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GESTIONAREA EFICIENTĂ A STRESULUI TERMIC ÎN LIVEZI PRIN IMPLEMENTAREA UNOR TEHNOLOGII INOVATOARE DE IRIGARE SI BIOFERTILIZARE
EFFICIENT MANAGEMENT OF THERMAL STRESS IN ORCHARDS THROUGH THE IMPLEMENTATION OF INNOVATIVE IRRIGATION AND BIOFERTILIZATION TECHNOLOGIES

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Abstract

In the context of climate change, improving orchard crop management is essential for effectively addressing the major challenges facing contemporary agriculture. Among these, the thermal stress generated by extreme temperatures and climate variability has an important negative impact on biodiversity, fertility, and soil health. In addition, it is vital to properly manage pests and pathogens that can affect crop quality and yield, as well as to adapt to hyper-intensive cultivation systems that aim to optimize the use of space and simplify harvesting processes. This study explores a number of alternative, sustainable, and effective technologies to improve productivity in orchards using advanced irrigation systems and the use of emergent biofertilizers. These agricultural technologies facilitate precise and efficient management of nutrients, water and biopesticide. The results of the conducted research have demonstrated that these innovative technologies can contribute to a significant long-term increase in productivity, as well as improve the quality of agricultural soils.

Cuvinte cheie: livezi, agricultură durabilă, schimbari climatice, biodiversitate
Key words: orchards, sustainable agriculture, climate change, biodiversity

1. Introduction

With a continuously growing world population estimated to reach 9 to 10 billion people by 2050, precision agriculture has become increasingly important for modern agricultural research. Innovative technologies applied in precision agriculture and data analysis are used to maximize crop yields, increase agricultural productivity, reduce waste, and reduce the negative impact on the environment (Karunathilake et al., 2023).

In recent decades, multiple studies have investigated the automation of tasks in an orchard, from establishment (Eceoğlu et al., 2024), cutting, pollination, and thinning (Lei et al., 2023), to spraying, harvesting and sorting (Verbiest et al., 2020; Mhamed et al., 2024). Fruit crops are vulnerable to climate change, and environmental stress. Often, the biodiversity of the soil in orchards and the ecosystem services that they offer are threatened by a series of natural and anthropogenic factors; therefore,it is essential to use sustainable alternatives in production management.

Establishing high-density orchards with small trees could reduce production costs and increase orchard sustainability. Precision horticulture is achieved using modern sensors and devices for monitoring production and diseases that suggest inputs for nutrition, irrigation, and phytosanitary guidelines (Manganaris et al., 2022).To reduce the effects of high heat, growers use various management methods such as evaporative cooling (EC), shade nets, and spray protectants (e.g., kaolin and calcium carbonate) (Amogi et al., 2023). Frost exposure and poor pollination pose major challenges to growing perennial orchard systems. Such climate risks are rather difficult to manage due to the complexity of future climate predictions and difficulties in quantifying the risks of late spring frost and poor pollination (Ru et al., 2023).

Therefore, innovation in orchard systems is essential. A series of technologies that would have a notable contribution in increasing productivity, sustainability, and efficiency in fruit cultivation could be: precision agriculture; data analysis and predictive modeling (Lassoued et al., 2021; Kunal et al., 2019); intelligent irrigation systems (Conesa et al., 2021; Millán et al., 2020); agroforestry and polyculture: the implementation of agroforestry practices that integrate fruit trees with other crops, increasing biodiversity, soil fertility and ecosystem services within orchard systems (Lovell et al., 2017; Yahya et al., 2022); Smart Farming applications (Ghobadpour et al., 2022);, biological pest control: integrated pest management strategies using natural predators and beneficial organisms to control pests and diseases in fruit orchards, reducing reliance on chemical pesticides (Dara, 2019).

2. Material and methods

Globally, agriculture has been severely affected by climate change. Rising temperatures, day-night fluctuations, and seasonal instability of rainfall have led to an increase in extreme weather events such as flash floods, droughts, and disease outbreaks. The impact of climate change has triggered the need to adopt climate-smart adaptation systems to support year-round productivity and availability. Such adaptation technologies are presented in figure 1 (Ali et al., 2023).

The flowering period is one of the most used widely used indices of the negative impact of climate change on the biological processes of perennial plants. In this sense, over a long period of 40 years (1973-2016), the climatic trend and their influence on the flowering intensity of several varieties of apricot (*Prunus armeniaca* L.) grown in central Italy were evaluated. Most of the varieties analyzed and selected for different flowering periods showed significant flowering delays and reductions in flowering intensity. The varieties with early flowering had the largest average change of almost 12 days and a reduction in the intensity of flowering, which decreased to approximately 50% compared with the previous periods. The autumn-winter cold variability in recent years may have a negative impact in the future with possible geographical shifts of apricot cultivation areas to more suitable areas and considerable socioeconomic inference (Bartolini et al., 2019).

