Scientific Papers. Series B, Horticulture. Vol. LXIX, No. 1, 2025
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

DIGITAL MANAGEMENT OF ARONIA CROP: THE BENEFITS OF HUMIDITY AND TEMPERATURE MONITORING THROUGH SPECIFIC SENSORS

Anca Maria CHIOREAN[1, 2], Zsolt JAKAB- ILYEFALVI[1], Ioan ZAGRAI[1], Smaranda ROŞU- MAREŞ[1], Georgeta Maria GUZU[1], Claudiu MOLDOVAN[1], Adrian ASĂNICĂ[3]

[1]Fruit Research & Development Station Bistrita, 3 Drumul Dumitrei Nou Street, Bistrita, Romania
[2]Faculty of Horticulture and Bussines in Rural Development,
University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca,
3-5 Calea Mănăștur Street, Cluj-Napoca, Romania
[3]University of Agronomic Sciences and Veterinary Medicine of Bucharest, Faculty of Horticulture,
59 Mărăşti Blvd, District 1, Bucharest, Romania

Corresponding author email: ancasofron09@gmail.com

Abstract

This study investigated the digitalization of chokeberry (Aronia melanocarpa) cultivation in the Bistrița region through the implementation of a cost-effective and optimized NB-IoT (Narrowband Internet of Things) sensor network, designed to monitor critical environmental parameters essential for optimal plant growth and yield. The objectives of the research were to identify critical phenological stages in chokeberry development and to validate the effectiveness of soil and air sensors for automated control, integrated via a mobile application. Climatic factors were monitored in real-time using an nMETOS 80SM agrometeorological station installed within the chokeberry experimental plot at the Fruit Research and Development Station Bistrița, with data acquisition and visualization facilitated by the FieldClimate platform. Analysis of sensor data recorded during the 2024 vegetation period highlighted intervals of pronounced soil moisture deficit, enabling timely and targeted agronomic interventions. Results emphasized that the implementation of digital technologies for crop management represents a valuable and sustainable strategy for chokeberry crop and is a great decisional support instrument with a significant potential for improving yield performance and fruit quality in general.

***Key words**: precision, smart technology, sustainability, irrigation, sensors.*

INTRODUCTION

Precision agriculture is a management approach that uses technologies and principles to address the spatial and temporal variability of agricultural production, ultimately leading to better crop performance and environmental quality (Pierce & Nowak, 1999).

Farmers are increasingly adopting digital crop management, which relies on a range of sensors to optimize their operations (Queiroz et al., 2021). Soil sensors provide data on moisture, nutrients, allow precise determination of water content, leading to reduced waste in case of irrigated crops (Santos et al., 2024).

Weather stations equipped with specific air temperature and humidity sensors represents an important tool for monitoring climatic factors and provide essential information about the microclimate of the crop, allowing the anticipation and prevention of heat stress or the risk of some diseases (McBratney et al., 2005; Pradipta et al., 2022).

The valuable data gathered by these sensors, when combined with data analytics, empowers informed decision-making, leading to precision agriculture with its advantages of increased efficiency, reduced waste, and higher crop yields (Johnson et al., 2020).

Wireless sensor networks (WSNs) are used in agriculture for environmental monitoring including water and temperature levels to control plant growing conditions through data collection (Khoa et al., 2019; Shaheb et al, 2022).

The use of specific type of sensors in berry crops is a valuable investment, contributing to resource optimization, cost reduction, sustainable and increased yields (Banđur et al.,

2019). This technology allows real-time monitoring of essential parameters, providing crucial data for informed decision-making in crop management (Weiss et al., 2020; Vera et al., 2021). Furthermore, sensors can play a crucial role in the early detection of any signs or problems targeted for rapid interventions and contributes to the increase of the productivity and fruit quality (Pereira et al., 2022; Adu-Manu et al., 2017).
With the goal of optimizing crop management, the precision in agriculture is a modern approach relying on advanced technologies to collect and analyze data, facilitating informed decisions about irrigation, fertilization and pest control (Mulla, 2013; Mgendi, 2024; Ali et al., 2023).
The aim of the study was to identify through the use of specific soil and air sensors, the critical periods within the annual development cycle of chokeberry plants and to validate a low-cost NB-IoT (Narrowband-Internet of Things) sensor network designed for efficient automated monitoring via a mobile application.

MATERIALS AND METHODS

The research was carried out in a chokeberry experimental plot, established at Fruit Research and Development Station Bistrita (FRDS Bistrita) comprising four cultivars, under the specific pedoclimatic conditions of Northern Transylvania (Figure 1).

