growth regulators, hormones, antibiotics and intensive animal breeding systems becomes current. (*Dewi et al. 2022*).

The growing population, which imposes ever–increasing demands on food production, together with the scarcity and high cost of labour in agriculture, leads to the demand for robots in agriculture (*Bakker et al. 2011; Fennimore et al. 2019*). Developed countries have long used mechanization in agriculture as the number of people involved in the sector has declined in recent decades. Experts have categorized the most common applications for robotics in agriculture based on five key activities: Crop Seeding, Fertilizing and Irrigation, Thinning and Pruning, Weeding and Spraying, and Picking and Harvesting (*Chisnicean et al. 2019; Griepentrog et al. 2010; Ghergan et al. 2019*). In addition to being labor intensive, these are time–constrained activities and need precision and accuracy to be truly effective. Another important function of agricultural robots is to collect data to monitor various parameters like soil, crop growth, infections, etc.

Modern robots are operated through a computer system equipped with the robot's operating system and essential software components required for automated task execution. Control can be done remotely or via portable control consoles, connected by cables to the robot and the control computer (*Rai et al. 2021*).

These robots feature mechanical parts, robot arms, vision cameras, sensing technology and artificial intelligence to improve crop production by minimizing the use of arable land. Several of these robots are equipped with 3D cameras that scan modules placed in front of them and collect information to perform specific operations further. These robots can be largely classified as semi–autonomous and fully autonomous robots. Fully autonomous robots use artificial intelligence and sensors to calculate how to raise plants without disturbing nearby crops. As with other industry segments, the major factor driving the agricultural robot market is the need to increase production and reduce costs at the same time.

These robots reduce the need for human labor and are much more efficient, able to work around the clock. In addition to being effective, they are also precise and thus help avoid the harmful effects of chemicals by pinpointing the correct dose at the exact place where it is needed, eliminating wastage as well as contamination.

Just because the technology is available, it is not necessarily implementable. One of the main causes of the technology's limited use is affordability and the ever–present ROI or ROI equation. Like mechanization, robotics require huge investment, which puts them out of reach for small farmers. It is about size and scale, and the benefits only come with the ability to invest in such high technology (*https://www.futurefarming.com/*).

MATERIAL AND METHOD

Since the 1960s, several automatic plant thinning systems have been marketed. Weeds can be cut or pulled from the ground with the help of a mechanical actuator (*Bakker, 2009b. In 2002, Astrand and Baerveldt*) (*Astrand et al., 2002*) presented a rotary hoe for weed removal. The weeder was attached to a robot used to control weeds in sugar beet crops. Home et al. (2002), from Cranfield University in England, conducted a study on precision positioning of weeding tools using artificial vision (Figure1).

Figure 1 – Grain weeder, guided by artificial vision (Klose et al. 2008)

The guided weeder is fitted with hydraulic paddles designed for mechanical weed control. These paddles can be rotated around the vertical axis (see Figure 2). Each blade has a specific design that enables the tool to navigate around cultivated plants without causing harm or destruction to them (*Tillett, 2007*).

Figure 2 – Rotary disc provided with a section to protect cultivated plants *(https://optics.org/news/12/3/52)*

Cycloidal harrow for mechanical weed control inside crop rows (*Ruckelshausen, et al., 2006*). The cycloidal sweeper in Figure 3 was built at the University of Osnabrück, Germany.

Figure 3 – "Querhacke" cycloidal harrow designed at the University of Osnabrück, Germany *(Gruľová et al. 2020)*

The Lukas robot (Figure4) was designed at Halmstad University in Sweden. Lukas is a mobile robot for agriculture, used for mechanical weed control on agricultural land. The robot is equipped with two visual systems. The first system works based on gray levels, and is used to recognize crop rows and guide the robot along the row. The second system, based on color vision, is able to identify crop plants among weeds. The second visual system controls a crop row weeding tool.

