TECHNOLOGIES AND CONSTRUCTIVE SOLUTIONS REGARDING THE INTER-ROW MANAGEMENT OF VINEYARD AND FRUIT TREES
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TEHNOLOGII ȘI SOLUȚII CONSTRUCTIVE PRIVIND MANAGEMENTUL INTERVALULUI DINTRE RÂNDURILE DE VIȚĂ DE VIE ȘI POMI FRUCTIFERI

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***Keywords:** vine and fruit tree management, inter-row management, sensors, intelligent system, seeder, mower.*

ABSTRACT
The management of inter-row space of vineyards and fruit trees has emerged as an essential approach in sustainable agriculture, optimizing resource use and improving ecosystem services. This paper reviews a range of innovative technologies and solutions aimed at revolutionizing line management practices. Modern sensing and monitoring systems provide real-time data on soil moisture, nutrient levels and plant health, facilitating precision row-to-row management. Furthermore, techniques for grassing the space between rows of vines and fruit trees are important for space management, ensuring good air circulation and facilitating agricultural activities such as maintenance and harvesting. In addition, the advent of inter-row seeding machines simplified the implementation of cover crops. These machines use advanced seed delivery mechanisms, precisely distributing the cover seed into the spaces between the rows. This not only encourages soil health and erosion prevention, but also mitigates weed competition, increasing the overall resilience of the agroecosystem. The purpose of this review is to discuss the combination of state-of-the-art technologies such as 3D LIDAR technology, intelligent systems used for inter-row management of vines and fruit trees, and inter-row solar panel systems, all these examples have revolutionized inter-row management in vineyards and orchards. This holistic approach optimizes resource allocation, improves soil health and encourages sustainable agricultural practices, paving the way for greener and more resilient inter-row spaces in modern agroecosystems.

REZUMAT
Managementul spațiilor între rânduri dintre viță de vie și pomi fructiferi a apărut ca o abordare esențială în agricultură durabilă, optimizarea utilizării resurselor și îmbunătățirea serviciilor eco-sistemice. Această lucrare analizează o serie de tehnologii și soluții inovatoare care vizează revoluționarea practicilor de management între rânduri. Sistemele de detectare și monitorizare moderne oferă date în timp real despre umiditatea solului, nivelurile de nutrienți și sănătatea plantelor, facilitând managementul de precizie între rânduri. Mai mult, tehnicile de înierbare a intervalului dintre rândurile de viță de vie și pomi fructiferi sunt importante pentru gestionarea spațiului, asigurarea unei bune circulații a aerului și ușurarea activităților agricole, cum ar fi lucrările de întreținere și recoltare. În plus, apariția mașinilor de semănat între rânduri a simplificat implementarea culturilor de acoperire. Aceste mașini utilizează mecanisme avansate de livrare a semințelor, distribuind cu precizie semințele de acoperire în spații între rânduri. Acest lucru nu numai că încurajează sănătatea solului și prevenirea eroziunii, dar și atenuează competiția buruienilor, sporind rezistența generală a agroecosistemului. Scopul acestei revizuiri este de a discuta despre combinarea tehnologiilor de ultimă oră, cum ar fi tehnologia 3D LIDAR, sisteme inteligente utilizate pentru managementul între rândurile de viță de vie şi pomi fructiferi şi sisteme de panouri solare amplasate între rândurile de viță de vie şi pomi fructiferi, toate aceste exemple au revoluționat managementul între rânduri în podgorii și livezi.. Această abordare holistică optimizează alocarea resurselor, îmbunătățește sănătatea solului și încurajează practicile agricole durabile, deschizând astfel calea pentru spații între rânduri mai verzi și mai rezistente în agro-ecosistemele moderne.

INTRODUCTION

Worldwide, fruit tree and vine plantations represent a very important sector in the field of agriculture, occupying large areas of land.

In the European Union, the land area dedicated to the cultivation of fruit trees and vines has a total of 11,301,345 ha, (https://www.fao.org/faostat/en/#home). The first three fruit crops that cover the largest areas of the total cultivated area are, as shown in fig.1, olive orchards, 45%, followed by vines that cover 28% of the area, and in third place are almond and other nut plantations, 11%. Other orchards covering the remaining area include: apples and pears, 5%; pome fruits (peaches, nectarines, apricots, cherries and plums) covering 4%; citrus fruits 4% and other exotic fruits (figs, avocados, kiwi, other tropical fruits and bananas) approximately 1.3%.