Figure 1. Aronia plantation at FRDS Bistrita

For the purpose of this study, in 2024 a latest-generation mini weather station (nMETOS 80SM) was installed, operating on the NB-IoT (Narrowband-Internet of Things) network in order to provide real time monitoring weather data (Khoa et al., 2019; Muangprathuba et al., 2019; Munir et al. 2018) (Figure 2).
The Mini nMETOS from Pessl Instruments (Austria) is a low-cost compact weather station designed for environmental monitoring. It typically measures parameters like air temperature, relative humidity and it integrates essential sensors (PI54-D and Watermark) that continuously measure soil parameters.
The PI54-D sensor provides precise data on soil temperature and volumetric water content (VWC) expressed as a percentage of total soil volume that is occupied by water (Figure 2).

Figure 2. nMetos 80SM mini weather station

The Watermark sensor offers near real-time measurements of soil moisture (Figure 2). These units (kPa) represent the soil water tension, which is the force that a plants roots must exert to extract water from the soil. The reading values approaching zero in watermark sensor indicate an increase in soil moisture content, meaning that water is readily available for the plants (www.specmeters.com) (Table 1).

Table 1. Analysis and interpretation of Watermark sensor reading

Watermark values	
0-10 kPa	Saturated soil
10-30 kPa	Adequately moist soil, field capacity range (except for coarse sandy soils)
30-60 kPa	Usual irrigation range (except for heavy clay soils)
60-100 kPa	Fairly dry soil, many plants begin to experience water stress
100-200 kPa	Very dry soil, significant water stress for most plants

Source: www.specmeters.com

The logger is installed completely underground (Figure 3) protecting the device from external factors, and is powered by a high-capacity primary battery, ensuring autonomy between 6 and 12 months.

The system provides detailed data on soil moisture and temperature allowing for precise identification of water stress areas, which enables rapid and efficient interventions to protect crops. All climatic parameters were monitored and recorded at 15-minute intervals.

Figure 3. Temperature and humidity soil sensors installed in the field

The data is centralized on the Field Climate online platform, which generates graphs illustrating the daily evolution of the recorded values that are stored, enabling remote access and analysis, facilitating the identification of climatic trends

The interpretation of sensor data was carried out in accordance with the manufacturer's guidelines, considering the soil type specific to the experimental plot and the specie requirements with related to soil moisture.

RESULTS AND DISCUSSIONS

The meteorological statistics for Bistrița region over the past decade indicate a significant trend of increasing average temperatures (approximately 1.1°C), accompanied by the occurrence of severe seasonal droughts and irregular rainfall distribution in certain periods of the vegetation cycle.

Considered a dry year due to a combination of high temperatures and decreased precipitation, 2024 particularly fulfilled these conditions during its growing season, notably the fruit development phenophase, when the water requirements of chokeberry plants are at their highest (Figure 4).

During the vegetation period, fluctuations in both temperatures and relative air humidity can be observed, which indicates the dynamic and often unpredictable nature of the environmental conditions influencing plant development (Figure 4).

Figure 4. Climatic data extracted from the meteorological online platform

Periods of high temperature coupled with low humidity can lead to increased water stress, potentially hindering growth and development of the Aronia plants.

The beginning of the growing season was promising given that sufficient water accumulated in the soil during the dormant period, ensuring optimal conditions for vegetative growth and a uniform start of plant development.

The recorded temperature data showed high average and maximum temperatures starting from April, which accelerated the progression of the phenophases in the studied Aronia cultivars (Figure 5).

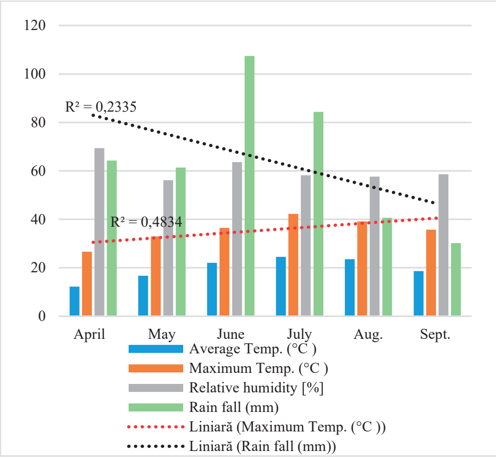

Figure 5. Evolution of temperatures, relative humidity and rain fall during the vegetation stage of Aronia

At the time when the digital monitoring system was installed, the plants from the experimental plot underwent the phenophases of blossoming corresponding to BBCH 56/73.

Aronia is known for its limited water requirements and resistance to short-time drought. The optimal development of the specie is associated with moderately humid environments and a rainfall requirement of 400-500 mm throughout the growing season (Roșca et al., 2022). These needs regarding water consumption may increase depending on each phenophase the plant goes through it and also is influenced by the high temperatures and soil type.