Figure 4 – Autonomous weed–fighting robot designed at Halmstad University

The API robot (Figure 5N) was designed at Aalborg University in Denmark. The first studies began in 2000, at the initiative of the Danish Institute for Agriculture. The API robot is used in plant mapping and selective herbicide applications.

Figure 5 – Autonomous weed control robot designed at the Danish Institute of Agricultural Sciences, Denmark *(https://optics.org/news/12/3/52)*

Another agricultural robot prototype was designed at Wageningen University in the Netherlands (Figure 6). The robot allows the investigation of a wide spectrum of research options regarding the detection of weeds and the actuation of the actuator used to remove them. The robot has implemented an autonomous navigation system based on RTK–DGPS (Real Time Kinematic Differential Global Positioning System) which, in combination with a visual system, allows the mapping of crop rows (*Bakker, 2011*).

Figure 6 – Autonomous weed–fighting robot designed at Wageningen University, Netherlands *(Boris et al. 2022)*

Figure 7 – Autonomous robot for protecting agricultural crops designed at the University of Aarhus, Denmark *(Gruľová et al. 2020)*

The autonomous robot HortiBot (Figure 7) was developed at Aarhus University in Denmark for use in agricultural applications. It is equipped with a camera that allows navigation by following the rows of crops. In areas without rows, the robot is positioned by an RTK–GPS system. The herbicide spraying system is equipped with a set of video cameras that take images of the soil surface. The images are analyzed to detect weeds. When one or more weeds are detected in the image, information about their location is saved (*Griepentrog et al., 2010*).

The Weedy robot (Figure 8) was developed at Osnabrück University in Germany for use in weed control applications. The robot is a mechatronic system based on sensory fusion, for selective weed control.

Figure 8 – Autonomous weed control robot "Weedy" designed at the University of Osnabrück, Germany *(Macrii et al. 2022)*

The BoniRob robot (Figure 9) was developed at Osnabrück University in Germany, in collaboration with Amazone and Bosch. In 2009, Ruckelshausen et al. (2009) published a paper on the BoniRob autonomous robot (*Ruckelshausen, 2009*).

Figure 9 – Autonomous robot for agriculture designed at the University of Osnabrück in collaboration with Amazone and Bosch *(Tilneac et al. 2012)*

FarmWise's new weeding tool, the Vulcan, debuted at World Ag Expo 2023 and was included in the top 10 new products. Thanks to computer vision and deep learning models, Vulcan can differentiate, identify plants and remove surrounding weeds with high precision. The objective of this machine is to reduce manual weeding costs for more than 20 different vegetable crops, especially in organic farms where herbicides are prohibited.

Figure 10 – The Vulcan advanced weeding tool
https://newatlas.com/good–thinking/farmwise–vulcan–automatic–weed–pulling/

Ecorobotix is revolutionizing agriculture with its ARA ultra–high precision sprayer. ARA uses cameras and artificial intelligence to identify individual plants (both crops and weeds) in real time and provide ultra–precise crop treatment to an accuracy of 6x6cm, treating only weeds without spraying surrounding crops or soil, allowing for precise herbicide application, insecticides and fungicides plant by plant.

Ecorobotix was founded to radically change agriculture for the better, respecting the environment and reducing the use of chemicals, the impact on the soil, the use of water and energy. Ecorobotix offers a revolutionary plant–by–plant data solution and ultra–high precision crop treatment that reduces the use of chemicals (herbicides, pesticides, liquid fertilizers) by 70–95%, while increasing crop yields by ~5% and massively reducing the CO2 footprint.

Figure 11 – ARA – EcoRobotix's plant sprayer that uses artificial intelligence, computer vision and computer systems to detect and selectively spray weeds with a micro–dose of herbicide | © Ecorobotix *(https://optics.org/news/12/3/52)*

Weeding tools are upgraded to self–thinking smart tools with cameras and AI. Especially for arable crops, gardening and vegetables, but not only. Pasture weeds such as dandelions, docks and thistles are also targeted with algorithms. – Photo: René Koerhuis

For several years now, there has been a clear trend when it comes to weeding tools. These are upgraded with cameras and AI to smart tools that think for themselves, with parts, teeth, spray nozzles and even lasers. The availability of sophisticated cameras at affordable prices has led to an enormous uptake of AI–powered desert tools. Especially in relation to autonomous rovers and field robots.