For the irrigation of agricultural crops, the need for water is continuously increasing from year to year, due to climate changes, and this situation may create problems in the future. The decrease in water resources requires the urgent implementation of measures to ensure their rational use.

The purpose of a study was to test in field conditions and adapt, where necessary, an automated irrigation system that allows the establishment of regulated deficit irrigation (RDI) strategies in a plum orchard. For this purpose, an automatic device was used with an algorithm that combines irrigation programing based on water balance with a feedback adjustment mechanism using 15 capacitive sensors for continuous soil moisture measurement. A drip irrigation system was used with, an irrigation strip per tree row located close to the base of the tree (figure 2) (Millán et al., 2019).

Fruits have been shown to contain significant levels of pesticide residues and chemical fertilizers harmful to human health and the natural environment; therefore, it is necessary to develop alternatives to reduce the use of fertilizers in fruit trees (Al-Hchami et al., 2023). A series of studies have described possible ecological alternatives such as mycorrhizal fungi, organic compost, mulches, and biofertilizers.

3. Results and discussions

3.1. Innovative irrigation technologies

An automatic intelligent drip irrigation system for crop irrigation has been developed, where a smartphone first takes a picture of the soil, calculates its moisture level, and periodically transmits data to the microcontroller through a GSM module. Using the smart irrigation system saved about 42% and 15% of the water consumption of traditional and drip irrigation methods (Djalilov et al., 2022). Establishing a strategy of regulated deficit irrigation (RDI) avoided, water stress in the more sensitive stages of the variety and induced moderate to severe stress in the less sensitive stages, table 1 (Millán S. et al., 2019).The application of new irrigation techniques that save water without changing the performance of trees and the quality of fruits represents a challenge in the field of research.

A study investigated the effect of applying three different treatments on the better management of irrigation water without affecting the functions of trees. In addition to better management of irrigation water, CDI also improved the quality of fruits by increasing the content of vitamin C and sugar both in the skin and pulp (Guizani et al., 2019). Agriculture considerably reduces water reserve through irrigation; therefore, at, the global level, scientists have analyzed sustainable solutions applying innovative techniques to reduce high water consumption and avoid losses.

In the specialized literature, a series of technologies (unmanned aerial vehicles (UAV), machine learning (ML), and the Internet of Things (IoT)) have been presented, which have demonstrated their great potential in precision agriculture and irrigation management (table 3) (Ahansal et al., 2022). According to the Food and Agriculture Organization of the United Nations (FAO), agriculture is the world's largest consumer of water in terms of volume, but also a low-value and efficient user of water. This is why there is a need to implement smart irrigation systems. Researchers present an intelligent irrigation system based on the Internet of Things and cloud computing architecture. Machine learning algorithms have been used to predict the appropriate amount of fresh water needed for a crop to be grown.As a result, by applying this system, significant amounts of fresh water are saved (Phasinam et al., 2022). Water and fertilization management are farmers'main concerns in obtaining high fruit quality and economic yield.

Fertilization management is essential not only for ensuring high productivity and fruit quality, but also for maintaining soil health and water resources (Maatallah et al., 2024). Considering the influence of climate on plant diseases, which can alter host physiology, resistance, and pathogen development rates, sustaining fruit tree productivity is a major concern for farmers.

Two treatments were applied to an early maturing nectarine orchard: control (well irrigated) and precise deficit irrigation (PDI, based on soil water content thresholds). Precision deficit irrigation based on soil water content (SWC) used 40% less total irrigation volume than a traditionally scheduled treatment with no yield penalty in early maturing nectarine trees (Conesa et al., 2019). It is known that during the ripening period of fruit, the temperature difference between the day and night of the orchard has a substantial impact on the quality of the fruit. In this sense, in a work Smart Orchard Internet of Things (IoT) was designed uysing, the fuzzy PID (Proportion-Integration-Differentiation) algorithm to control the spraying of water to regulate the temperature difference between day and night in the orchard. The technology had a special contribution to the energy conversion process in the orchard and promoted the accumulation of sugar from the fruits. The graph according to the temperature data is shown in figure 4 (Zhang et al., 2022).The results of a study determined that at a lateral depth of 30 cm subsurface drip irrigation (SSDI) can enhance the quality of fragrant pear, increase yield by 13.14% to 47.03%, and increase water productivity (WP) by 44.65% to 137.23% (Wang et al., 2024).