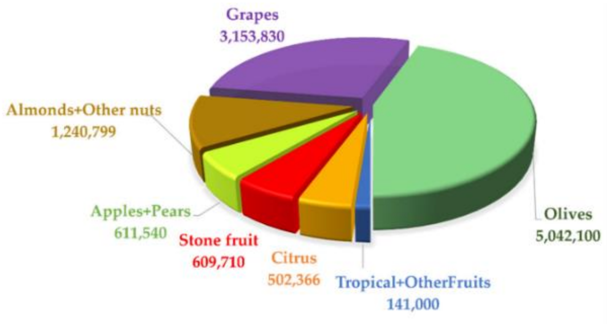

Fig. 1 - The total area at EU level of fruit tree and vine plantations
(https://www.fao.org/faostat/en/#home)

Regarding the distribution of the orchard area in the EU member countries, Spain stands out with 43% of the total area, followed by Italy with 21%, Greece with 10%, France with 8%, Portugal with 6% and Poland and Romania with 3%, as shown in fig. 2. Grapes represent an important cultural, economic and ecological feature of the Mediterranean basin, but also a cosmopolitan culture, with the largest area and the highest economic value among fruit crops globally. The EU members with the largest areas of vines are Spain, France and Italy.

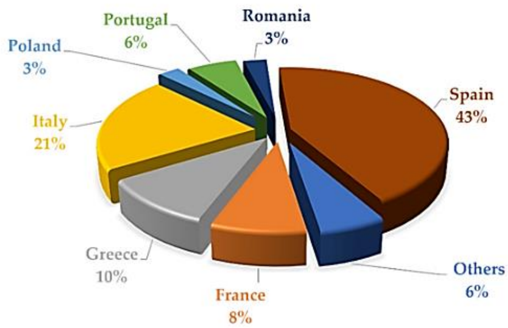

Fig. 2 - The total area at EU level of fruit tree and vine plantations
(https://www.fao.org/faostat/en/#home)

In Romania, fruit growing and viticulture play an important role in agriculture due to the favourable pedoclimatic conditions, but also due to the established fruit/vine growing areas, with tradition and high production potential.

A study carried out by the National Institute of Statistics, regarding the productive potential of fruit and viticulture plantations carried out in 2018 (National Institute of Statistics online page), shows that the total percentage of apple and pear orchards is the most considerable, respectively approx. 55050 ha of apple orchards and approx. 3231 ha of pear orchards. The apricot, peach and nectarine orchards accumulate together a total area of 4206 ha, where approximately half of this area is intended for apricot orchards, 2362 ha, followed by peach orchards 1693 ha, and the rest of 152 ha belong to the plantations of nectarine.

At the same time, vineyards represent an important area in agriculture in Romania, so that it is recognized at the EU level in 15 grape-producing countries. The official data from MADR, highlight the evolution of the vineyard areas in recent years in which small fluctuations are observed, in 2020 approximately 173.7 thousand ha were recorded, (Ministry of Agriculture and Sustainable Development online page).

Historically, the spaces between crop rows have often been viewed as mere passages or neglected areas, left to the whims of nature. However, as concerns about soil erosion, biodiversity loss and resource scarcity have escalated, a paradigm shift has emerged. Greening the inter-row spaces has emerged as a powerful strategy to address these challenges, embracing the principles of agroecology and precision agriculture. Essentially, this practice involves planting cover crops, grasses, legumes, or even low-growing cash crops in the open spaces between primary crop rows. These secondary vegetation covers serve multiple purposes.

Erosion control techniques in agriculture, such as terracing (*Zalidis G. et. al., 2002*), or the use of cover crops (*Francis C.F. et al., 1990; Reeves D.W., et al. 1994*), break the cycle of processes that lead to soil degradation (*Lesschen J.P. et al., 2009*), however the soil remains degraded in those areas that are still rely on traditional intensive processing methods. The advantages of tillage over the use of herbicides in terms of less soil loss and runoff have been documented (*Raclot D. et. al., 2009*). In sub-humid or semi-arid environments, however, it is normal for prolonged tillage to lead to a loss of soil structure and a decrease in organic matter (OM) (*Hermle S. et al., 2008*). Erosion is responsible for OM losses of up to 21g C m^{-2} /y (*Farage P. et. al., 2009*), or up to 19% decrease in total organic carbon in treatments without organic fertilizers (Morlat, R. et.al. 2008), which means that any crop that does not include a change in OM will result in a decrease in soil carbon (*Sanchez-Maranon M. et al., 2002*).

Currently, an eco-biological method practiced in viticulture and fruit growing, which is one of the most effective soil maintenance technologies in vineyards and orchards, is the weeding of the space between the rows. The weeding of the intervals between the rows in the vineyards and fruit plantations, contributes to the conservation and enhancement of the biodiversity of the plantations and the surrounding environment, as well as to the protection and reconstruction of habitats or species, the increase of water reserves in the soil, including the maintenance and creation of landscape features or non-productive areas, in the context of climate change. A beneficial contribution of this eco-scheme also aims to ensure favourable conditions for pollinators (*AGR inteligenta, 2023*).