The Dutch company Andela Techniek & Innovation is developing a machine for robotic weed removal, and the One prototype – the 12–row ARW–912 – is running on an organic carrot and onion farm in the Netherlands. The weeding robot was specially developed for removing weeds from the row. The Andela Robot Weeder (ARW–912) has 12 weeding units for rows at a maximum distance of 75 centimeters.

The width of the all–aluminium vehicle is 9 meters long with a caterpillar undercarriage on a 3–meter track width and a single wheel at the front. RTK GPS ensures that the weeding robot stays on course.

The electric power for the propulsion of the machine, for the computing unit and for the control and weeding system comes entirely from solar panels mounted on the roof. There are a total of 43 electric motors on the ARW–912.

Figure 12 – The autonomous weeding robot is 9 meters wide and has 12 weeding units. On the roof are solar panels for electric motors.

The CEOL field robot is an inter–row crawler developed in Toulouse by the company Agreenculture. It can work several hectares per day completely autonomously thanks to its GPS RTK and the rear tool holder allows it to tow different implements.

Figure 13 – The CEOL field robot

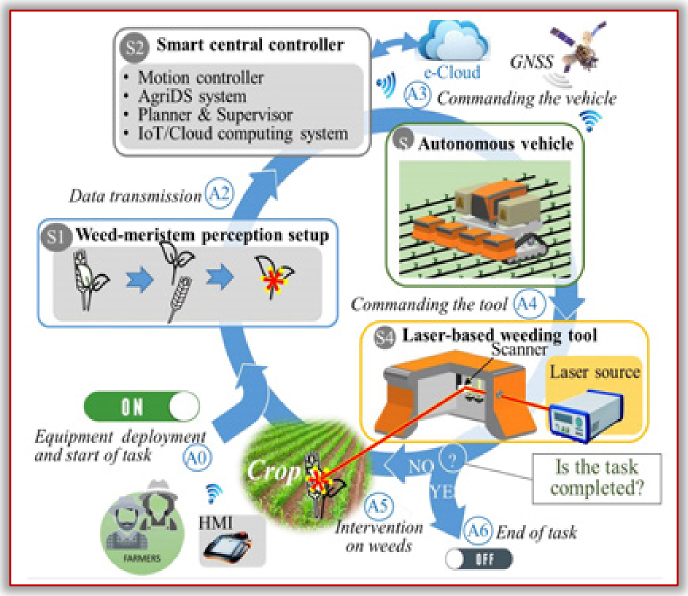

Figure 14 – WeLASER autonomous weed controlling system with lasers

The WeLASER solution is focused on non–chemical weed control. The idea behind it is to damage the growth center of the weed with high energy blasts from a high–powered laser beam source.

Scientists from Laser Zentrum Hannover (LZH) are developing an image processing system that uses artificial intelligence to distinguish crops from weeds. They also teach the system to recognize the position of the weed meristem (plant growth center). Target coordinates are used at LZH to control a robust multi–row scanning system so that the laser beam is directed to destroy the weed.

For field use, the systems will be installed on an autonomous vehicle. These will then be coordinated through an intelligent controller that uses the Internet of Things (IOT) and cloud computing techniques to manage and implement agricultural data.

LZH also develops concepts for ensuring laser safety for all involved, such as farmers and machine operators. The partners want to test the prototype on sugar beet, corn and winter grain crops. The prototype should be available by 2023 and then further developed for commercialization.

Dahlia Robotics' vision is to eliminate the need for herbicides in agriculture and make organic food production the standard.

A robot that drives autonomously in the field, recognizes weeds in crops and mechanically removes weeds. Guided by artificial intelligence, the robot controls an internal weeding system while avoiding accidental damage to crop plants. A mechanical end effector removes the weed plants.