According to the analysis, average soil moisture content increased with lateral depth and irrigation amount. During 2021-2023, the impact of single-factor lateral depth on soluble solids, total sugar, vitamin C, sugar-acid ratio, solid-acid ratio, single fruit weight, and peel hardness was significant ($p < 0.05$) (Wang et al., 2024).

3.2. Biofertilization systems

A possible alternative to adapting trees to climate change is described in the specialized literature. For example, the effect of arbuscular mycorrhizal fungi on the growth indices of micropropagated pear rootstock improvement (Pyrodwarf) under drought stress were studied. Pear seedlings treated with arbuscular mycorrhizal fungi showed better acclimation, growth, and tolerance to normal and drought stress conditions (Srivastava et al., 2021).

Organic compost plays a particularly important role in sustainable management of agricultural practices. The yield of tree crops and the quality of fruits can be improved through organic fertilization, and interest in ecological products is continuously growing. In the future, it is estimated that obtaining superior quality of fruit will play an essential role in the market for certified organic products because of, the higher prices obtained (Chatzistathis et al., 2021; Montanaro et al., 2017). Figure 6 shows the types of organic fertilizers that can be used to increase the productivity of tree crops; according to researchers, most of them play a vital role in increasing tree yields and partially replacing inorganic fertilizers (to decrease high fertilization rates (Chatzistathis et al., 2021).

In an experiment, the impact of the innovative organic fertilizers: BioIlsa, BioFeed Ecomix, Ausma biostimulation, and Mykoflor mycorrhizal inoculum on the growth characteristics of the fine roots of "Vanda" cherry was analyzed compared with mineral NPK fertilization. The results indicated that there were significant differences in the median root lifespan and, the visible number of roots between treatments. Fertilization with BioFeed Ecomix significantly extends the average lifespan of cherry roots. After applying the mycorrhizal substrate and BioIlsa fertilizer, severel roots were observed, figure 7 (Głuszek et al., 2021).

Another study presents the influences of an innovative liquid product based on vermicompost enriched with selected strains of beneficial microorganisms (VCMo) on the morphometric characteristics (fruit weight, length and width), chemical properties (total phenolic and anthocyanin content, and antioxidant activity) and internal quality characteristics (soluble solids content and firmness) of the plum cultivars 'Stanley' and 'Čačanska Lepotica'. The results of this study show that liquid vermicompost enriched with selected strains of beneficial microorganisms (VCMo) has a significant potential in obtaining a sustainable production of plums and indicates the importance of adopting the declared growth technology as a powerful tool in orchard management (Pešaković et al., 2021). Table 4 presents specific examples of the application of plant growth-promoting bacteria (PGPB) in fruit orchards for different species can be found. In the case of apples, fruit yield (kg tr^{-1}), was improved when PGPB was applied (12–13%) compared with the control (11%) Adaptation after (Freitas et al., 2022).

To study the effecst of orchard grass and microbial preparations (MP), an experiment was carried out on calcareous alluvial meadow soil in Crimea. Grass mixtures (MH) were investigated: MH_2: multiflorous ryegrass + blue alfalfa; MH_3: meadow grass + meadow clover; MH_4: multifloral ryegrass + blue alfalfa + meadow fescue + meadow clover + awnless rump. The control was natural grass (NG). PM: Azotobacterin (AB) and Complex of Microbial Preparations (CMP) were used. The results show that the combination of MH3 and CMP is most effective on the content of phosphorus and potassium and increasing the productivity of apples by 22-43% (Klimenko et al., 2021). Another research established that MPs increase the total nitrogen content of the leaves of apricot seedlings: Azotobacterin (AB) by 73%; mahaleb cherry: Diazophyte (DA) with 25%. The content of total phosphorus in the leaves of apricot and almond seedlings increased by 9-29% under the influence of Phosphoenterin (PE) and CMP compared with the control. Because of improving mineral nutrition in fruit plant seedlings using MP, the production of standard planting material per surface unit increased. The most effective treatments were PE on peach and cherry seedlings, CMP on apricot and cherry plum (Klimenko et al., 2023). Azotobacter has also been analyzed by other researchers, who demonstrated its potential as a bio-fertilizer for soil and plant health management (Sumbul et al., 2020).

The aim of this study was to analyze the nitrogen in a Gala apple orchard in Trentino over a five-year trial period (2018-2022) under two agronomic managements: integrated (INT) fertilized once a year with mineral products and organic matter (ORG) amended with mature manure every three years. The use of organic matrices in organic farming, in addition to having an amendment effect, has been shown to act as a fertilizer in apple orchards, reducing environmental impact (Morelli et al., 2023).