Viticulture, a sector with a deep history and global significance, provides an illuminating case study for the greening of inter-row spaces. Vineyards, often characterized by their orderly rows of vines, began to embrace this paradigm. For example, the distance between vine rows depends on the grape variety, soil type, and trellis system. Generally, row spacing ranges from 1.8 to 3 m, (*Grant S., 2000; Bobillet W. et. al., 2003*). Row spacing varies based on the type of fruit trees. For apple orchards, typical row spacing is around 3.6 to 5.5 m (*Gómez-del-Campo M. et al., 2020*). Planting grasses, legumes or even wildflowers between the vines not only conserves the soil, but also regulates the vigour of the vines, leading to improved grape quality. In addition, these secondary coverings act as a natural deterrent against vine diseases, alleviating the need for excessive fungicide application. While adopting row greening has numerous benefits, there are challenges. Integrating cover crops requires careful planning, taking into account factors such as water availability, climatic conditions and crop compatibility.

In this review, applications of grapevine and orchard row spacing in agriculture were discussed, with special attention to experiments and studies that have been reported in scientific papers, and analysing the advantages and constraints of using the technology in agriculture. This overview will provide guidelines for further research, the development of new ozone plant protection machines, and the expansion of its applications in agricultural production.

MATERIALS AND METHODS

Managing inter-row spaces in vineyards or orchards involves implementing various practices to optimize the space between rows of crops. This management is crucial for maintaining a healthy and productive crop, promoting soil health, controlling weeds, and facilitating efficient farm operations. Key aspects of inter-row space management are: weed control, soil fertility and nutrition, erosion control, water management, equipment and access aisles, integrated pest management, organic and sustainable practices, wildlife habitat preservation, monitoring and record keeping.

Effective inter-row space management involves a holistic approach that considers the specific needs of the crops, soil conditions, and environmental factors. Regular monitoring and adaptive management practices are essential to address changing conditions and optimize overall farm productivity.

The technologies used for row spacing management of vines and fruit trees have been used in many aspects of agriculture, such as sensors, intelligent cover system, soil vehicles, robots and seeders.

3D points, Sensors

3D LIDAR technology represents a key innovation in agriculture, with the potential to revolutionize the way vine and fruit tree crops are managed. LIDAR, which stands for "Light Detection and Ranging," uses pulses of laser light to measure distances and create detailed three-dimensional maps of the environment, as shown in fig. 3.

In the context of viticulture and fruit growing, 3D LIDAR technology can provide highly accurate and relevant information. It can measure the height and shape of trees or bushes, detecting even the smallest variations in the terrain. Thus, it helps in efficient planting planning, optimal plant spacing and uniform sunlight management. 3D LIDAR technology can also identify plant stress or disease at an early stage, enabling rapid and targeted interventions.

Benefits include increased yield, reduced wastage and more efficient use of resources such as water and pesticides. At the same time, it optimizes harvesting and maintenance methods, contributing to higher quality productions. However, for widespread and successful adoption, continued research is needed to develop LIDAR sensors that are more compact, affordable and better suited to the specific needs of viticulture and fruit growing. Ultimately, 3D LIDAR technology paves the way for more precise, sustainable and resource-efficient agriculture.