Once the weather station installed, we were able to closely monitor soil and atmospheric parameters dynamics, with the high-precision sensors. This system enables to quickly detect any significant changes, such as drought, excessive moisture, sudden temperature fluctuations, allowing for a prompt appropriate technological interventions to maintain optimal growing conditions for the plants in the field.

The rising temperatures that occurred during May, synchronized with a reduction in precipitation levels, which lead to a slight drying of the soil, indicated by the watermark sensor (Table 2). High watermark values (above 60-80 kPa) means that the soil slowly become drier and that the Aronia plants faced difficulty in absorbing water (Alahmad et al., 2023).

Both the data provided by the watermark sensor (over 60kPa) and the PI54D volumetric water content sensor (53.57%), in May, indicated that the soil currently holds sufficient water, which means the irrigation is not required (Table 2).

Table 2. Monthly average of soil parameters

Month	VPD (%)	PI54D (%)	Watermark (kPa)	PI54D temp (°C)
May	0.98	53.57	66.89	16.92
June	1.19	67.95	25.21	22.42
July	1.64	62.04	102.72	24.74
August	1.55	49.09	178.86	23.46
Sept	1.16	47.70	165.37	9.78

The data from the first decade of June revealed a total of precipitation of 58.4 mm, which was reflected in the readings transmitted by the Watermark (28.80 kPa) and PI54D (57.7%), both indicating high level of soil moisture. (Figure 5).

This situation persisted throughout the second and third decades of June, as the soil became saturated in water due to the 48.4 mm of total precipitation recorded during this period.

The second decade of July was characterized by practically no rainfall, and a significant increase in temperature, climatic conditions that caused a pedological drought. This is reflected in the rising values recorded by the Watermark sensor, indicating a high level of soil dryness, which suggest that irrigation of the crop is requested (Figure 6).

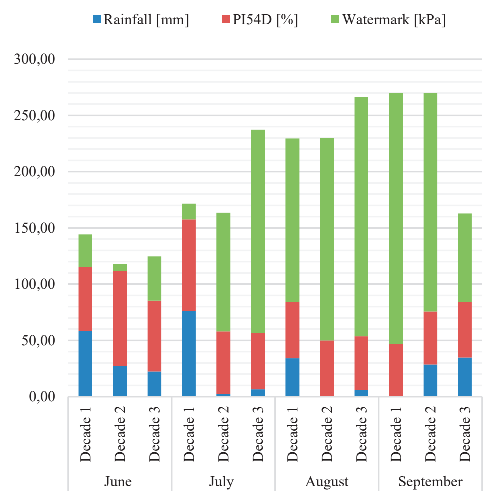

Figure 6. Dynamic of indicators regarding soil moisture content during June to September in Aronia crop

The graph above clearly illustrates that between the second decade of July and the last decade of

September the Aronia plants had to put much more energy to extract the water from the soil. This increased water stress were further combined with the heat stress caused by the high atmospheric temperatures in that period (Figure 4).
Despite the fact that some amounts of rain were recorded in the subsequent period (August-September) it was not enough to effectively restore the water in the soil. The effects of the drought have been observed in fruits, which showed signs of the water stress (Figure 7).

Figure 7. Aronia cluster fruits developed in a water stress condition

Considering the spread of computer-assisted irrigation in berry crops, we believe that the data provided by digital monitoring systems such as these one tested in this experiment can contribute to a digital automation of production. Thus, the data received through the mobile application can help the farmer in real-time to fast decide on the intervention by starting irrigation in case of under-optimal values of water content, preventing drought in the roots area.
Maintaining optimal water content in the soil has beneficial effects on the absorption of nutrients from the soil steadily throughout the growing season.
In addition, the detection of atmospheric humidity levels exceeding certain limits, when coupled with optimal temperatures for the development of pathogens, could serve as a basis for a timely intervention with appropriate phytosanitary treatments.

CONCLUSIONS

This research contributes to the advancement of smart horticulture by demonstrating the importance, feasibility and benefits of integrating IoT-based sensor networks for sustainable and efficient farming practices in a Aronia experimental plantation.
The implementation of high-precision sensors for continuous monitoring of soil and atmospheric parameters lead to an early detection of environmental shifts like drought, excessive moisture, or rapid temperature changes.
This proactive approach empowers timely technological interventions to sustain optimal growing conditions for the Aronia crop.
The research indicate that the period of July to September 2024 proved to be a critical phase for Aronia fruits development in Bistrita region. Characterized by insufficient rain and high temperatures, this period was accurately reflected in the values recorded by the soil (PI54-D, Watermark) and air sensors.
Developing a strategy based on soil and air parameters, data retrieved from the sensors can help to mitigate drought, to secure healthy yields and to optimize water use through precise irrigation interventions.
To ensure sustainable and high-quality Aronia production, future research is required to optimize technological practices that mitigate the negative impacts of abiotic stress factors.