Figure 15 – Dahlia Robotics weeding system

The robots named Tom, Dick and Harry, were developed by the Small Robot Company to rid the field of ingrown weeds with minimal use of chemicals and heavy machinery.

Figure 16 – Modern agricultural systems named Tom, Dick and Harry, developed by the Small Robot Company

The technology can scan 20 hectares a day, collecting data that is then used by Dick, a "crop care" robot, to destroy weeds. Then it's Harry robot turn to plant seeds in the weed–free soil.

The company has been working on its autonomous weed killers since 2017, and in April this year launched Tom, its first commercial robot, which is now operational on three UK farms. The other robots are still in the prototype stage, being tested.

Scott–Robinson says the company hopes to launch its full robot system by 2023, which will be offered as a service at a rate of around £400 per hectare. The monitoring robot is first placed on a farm, and the weeding and seeding robots are only delivered when the data shows they are needed. To develop the zapping technology, Small Robot Company has partnered with another UK start–up, RootWave (*Bakker et al. 2011*).

Figure 17 – Naio OZ robot design

The Naio OZ robot can perform a wide variety of operations by itself, such as weeding, or seeding. Additional advantages of the OZ robot include its constant availability and lack of fatigue, its ability to work for 8 hours on a single charge (covering 1 hectare), its precision through the use of RTK GPS, its capability to tow loads of up to 150 kilograms, its soil–friendly design with a weight of only 180 kilograms when equipped with all tools, its agility thanks to 4–wheel drive, its versatility with a wide range of compatible tools, and its eco–friendliness achieved by using an electric motor and batteries.

Advanced agricultural management equipment is not limited to conventional agricultural applications; it can also encompass decentralized systems. One example is an automated composting system proposed in recent research (*Nenciu et al., 2022*). Decentralized thermophilic composting has demonstrated its effectiveness in managing organic waste, especially fruits and vegetables. This approach reduces processing time, decreases the waste's mass, volume, and moisture content, all while providing superior control over the composting process. This innovative composting technology using emerging tools ensures efficient management of critical processing parameters, including temperature, material moisture content, mixing intensity, and airflow rate. As a result, it leads to better waste treatment, eliminates unpleasant odors, and minimizes the presence of pathogenic agents.

CONCLUSIONS

Robotization encompasses a range of equipment and processes designed to enhance the efficiency of all production lines. In essence, tasks once performed by humans in the past can now be executed by robots with an extremely low error rate. Elements such as artificial intelligence, software, sensors, and electric motors contribute to the extensive field of robotics. Some of the key advantages of robotization include increased production throughput, guaranteed quality, the ability to sustain operations without interruptions, independence from weather conditions, quick decision–making in response to encountering specific obstacles, and the potential for utilizing renewable energy sources.

Among the drawbacks of robotization, we can mention high development costs associated with altering work processes or technologies, the necessity for human intervention in the case of system errors or updates, and the potential for malfunctions in terms of the proper functioning of the programs governing robot operations.

Acknowledgement

This research was supported by Project PN 23 04 02 01 Contract no.: 9N/ 01.01.2023 SUSTAIN–DIGI –AGRI: Innovative biofertilizer production technology used to restore soil biodiversity and reduce the effects of drought on agricultural lands and through Program 1 – Development of the national research–development system, Subprogram 1.2 – Institutional performance – Projects for financing excellence in RDI, Contract no. 1PFE/30.12.2021.