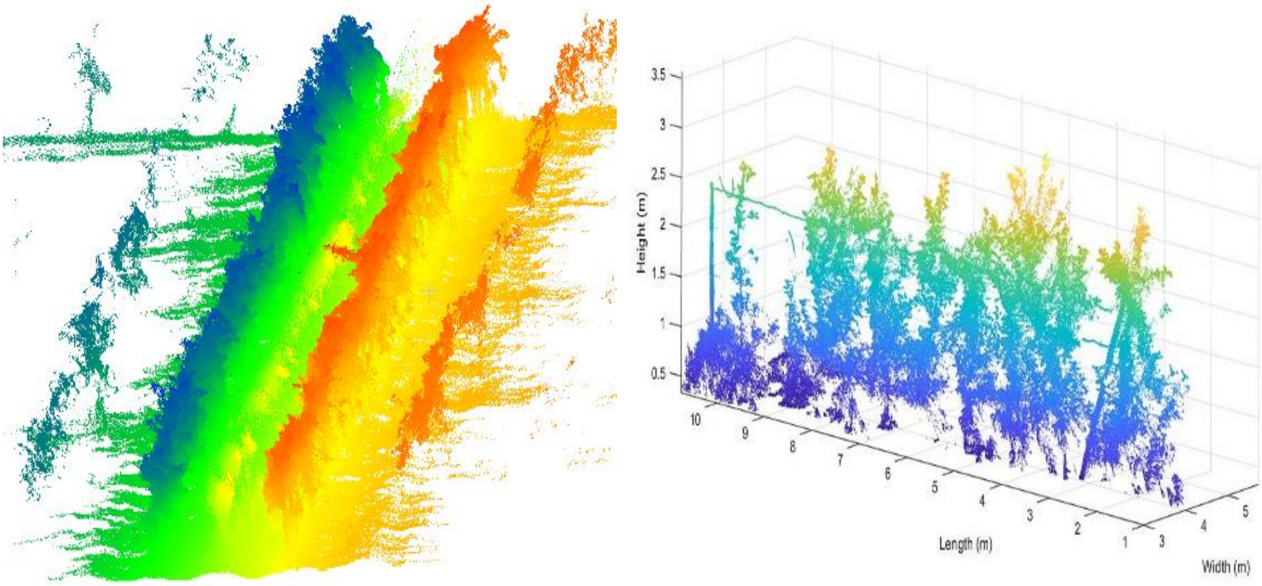

Fig. 3 - 3D LIDAR technology for vines and fruit trees
(*Biglia A. et. al, 2022, Matteo Gatti et. al, 2016*)
1 – Length; 2 – Width; 3 - Height

The article published by *Biglia A. et. al. (2022)*, proposes an innovative method for analysing 3D point clouds in vineyards, extracting information about the orientation and appearance of each row of vines. The method is based on key point detection and density-based clustering, being adaptable to different types of sensors and plant configurations. The data is obtained by multispectral cameras mounted on drones, and the algorithm is applied in three steps: detecting the centre of the vine trees, grouping these points into individual rows, and defining key points and interpolation curves for each row. The method is evaluated on various plots, achieving accurate results in row location and drone path planning. This autonomous and versatile algorithm brings significant benefits in crop monitoring and optimization of agricultural operations.

Nuno Figueiredo et. al. (2023), emphasizes the importance of automated detection of vine rows in terraced vineyards for essential agricultural objectives such as crop evaluation and yield estimation. Integrating remote sensing and artificial intelligence (AI) technologies into precision agriculture practices is essential. The text explores the use of satellite, aircraft, and drone imagery to capture vineyard data, and the application of AI algorithms, including machine learning (ML) and deep learning (DL), to analyse this imagery. Furthermore, the study investigates various ML and DL algorithms for vineyard segmentation, grape detection, and creating a 3D representation of vineyard structure. Despite the progress, the article highlights the challenges associated with row identification in terraced vineyards with curved lines due to the complexity of the land.

Gatti M. et. al. (2016), tested a new proximal sensing system called MECS-VINE® that can measure and map several parameters related to canopy development and vineyard microclimate using two array-based optical RGB image sensors and a series of microclimate sensors. The paper calibrated the canopy index (CI) derived from the MECS-VINE® system with traditional point quadrat analysis (PQA) of tree structure parameters such as number of leaf layer, fraction of tree voids and fraction of inner leaves. The work also correlated CI with other vegetative, yield and grape quality parameters such as leaf gas exchange, light interception, cutting weight, bunch weight and berry weight. They found that CI had a high correlation with PQA parameters at different tree sectors and dates, as well as with cluster weight, grain weight and light intercept. The paper also found that CI could reflect seasonal variation in tree growth and the effects of summer pruning on tree density and openness. The work suggests that the MECS-VINE® system can be a useful tool for assessing grapevine canopy structure and microclimate in a fast, accurate and non-destructive way. CI can also be used as an indicator of vine vigour, yield potential and grape quality, as well as a basis for optimizing vineyard management practices such as irrigation, fertilization, pest control and tree handling.

Hugo Moreno et. al, (2023), presents a method to obtain 3D models of vineyards using a mobile platform equipped with a LiDAR sensor and an RTK-GPS receiver. The paper aims to evaluate shoot volume and dry biomass as indicators of plant growth and health. The paper also evaluates the accuracy and performance of the LiDAR system for crop phenotyping and precision agriculture. The work demonstrates that the LiDAR system can scan large crop areas with high geometric detail and resolution, producing dense 3D point clouds that represent vine structure. The paper uses an alpha shape algorithm to generate a 3D surface that encompasses the outer points of the point cloud and calculates the volume contained by this surface as an estimate of the volume of the branches. The paper shows that there is a strong linear correlation between LiDAR-estimated branch volume and actual dry biomass measured in the field, with an R-squared value of 0.75. This suggests that the LiDAR system can reliably estimate vine cutting weight, which is an important parameter for vineyard management and yield prediction. The paper also shows that the number of LiDAR scans influences the relationship with the actual biomass measurements and has a significant effect on the different treatments. The paper finds that an R-squared value of 0.85 is obtained when comparing the average number of scans and volumes to the average dry biomass values. The paper indicates that the LiDAR system has potential applications for automated pruning, site-specific fertilization, variable rate technology and decision support systems, as it can provide fast and accurate information on crop vigour and spatial variability.