An experiment carried out in an apricot orchard in Italy investigated whether the supply of biofertilizers could differently stimulate the native microbiota, thereby determining different patterns of organic material decomposition processes. After the application of two different types of biofertilizers (AMF and *Trichoderma spp.*) and comparison with the unfertilized control for one year, *Trichoderma spp.* showed faster and greater degradation of litter than the AMF biofertilizers. The results show that the foundation can be laid for efficient orchard use. AMF and *Trichoderma* biofertilizers were Iplaced under the dropper closest to the plant through a syringe to simulate fertilization, and their effects are shown in table 5 (Baldi et al., 2021). Foliar application of *A. nodosum* seaweed extract on trees from an apple orchard produces a larger leaf surface and an increased photosynthetic capacity for organically grown apples (Mousavi et al., 2024).

In "Flordaprince" peaches, foliar or soil application of a humic acid solution (0.25-0.50%; 5 L per tree) significantly increased fruit size (Basile et al., 2020). The effect of biological fertilizers on the yield of apple crops was also demonstrated in a study that analyzed the potential for improving photosynthesis by applying bacteria such as Mucosas, Vertigo, Humus & Humus Active + Aktywit pm in relation to N, P, and K, and the results were encouraging (Singh at al., 2020). In Serbia, a new formula has been developed for a liquid biofertilizer derived from vermicompost and enriched with different strains of beneficial microorganisms from the genera *Bacillus, Pseudomonas, Azotobacter, and Trichoderma*. The contribution of biofertilizers to increasing productivity, quality characteristics, and economic efficiency has been demonstrated with, respect to ecological and health safety standards (Pešaković et al., 2023).

4. Conclusions

This paper demonstrates the urgent need to adopt alternative technologies and solutions to reduce the negative impacts of climate change and traditional agricultural practices on fruit crops.Thermal stress is one of the biggest challenges for farmers because it causes serious damage to fruit trees and soil in orchards. As agriculture is known as one of the largest consumers of water globally, intelligent irrigation is an important step toward making water management more efficient for agricultural crops. The presented solutions describe a series of advanced technologies that through the Internet of Things (artificial intelligence) and cloud computing architecture can develop complex systems: automated drip irrigation systems that have demonstrated the system's self-learning capacity, deficit irrigation strategies (CDI) with potential in managing irrigation water but also the ability to improve fruit quality, underground drip irrigation (SSDI), and web applications that manage databases collected from the field with the help of various devices (drones, sensors, IoT platforms).

In addition to intelligent irrigation systems, the fertilization of fruit crops with organic fertilizer has an essential role in improving vegetative growth, increasing tree productivity, and obtaining the healthiest vegetable products by reducing chemical residues. In conclusion, organic fertilization brings multiple benefits to agroecosystems by increasing productivity, improving physical properties and increasing soil fertility while respecting health safety and reducing environmental pollution.

These positive aspects encourage the field of research to obtain even more advanced solutions to improve the management of fruit crops.

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Tables and Figures

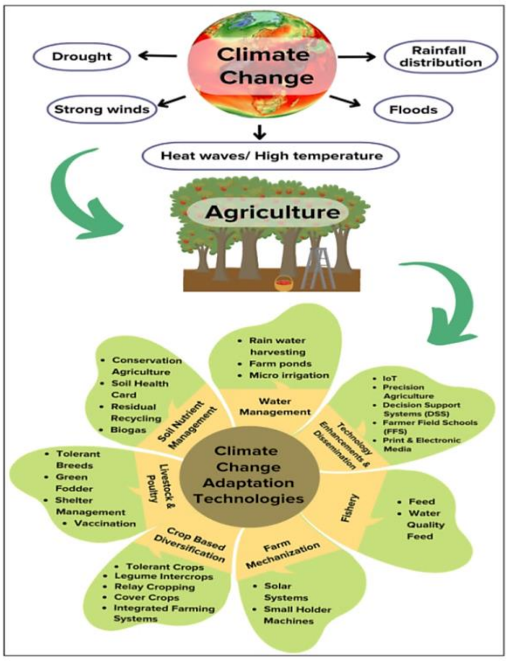

Fig. 1. Climate impacts on agriculture and adaptation technologies to combat climate change (Ali et al., 2023)