References

[1] Astrand B., Baerveldt A. J., (2005) A visionbased row–following system for agricultural field machinery, Mechatronics, Volume 15, Issue 2, Pag. 251–269.
[2] Babanatsas T. (2019). Integrarea elementelor de robotică în realizarea unui sistem pentru recoltarea măslinelor, Teză doctorat, Timișoara,
[3] Bakker T., van Asselt K., Bontsema J., Müller J., van Straten G., (2011). Autonomous navigation using a robot platform in a sugar beet field, Biosystems Engineering.
[4] Boris B., Cebanu, D. (2022). Sănătatea solului ca bază pentru tranziția către o agricultură mai durabilă,
[5] Chen, J., Wu, J., Wang, Z., Qiang, H., Cai, G., Tan, C., & Zhao, C. (2021). Detecting ripe fruits under natural occlusion and illumination conditions. Computers and Electronics in Agriculture, 190, 106450.
[6] Chisnicean L., Bobicev T., Chisnicean V., (2019). Aplicarea unor elemente organice la cultivarea speciilor aromatice și condimentare, Conferința Știința în Nordul Republicii Moldova:realizări,probleme,perspective, Bălți, Moldova, 26–27 iunie 39–42
[7] Dewi, T., Risma, P., & Oktarina, Y. (2020). Fruit sorting robot based on color and size for an agricultural product packaging system. Bulletin of Electrical Engineering and Informatics, 9(4), 1438–1445
[8] Fennimore, S. A., & Cutulle, M. (2019). Robotic weeders can improve weed control options for specialty crops. Pest management science, 75(7), 1767–1774.