In the framework of an experimental-demonstration research project carried out by the researchers of the National Institute of Research–Development for Machines and Installations Designed for Agriculture and Food Industry-INMA Bucharest, applied research was carried out for the design, realization and testing of an equipment intended for the management of the grass cover in fruit plantations, which integrates LiDAR technology for tree trunk recognition and for the protection them while mowing the grass between the trees in a row *(https://inma.ro/wp-content/uploads/2022/12/Pagina-WEB-650-PED.pdf; Popa L. et al, 2023)*.

Fig. 4 - Intelligent Equipment for the Management of the Green Cover in Orchards in aggregate with the tractor

Intelligent systems used for inter-row management of vines and fruit trees

Intelligent soil and air systems have revolutionized agriculture through automation and efficiency. These include autonomous tractors, agricultural drones and robots used for sowing and harvesting, as shown in fig. 5.

Using technologies such as GPS, sensors and machine vision, these vehicles can precisely navigate complex agricultural terrain. They can perform various tasks such as ploughing, sowing, spraying and harvesting. Automation reduces human effort and human error, optimizing production. The vehicles can collect data on soil, plant and weather conditions, helping to make more informed crop management decisions. However, initial costs and the need for technology training remain challenges. Despite these challenges, ground vehicles continue to redefine the way modern agriculture is practiced.

Fig. 5 - Intelligent soil and air systems used for inter-row management of vines and fruit trees
(*Martina M.et al. al, 2022; Lan Y. et. al, 2021*)

Dionisio A. et. al. (2019), compare three different methods of creating 3D vineyard models based on UAV aerial imagery, ground-based LiDAR scanning, and ground-based RGB-D camera detection. The paper assesses the economic feasibility of site-specific fertilizer application based on 3D models, considering the costs and benefits of each method. The paper implies that the use of 3D models for site-specific management can reduce the environmental impact and economic cost of agrochemicals, as well as improve the quality and yield of grapevine crops.

Martina M. et al. (2022), proposes a multi-phase approach involving different unmanned aerial and ground vehicles to perform remote sensing and field operations in a vineyard. The paper describes the guidance and control strategy for the MH900 fixed-wing UAV, which is equipped with a multispectral camera, to obtain aerial images of the vineyard. The paper presents a guidance scheme that follows a snake-like path with a terrain tracking strategy and a tube-based robust model predictive control scheme that follows the reference trajectory while handling wind disturbances and constraints. The paper explains how aerial images are processed to obtain high-density 3D point clouds of vines and how these point clouds are semantically interpreted to generate low-complexity 3D meshed vine row models. The paper states that these models provide useful information for ground operations of land and rotary-wing vehicles. It discusses the design and implementation of guidance, navigation and control algorithms for the guided four-wheeled ground vehicle and the quadrotor UAV, which are used for research and spraying activities in grapevine rows. The paper shows how low-complexity 3D maps are exploited to plan the optimal path for both vehicles and how advanced control techniques are applied to ensure autonomous navigation and obstacle avoidance.

Grazia T. et al., (2019), develops and tests a system that can autonomously navigate and map a vineyard using a 2D LiDAR sensor without relying on GPS. The system aims to obtain geo-referenced images of vines for yield forecasting. The paper presents a line-based SLAM algorithm that uses vineyard rows as features to estimate the position and location of the robot. It also presents a navigation algorithm that uses the extracted lines to guide the robot along the centre of the rows and to move between them. The paper claims that these algorithms are robust and accurate in difficult and unstructured environments such as uneven terrain, overhanging branches, and long grass.

Hugo M. et al., (2020), presents a method for obtaining 3D models of vineyards using a mobile platform equipped with a LiDAR sensor and an RTK-GPS receiver. The paper aims to evaluate shoot volume and dry biomass as indicators of plant growth and health. The work demonstrates that the LiDAR system can scan large crop areas with high geometric detail and resolution, producing dense 3D point clouds that represent vine structure. The paper uses an alpha shape algorithm to generate a 3D surface that encompasses the outer points of the point cloud and calculates the volume contained by this surface as an estimate of the volume of the branches.

Biglia A. et. al., (2022), reviews how different configurations of UAV spray systems affect deposit, coverage and off-target losses in vineyards. The main argument is that the UAV flight mode is a key factor influencing the efficiency of spray application in 3D crops. The main contribution is that the paper provides empirical evidence on how the band spray mode can improve canopy deposition and reduce soil loss compared to diffuse spray modes when using UAVs for vineyard spraying. The main implication is that UAV spraying can be a viable alternative to conventional aerial spraying in vineyards if appropriate flight modes and nozzle types are selected according to crop characteristics and pest management objectives.