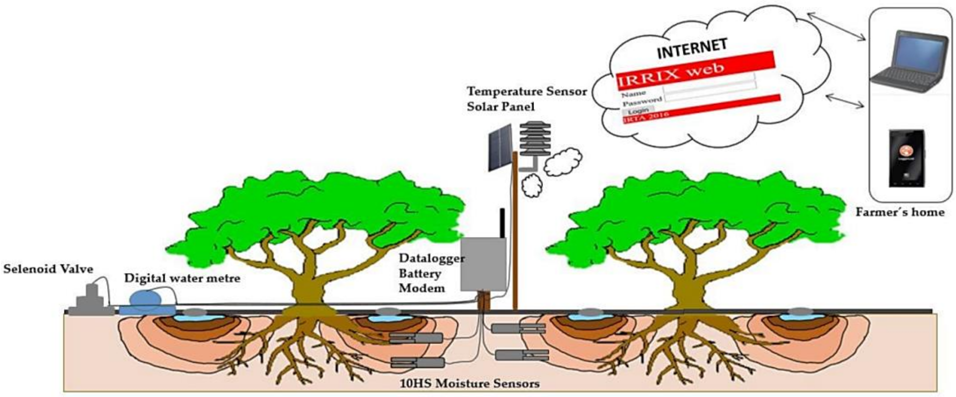

Fig. 2. Automatic irrigation system composed of two fundamental components: field equipment and IRRIX software (https://www.mdpi.com)

Table 1. Effects of irrigation on annual yield and number of fruits per tree in 2016, 2017, and 2018 (Millán S. et al., 2019)

Yield data	Treatments	2016	2017	2018
	C	15158 ± 2114.80	4076 ± 414.82 b	14491 ± 1090.55 b
Yield (kg/ha)	RDI	14240 ± 2081.19	6229 ± 587.07 a	16448 ± 1538.96 ab
	A	13697 ± 1652.65	7228 ± 818.03 a	19908 ± 1447.29 a
	Significance	**n.s.**	*	*
	C	721 ± 113.62	130 ± 14.31 b	404 ± 29.08
Number of fruit/trees	RDI	681 ± 99.08	203 ± 19.21 ab	456 ± 50.78
	A	629 ± 88.67	237 ± 27.50 a	485 ± 34.86
	Significance	**n.s.**	*	**n.s.**

* Indicates significant differences according to Duncan's multiple range test (p = 0.05); n.s. indicates not significant.

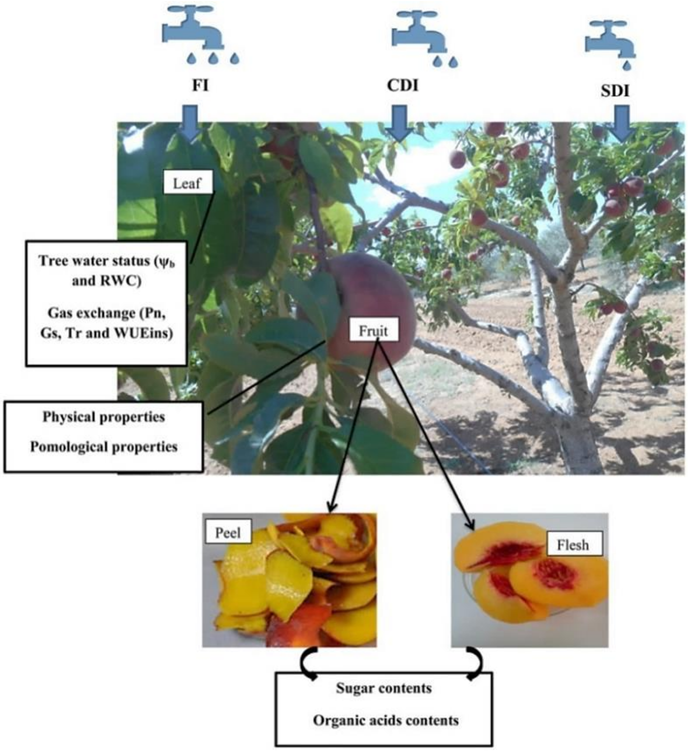

Fig. 3. Application of three different irrigation treatments: full irrigation (FI), sustained deficit irrigation (SDI) and cyclic deficit irrigation (CDI) (https://ars.els-cdn.com/content/image)