[9] Gan, H., Lee, W. S., Alchanatis, V., Ehsani, R., & Schueller, J. K. (2018). Immature green citrus fruit detection using color and thermal images. Computers and Electronics in Agriculture, 152, 117–125.
[10] Ghergan, O., Țucu, D., Iusco, A., Drăghicescu, D., & Merce, R. (2019). Small greenhouse robotized solutions: state of the art and future perspectives. În F. o. University of Zagreb (Ed.) Proceedings of the 47th International Symposium, Actual Tasks on Agricultural Engineering, Opatija, Croatia
[11] Griepentrog H.W., Ruckelshausen A., Jørgensen R.N., Lund I., (2010) Autonomous systems for plant protection, Precision Crop Protection, The Challenge and Use of Heterogeneity, Springer, pp. 323–334.
[12] Gruľová, D., Caputo, L., Elshafie, HS, Baranová, B., De Martino, L., Sedlák, V., De Feo, V. (2020). Chemotipul de timol Origanum vulgare L. ulei esențial ca potențial erbicid selectiv pe bază de bio pe specii de plante monocotiledone. Molecule, 25 (3) 595.
[13] Home M. C. W., Tillett N. D., Hague T., Godwin R. J., (2002) An experimental study of lateral positional accuracy achieved during inter–row cultivation, 5th EWRS Workshop on Physical and Cultural Weed Control, pp. 101– 110. http://www.ewrs.org/pwc/doc/2002_Pisa.pdf
[14] Klose R., Ruckelshausen A., Thiel M., Marquering J., (2008). Weedy – a Sensor Fusion Based Autonomous Field Robot for Selective Weed Control, International Conference Agricultural Engineering/AgEng, Pag. 167–172.
[15] Macrii, L., Cebanu, D., Zaharco, D., & Avram, A. (2022). Alcătuirea structurală a cernoziomului tipic sub diverse practici agricole de lungă durată , Conferința Știința în Nordul Republicii Moldova: realizări, probleme,perspective 6, Bălți, Moldova, 20–21 mai , pag.165–170
[16] Mariş, Ş. A. (2022). Optimizarea echipamentului tehnologic robotizat destinat lucrărilor în sere și solarii (Doctoral dissertation, Timişoara: Editura Politehnica).
[17] Mircea, C.; Nenciu, F.; Vlăduț, V.; Voicu, G.; Cujbescu, D.; Gageanu, I.; Voicea, I. (2020). Increasing the performance of cylindrical separators for cereal cleaning, by using an inner helical coil. INMATEH Agric. Eng., 62, 249–258.
[18] Nenciu F, Fatu V, Arsenoaia V, Persu C, Voicea I, Vladut N–V, Matache MG, Gageanu I, Marin E, Biris S–S, et al. (2023). Bioactive Compounds Extraction Using a Hybrid Ultrasound and High–Pressure Technology for Sustainable Farming Systems. Agriculture. 13(4):899.
[19] Nenciu F., Stanciulescu I., Vlad H., Gabur A., Turcu O.L., Apostol T., Vladut V.N., Cocarta D.M., Stan C. (2022). Decentralized Processing Performance of Fruit and Vegetable Waste Discarded from Retail, Using an Automated Thermophilic Composting Technology. Sustainability. 14(5):2835. https://doi.org/10.3390/su14052835
[20] Nenciu F., Voicea I., Cocarta D.M., Vladut V.N., Matache M.G., Arsenoaia V–N. (2022). "Zero–Waste" Food Production System Supporting the Synergic Interaction between Aquaculture and Horticulture. Sustainability., 14(20):13396
[21] Rai, M., Zimowska, B., Shinde, S. (2021) Potențialul bioerbicid al diferitelor specii de Phoma: oportunități și provocări. Appl Microbiol Biotechnol 105, 3009–3018
[22] Ruckelshausen A., Biber P., Dorna M., Gremmes H., Klose R., Linz A., Rahe R., Resch R., Thiel M., Trautz D. and Weiss U., (2009). BoniRob: an autonomous field robot platform for individual plant phenotyping, European Conference Precision Agriculture (ECPA) pp. 841–847.
[23] Slaughter D.C., Giles D.K., Downey D., (2008) Autonomous robotic weed control systems: A review, Computers and Electronics in Agriculture, Volume 61, Issue 1, April 2008, Pag. 63–78, www.sciencedirect.com.
[24] Tillett N.D., Hague T., Grundy A.C., Dedousis A.P., (2007). Mechanical within–row weed control for transplanted crops using computer vision, Biosystems Engineering, Volume 99, Issue 2, February 2008, pp. 171–178,
[25] Tilneac, M. (2012) Contribuții la Utilizarea Roboților in Agricultură Pentru Aplicații de Combatere a Buruienilor, Teză de doctorat, Timişoara–2012
[26] Vlăduț, N.–V.; Ungureanu, N.; Biriş, S.–Ş.; Voicea, I.; Nenciu, F.; Găgeanu, I.; Cujbescu, D.; Popa, L.–D.; Boruz, S.; Matei, G.; et al. (2023). Research on the Identification of Some Optimal Threshing and Separation Regimes in the Axial Flow Apparatus. Agriculture 13, 838
[27] https://optics.org/news/12/3/52
[28] https://www.futurefarming.com/tech–in–focus/field–robots/dahlia–robotics–develops–rob
[29] https://www.futurefarming.com/tech–in–focus/field–robots/12–row–weeding–robot–clears–weeds–autonomously/
[30] https://www.industrialautomationindia.in/articleitm/11821/Robots–in–Agriculture/articles
[31] http://madr.ro/docs/dezvoltare–rurala/rndr/buletine–tematice/PT4.pdf
[32] https://newatlas.com/good–thinking/farmwise–vulcan–automatic–weed–pulling/
[33] https://optics.org/news/12/3/52
[34] https://www.ggba–switzerland.ch/10–foodtech–and–agritech–companies–that–are–revolutionizing–the–food–industry–in–western–switzerland/
[35] https://www.vmdtv.eu/trei–roboti–ajuta–fermierii–sa–curete–solul–de–buruieni–si–sa–planteze/

Note: This paper was presented at ISB–INMA TEH' 2023 – International Symposium on Technologies and Technical Systems in Agriculture, Food Industry and Environment, organized by University "POLITEHNICA" of Bucuresti, Faculty of Biotechnical Systems Engineering, National Institute for Research–Development of Machines and Installations designed for Agriculture and Food Industry (INMA Bucuresti), National Research & Development Institute for Food Bioresources (IBA Bucuresti), University of Agronomic Sciences and Veterinary Medicine of Bucuresti (UASVMB), Research–Development Institute for Plant Protection – (ICDPP Bucuresti), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and Romanian Agricultural Mechanical Engineers Society (SIMAR), in Bucuresti, ROMANIA, in 5–6 October, 2023.

ISSN: 2067–3809