Samuel Marden et al., (2014), proposes a line-based algorithm for locating and navigating a robot in a difficult environment such as a vineyard. This algorithm uses plant rows as reference points to estimate the position of the robot and guide it between these rows. The authors state that this algorithm is robust and accurate in unstructured environments, such as rough terrain or tall vegetation. A prototype equipped with various sensors, such as 2D LiDAR (includes a single laser beam, for single-plane detection), IMU (inertial measurement unit), encoders, GPS and camera, is used to demonstrate the system's effectiveness. By comparing the results with high-precision data obtained from GPS and aerial LiDAR, the paper shows that the proposed algorithm has superior localization accuracy and reliability compared to traditional GPS.

A system intended for the field of robotics for the grapevine in agriculture represents a revolutionary approach in the management of wine crops. This innovative technology combines robots and automation to streamline agricultural processes related to the cultivation, maintenance and harvesting of vines. This system involves the use of specialized robots for tasks such as precise bunch cutting, plant health monitoring, proper nutrient administration and even fruit harvesting. These robots are equipped with advanced sensors to detect the needs of the plants and collect essential data about the condition of the crop. Through communication technology and real-time data analysis, robots can automatically adjust their actions to respond to changes in the environment. For example, if a bunch needs pruning to stimulate growth, robots can intervene with surgical precision. They can also detect early signs of disease or stress in plants, allowing farmers to take preventative measures. The robotics system for the vineyard in agriculture brings multiple advantages, such as increasing operational efficiency, reducing the need for human intervention and optimizing resources. Ultimately, this revolutionary technology contributes to higher yields, higher quality and increased sustainability in the wine sector.

The paper published by *Lan Y. et. al, (2021)*, proposed an orchard tree row-based navigation guidance and localization algorithm for agricultural robots. The algorithm used the trunks of the parallel planted grape trees as auxiliary information, along with the relative position provided by the IMU (inertial measurement unit), odometer and 3D LiDAR, to calculate the position and orientation of the moving robot. The paper suggests that the algorithm can be a useful tool for autonomous navigation of agricultural robots in orchards, especially in environments where GNSS (Global Navigation Satellite System) signals are weak or unavailable. The algorithm can also be applied to other crops with similar tree row structures, such as apples or citrus.

At the same time, *Lopes CM. et. al, (2016),* within a European research project called VINBOT ("Autonomous cloud-computing vineyard robot to optimize yield management and wine quality") focused on yield estimation using machine vision tools. The paper describes a real soil evaluation process carried out in an experimental vineyard with the Portuguese white grape variety Viosinho, trained on a system of vertical shoot positioning and cut spur. A sample of adjacent vines was tagged and subjected to a detailed evaluation of vegetative and reproductive data to feed a viticultural data library. The researchers report that the vines were scanned during the ripening period of the 2015 season by the VINBOT sensor head composed of a set of sensors capable of capturing vineyard images and 3D data. Real ground data was used to relate to the images taken by the sensors and to test image analysis algorithms. The paper shows that the relationships between actual and estimated yield calculated using the area occupied by the clusters in the images were high, despite a slight underestimation of the ground truth, mainly caused by cluster occlusion and factors affecting the estimation accuracy, such as tree density, position cluster, image resolution and lighting conditions.

Inter-row solar panel systems

An intelligent agricultural vine covering system is an essential technological innovation to optimize the growth and protection of wine crops, fig. 6. This advanced system combines elements of technology with the specific needs of viticulture, ensuring ideal environmental conditions for healthy plant development. By using sensors to monitor factors such as temperature, humidity, light and rain, the system can adapt coverage in real time. For example, in the event of extreme temperatures or inclement weather, the system can automatically act to close the cover, providing protection from the elements. On colder days or with less light, it can open the cover to allow better exposure to natural light and maintain the optimal temperature. By intelligently managing the growing environment, this system contributes to maximizing crop quality and increasing yield, minimizing losses caused by external factors. In addition, automation and remote control facilitate efficient crop management, saving time and resources. The intelligent vine covering system represents a significant step forward in modern agriculture, putting technology at the service of achieving sustainable and high-quality wine production.

Fig. 6 - Inter-row solar panel systems
(*Shah et. al, 2019*)

A novel and inexpensive solution for vineyard protection that uses a covering system that can be opened and closed automatically and remotely depending on weather conditions is presented by *Karaman B. et. al, 2022*. The covering system can prevent damage to vines and grapes from natural events such as frost, hail and excessive heat or cold. The prototype consists of a DC gear motor, a control card, a solar battery, a photovoltaic panel and various sensors. The work shows that the coverage system can quickly respond to the detected data and take appropriate actions. The work uses MQTT (Lightweight Open Messaging Protocol) and a mobile application to enable remote monitoring and control of the coverage system. The work also uses the OpenWeatherMap program to obtain a three-hour weather forecast that can help anticipate and prevent potential risks. The researchers suggest that the proposed coverage system and forecasting approach may be more effective than traditional vineyard protection methods such as hail missiles, sprinklers or hail nets.