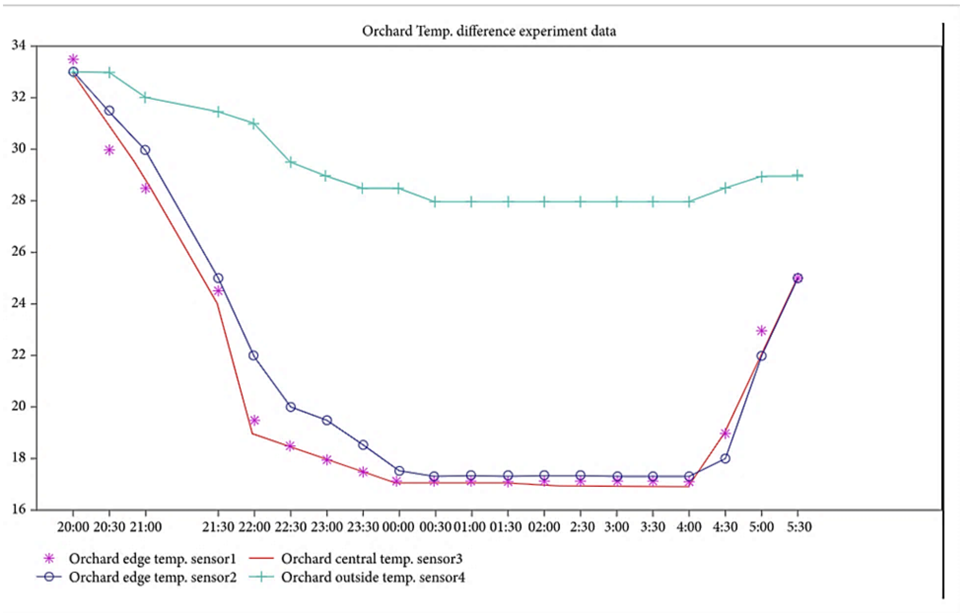

Fig. 4. Control data of temperature difference (Zhang et al., 2022)

Table 3. Technologies used in irrigation management (Adapted from Ahansal et al., 2022)

Techniques and equipment used	Mode of operation	Bibliographic references
Sensors/devices Humidity and temperature sensors Water pump / Processing system Raspberry Pi Transmission mounts Bluetooth Control interface Mobile application	The sensor first reads the soil moisture level data. When the humidity level is below the desired level, the humidity sensor sends the signal to the Raspberry Pi and sends an alert message that tells the water pump to start and supply water.	(Vaishali et al., 2017).
Sensors/devices Humidity and light sensors/ Water pump System of processing Arduino + server cloud Transmission mounts Radio waves Control interface Cloud web server + mobile app	The sensor first reads soil moisture level data to identify the level of soil dryness. The node then sends the information using a radio transceiver to the base station. The base station then sends both the data, the humidity level and the exposed light, to the storage server, which is a cloud server. After the treatment, the water pump will start and supply water.	(Kamaruddin et al., 2019).
Sensors/Devices Humidity and Light Sensors/Water Pump Processing system Arduino + Raspberry Pi Transmission mounts GSM și GPRS Control interface Mobile application	The Raspberry Pi computer makes the decision to supply water or not based on all the data received from the sensors. If the conditions are met, the Raspberry Pi commands the relay module to turn on the water pump for a specified time, after which the computer commands the relay module to turn off the pump.	(Imteaj et al., 2016; Vallejo-Gómez et al., 2023; Kumar et al., 2023; Djalilov et al., 2022).
Sensors/devices Humidity sensors, temperature/water pump, servomotor Processing system Arduino Transmission mounts GSM Control interface They are not mentioned	The humidity and temperature sensors are combined with the input pins of the controller. The water pump and actuator are coupled to the output pins. If the sensors deviate from the defined range, the regulator starts the pump.	(Rajkumar et al., 2017; Matache, M.G. et al., 2023; Cujbescu et al., 2023).
Sensors/devices Humidity and temperature sensors/valves, water meter Processing system Data logger + web platform IRRIX Fuzzy logic controller Transmission mounts 3G Control interface Web platform	IRRIX receives sensor data once a day from the data logger. IRRIX in turn transmits to the data logger the irrigation rates for each sector, in mm, for the new day. The data logger starts irrigation and ends it when it has measured the programmed rate; Drip irrigation prevents wastage of water and evaporation.	(Niño et al., 2020; Anand et al., 2015).
Sensors/devices Humidity and temperature sensors/pumping system, mains, branches and manifolds (supply), side arms, valves, water meters, pressure and flow regulators, automatic devices, non-return devices, vacuum valves, relief valves of air, filtration system, chemical injection equipment, Drippers Processing system An intelligent system built using Field-Programmable Gate Array Technology (FPGA) and HDL language Transmission mounts Radio waves Control interface They are not mentioned	The intelligent humidity sensor monitors both humidity and air temperature. The ratio of air humidity to the highest amount of moisture at a given air temperature is known as relative humidity. Therefore, this relative humidity becomes an essential component in the operation of water pumping systems.	(Oukaira et al., 2021; Nenciu et al., 2022; Matache et al., 2022; Nenciu et al., 2022)
Weather station node sensors/devices/humidity and soil electrical conductivity sensors Processing system Remote server Transmission mounts ZigBee/GPRS Control interface Webserver	The remote server receives the environmental data via the ZigBee and GPRS network, and the weather data directly via the GPRS network. The remote server then allows the use of the long-term memory (LSTM) deep learning algorithm to improve the prediction of soil moisture and electrical conductivity.	(Gao et al., 2021).
Neural networks Machine learning algorithm, ANN feedforward ANN	Prediction and tackles drought conditions 1 Optimization of water resources in a smart farm Neural network models with one hidden layer with four neurons for sugar beet and five neurons for wine grape provided excellent predictions of well-watered canopy temperature 2	(Arvind et al., 2017; Dela Cruz et al.,2017; King et al., 2020)
Water sensors/devices Fuzzy PID algorithm	The Fuzzy PID algorithm effectively controls the mist intensity precisely to achieve water conservation, in addition, useful for improving fruit quality and yield.	(Zhang et al, 2022)
Sensors/devices Soil moisture sensors, temperature and humidity sensors, rain sensors, Node-RED platform	The database uses a multi-sensor data acquisition card and the Node-RED platform to collect data used in decision support models using machine learning.	(Tace et al., 2022;Oprescu et al., 2023; Nenciu F. et al., 2022)