Seed sowing machines

The seed sowing machine between the rows of vines and fruit trees is an advanced and efficient technique in the field of agriculture. This specialized machine is designed to plant seeds or seedlings in the soil, in the spaces between already existing mature plants, that is, between already established rows of vines or fruit trees. By using this technology, farmers can maximize the use of available space in plantations, avoiding overcrowding and ensuring an even distribution of plants. The inter-row seeder can be programmed to plant the seeds at specific distances and appropriate depths depending on the requirements of the respective crops.

This approach not only saves time and labour, but also optimizes the plant growth process, ensuring that resources such as water, nutrients and light are efficiently distributed to each plant. In addition to increased efficiency, using the seeder between the rows reduces the risk of disease and competition between young and mature plants. However, successful implementation requires adapting the techniques to the specifics of the crops and the environment in which they grow. Thus, future research could focus on developing intelligent control systems and improving seed placement accuracy. The inter-row seeder makes a significant contribution to optimizing agricultural production through more efficient use of available resources and space.

Prakash V.B. et al., (2020), presents the design and implementation of a seed drill for intercropped fields, which can sow two types of seeds with correct spacing and depth in the agricultural field. The paper also proposes a detection algorithm based on colour features to identify the ripeness stage of each date fruit. The seed drill consists of a transport unit, a lighting and capture unit and a sorting unit. The device uses an LED light source and a Telecam camera to capture images of date fruits under a dome-shaped light box. The machine uses a paddle wheel feeder driven by stepper motors to move the Data fruits to the appropriate output ports based on their stage of ripeness. The detection algorithm uses an index based on the red, green, and blue colour components of the images to detect data fruits. The colour component coefficients are calculated by the taxonomy method. The performance of the system is evaluated by comparing it with human experts in visual sorting of date fruits. The paper suggests that the system can be improved by using other technologies that can sense the softness of the texture or by rotating the fruit in front of the camera. The paper also recommends testing the system on other date fruit varieties.

Kadu A.V. et al., (2019), presents a seed sowing machine that is made from old materials, making it cheap and available for small farms. The machine has a hopper, grooved roller, chain sprocket arrangement, soil wheel, furrow opener, seed tube and soil cover band. The machine can sow seeds of different diameters and row spacings by changing the plates on the grooved roller. The machine can also sow fertilizers along with seeds. The paper claims that the use of the proposed machine results in the uniform scattering of seeds over the field, which improves the germination rate and yield of the crop. The machine also minimizes seed and fertilizer waste by controlling seed rate and depth. The machine reduces the time and labour required for seeding, as well as the drudgery and health hazards associated with manual seeding. The paper suggests that using the BBF system with the proposed machine can improve soil fertility, moisture retention, drainage, aeration and sunlight availability for crops. The paper states that the BBF (broad bed preparation) system can save 25-30% of water and increase crop productivity by 5-10%. The paper also mentions that the BBF system allows farmers to implement various agricultural operations such as weeding, spraying, intercultural operation, irrigation.

Nemtinov V. et al., (2019), proposes the use of a self-propelled mini-pneumatic seeder with replaceable mechanical seeding devices designed and manufactured using computer technologies, advanced software and three-dimensional printing for seed selection. The paper claims that this approach can reduce the range of sowers and expand the sown seed set of different crops with a single grain feed brand. The paper tests the performance of these devices under laboratory and field conditions using different types of seeds, such as free-flowing and non-free-flowing seeds, grass seeds and bluegrass seeds. Qualitative indicators of the performance of the proposed grain-drilling fodder are determined, such as the dependence of seed supply on rotation frequency, seeding instability, uniformity of seed distribution, and energy consumption. The results obtained with the existing seeding methods and show that the proposed devices have advantages such as less labour, less time required, less seed wastage, less energy required, less pollution and more alarm and display functions.

Thenmozhi Andújar et al., (2020), aims to design and implement a radio frequency based solar controller for a seed sowing machine that can operate in three modes (slow, medium and speed) and perform seeding, spreading using an open-source software called Arduino. The paper also presents the results of testing the machine on a 45-degree inclined surface and detecting obstacles located in front and behind it. The RF Control Solar Seeder is designed to reduce skilled labour in agriculture, improve farming efficiency and save fuel cost by using electricity and solar panels. The machine can adjust the distance between the two seeds using a motor and can sow different types of seeds according to the user's choice. The machine can also spread fertilizers and plough the soil using various implements. Test results show that the machine can drive on a 45-degree inclined surface without losing balance or stability, and can detect obstacles within a 15 cm radius using ultrasonic sensors. The device can also be charged using solar panels when not in use.