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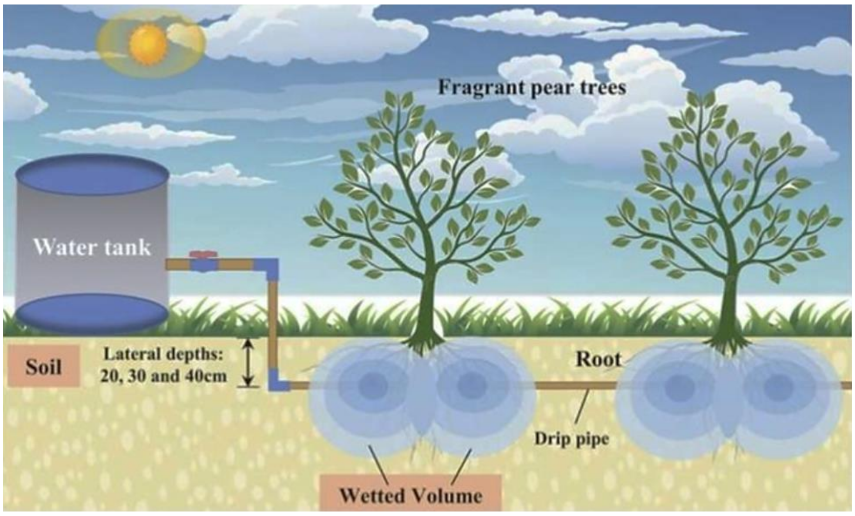

Fig. 5. Subsurface drip irrigation (SSDI) system (https://ars.els-cdn.com/content/image)

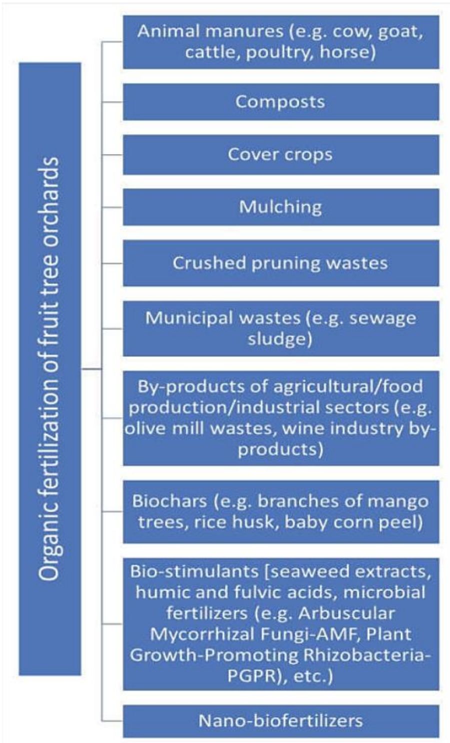

Fig. 6. Categories/types of organic fertilizers for tree crops (Chatzistathis et al., 2021)