Aduov M.D. etc. al, (2019), the paper aims to improve the seeding quality of non-flowing seeds, such as perennial and annual grasses, by developing and testing a new seeder design for a pneumatic seeder. The paper also presents the results of laboratory and field experiments of the proposed planter and compares them with existing planters. The new design of the seeder consists of a feed tank, a seed tube, a frame, a roller and a coulter. The seeder is capable of sowing loose, medium-flow and no-flow seeds using an auger or disc pin as a seed metering device. The constructive parameters of the seeder, such as the diameter and pitch of the screw, the diameter and number of pins on the disk, the distance between the seeds are determined by using mathematical models and formulas based on the physical and mechanical properties of the seeds and of the soil.

RESULTS

The use of technology in agriculture increases yield, reduces losses and optimizes resources. Data collection and analysis provide vital information for management decisions, such as fruit maturity status or seed distribution. These technologies have the potential to improve the productivity, quality and sustainability of wine production and more. Continuous research is needed to adapt technologies to specific agricultural requirements.

These researches aim to create an innovative technology and equipment for the sustainable development of agroecological crops, in order to use them in conditions of energy efficiency, protection of life, health and the environment.

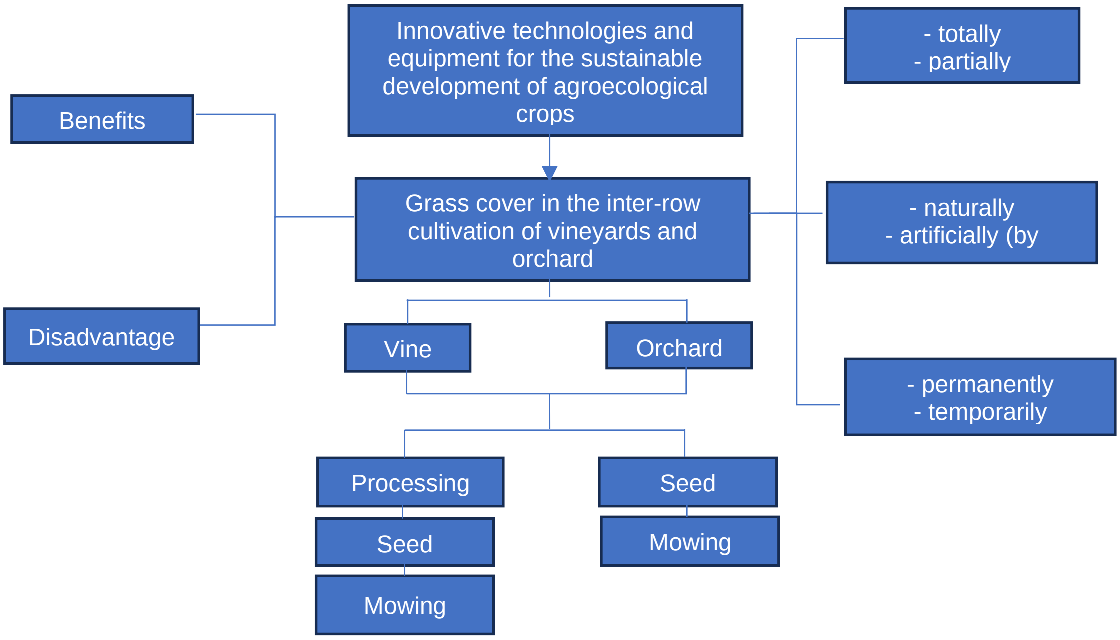

Fig. 7 - Innovative technology for greening the interval between rows of vines and fruit trees

The management of the interval between the rows of vines and fruit trees opens the opportunity to develop equipment and innovative and improved systems, which results in an increase in the quality and quantity of crops.

CONCLUSIONS

In this study, the impact and potential of using advanced technologies in the field of viticulture and fruit growing was investigated. The management of soil and light orientation, the use of 3D points and sensors, intelligent air and soil equipment, intelligent covering systems and vine robots were central to our research. The obtained results demonstrated that advanced technologies can bring significant improvements in the management of wine crops. Soil and light orientation management can optimize growing conditions by adjusting exposure angle and evenly distributing sunlight. The use of 3D points and sensors enabled detailed monitoring of land and plants, providing essential data for making accurate decisions and adapting cultivation methods. As for smart air and soil equipment, they have demonstrated increased efficiency in the precise application of nutrients and protective substances, thereby reducing waste and environmental impact. Intelligent cover systems have been able to provide crop protection against harmful weather factors, contributing to crop quality and yield. The viticulture robotics system has proven to be a promising solution for plant maintenance, monitoring and harvesting tasks. This can improve operational efficiency and free up human resources for more complex activities. Future research could explore the deeper integration of these technologies, the use of artificial intelligence for decision-making, the development of more advanced communication interfaces between agricultural devices, and the optimization of energy consumption. At the same time, more detailed assessment of the long-term costs and benefits of these technologies can contribute to their widespread adoption in the wine industry.

In conclusion, the adoption of advanced technologies in viticulture opens new perspectives for a more efficient, sustainable and quality production in the agricultural sector.

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