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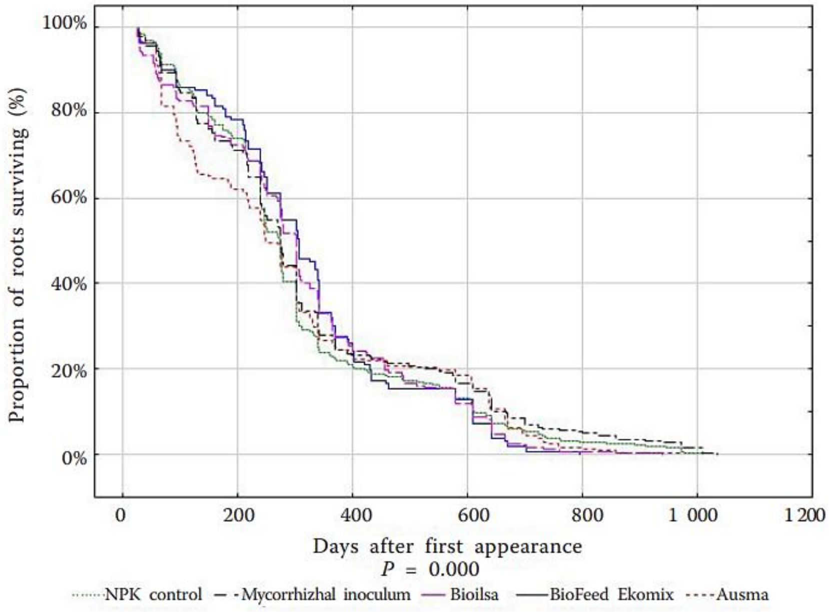

Fig. 7. Kaplan-Meier curves of root survival probability after the application of biofertilizers. P – probability c 2 calculated according to the Mantel procedure (Głuszek et al., 2021)

Table 4. PGPB studies on fruit orchards, Adaptation after (Freitas et al., 2022)

Fruit Crop	Microorganisms	Parameters Evaluated
Apple	*Azotobacter chroococcum*, *Bacillus subtilis*, *Bacillus megaterium*	Fruit yield, Nutrient efficiency
	Bacillus spp., *Burkholderia* spp., *Pseudomonas* spp.	Growth, Fruit yield
	Pseudomonas putid, *Bacillus subtilis*	Foliar application
	Alcaligenes spp., *Agrobacterium* spp., *Staphylococcus* spp., *Bacillus* spp., *Pant oea* sp.	Iron acquisition
	Pseudomonas fluorescens	Drought stress, Nutrient uptake, root grow
	Bacillus sp., *Bacillus amyloliquefaciens*, *Paenibacillus polymyxa*	Nutrient composition of apple leaves
	Bacillus amyloliquefaciens	Growth
	Pseudomonas aeruginosa, *Pseudomonas fluorescens*, *Pseudomonas putida*	Soil properties; Nutrient availability
	Bacillus subtilis; *Streptomyces* spp.	Nutritional status; Growth
Plum	*Pseudomonas stutzeri*; *Bacillus toyonensis*	Growth; Acclimatization; Disease tolerance
	Pantoea agglomerans	Fruit traits; Chemical composition
	Pseudomonas fluorescens; *Pantoea agglomerans*	Rootstock growth
Peach	*Bacillus flexus*	Disease tolerance; Growth
	Alcaligenes sp., *Agrobacterium* sp., *Staphylococcus* sp., *Bacillus* sp. and *Pantoea* sp.	Iron acquisition
	Azospirillum sp.; *Frateuria aurantia*; *Bacillus megaterium*	Nutrient uptake; Growth
	Bacillussubtilis; *Bacillustequilensis*; *Bacillusmethylotrophicus*	Disease tolerance
	Alcaligenes spp., *Agrobacterium* spp., *Staphylococcus* spp., *Bacillus* spp. and *Pantoea* spp.	Growth and Nutrient content

Table 5. Effect of treatments and time on litterbags organic matter stability (Baldi et al., 2021)

Treatment	0	85	162	279	372
Control	0.381 ± 0.020 [1]	0.446 ± 0.02	0.684 ± 0.05	0.767 ± 0.09	0.699 ± 0.04
AMF- biofertilizer	0.381 ± 0.020	0.750 ± 0.03	0.675 ± 0.02	0.674 ± 0.05	0.633 ±0.03
Trichoderma spp.	0.381 ± 0.020	0.617 ± 0.10	0.838 ± 0.04	0.532± 0.01	0.752 ±0.08
Significance	*2SEM[2]= 0.030*				

[1] mean ± standard error (n = 3); [2] values differing by 2 standard error od means (SEM) are statistically different. Interaction treatment*days from litter deposition was significant at $p \leq 0.05$. gunoi