ACKNOWLEDGEMENTS

This research work was carried out with the support of Ministry of Agriculture and Rural Development, Project ADER 6.1.3/2023.

REFERENCES

Adu-Manu, K. S., Tapparello, C., Heinzelman, W., Katsriku, F. A., & Abdulai, J. D. (2017). Water quality monitoring using wireless sensor networks: Current trends and future research directions. *ACM Transactions on Sensor Networks* (TOSN), *13*(1), 1-41.

Ali, A., Hussain, T., Tantashutikun, N., Hussain, N., & Cocetta, G. (2023). Application of smart techniques, internet of things and data mining for resource use efficient and sustainable crop production. *Agriculture*, *13*(2), 397.

Alahmad, T., Neményi, M., & Nyéki, A. (2023). Applying IoT sensors and big data to improve precision crop production: a review. *Agronomy*, *13*(10), 2603.

Banđur, Đ., Jakšić, B., Banđur, M., & Jović, S. (2019). An analysis of energy efficiency in Wireless Sensor Networks (WSNs) applied in smart agriculture. *Computers and electronics in agriculture*, *156*, 500-507.

Johnson, N., Kumar, M. S., & Dhannia, T. (2020). A study on the significance of smart IoT sensors and Data science in Digital agriculture. *Advanced Computing and Communication Technologies for High Performance Applications (ACCTHPA)*, 80-88.

Khoa, T. A., Man, M. M., Nguyen, T. Y., Nguyen, V., & Nam, N. H. (2019). Smart agriculture using IoT multi-sensors: A novel watering management system. *Journal of Sensor and Actuator Networks*, *8*(3), 45.

McBratney, A., Whelan, B., Ancev, T., & Bouma, J. (2005). Future directions of precision agriculture *Precision agriculture*, *6*, 7-23.

Mgendi, G. (2024). Unlocking the potential of precision agriculture for sustainable farming. *Discover Agriculture*, *2*(1), 87.

Muangprathub, J., Boonnam, N., Kajornkasirat, S., Lekbangpong, N., Wanichsombat, A., & Nillaor, P. (2019). IoT and agriculture data analysis for smart farm. *Computers and electronics in agriculture*, *156*, 467-474.

Munir, M. S., Bajwa, I. S., Naeem, M. A., & Ramzan, B. (2018). Design and implementation of an IoT system for smart energy consumption and smart irrigation in tunnel farming. *Energies*, *11*(12), 3427.

Mulla, D. J. (2013). Twenty five years of remote sensing in precision agriculture: Progress and prospects. *Precision Agriculture*, *14*(1), 1-17.

Pradipta, A., Soupios, P., Kourgialas, N., Doula, M., Dokou, Z., Makkawi, M., ... & Yassin, M. (2022). Remote sensing, geophysics, and modeling to support precision agriculture - Part 1: Soil applications. *Water*, *14*(7), 1158.

Pierce, F. J., & Nowak, P. (1999). Aspects of precision agriculture. *Advances in agronomy*, *67*, 1-85.

Pereira, L.S., Oweis, T., Zairi, A. (2002). Irrigation management under water scarcity. *Agricultural water management, 57*(3), 175-206.

Queiroz, D. M. D., Coelho, A. L. D. F., Valente, D. S. M., & Schueller, J. K. (2021). Sensors applied to Digital Agriculture: A review. *Revista Ciência Agronômica,* 51*,* e20207751.

Shaheb, M. R., Sarker, A., & Shearer, S. A. (2022). Precision agriculture for sustainable soil and crop management. In *Soil Science-Emerging Technologies, Global Perspectives and Applications*. IntechOpen.

Santos, M. M. D., Sousa, O. N. D., Guerra Filho, P. A., Dias, N. D. S., Aragão, A. R. D., Souza, Y. C. D. S., ... & Moreno-Pizani, M. A. (2024). Intelligent system for automated soil moisture monitoring. *Revista Brasileira de Engenharia Agrícola e Ambiental*, *29*(2), e279856.

Vera, J.; Conejero, W.; Mira-García, A. B.; Conesa, M. R.; Ruiz-Sánchez, M. C. Towards irrigation automation based on dielectric soil sensors. *The Journal of Horticultural Science and Biotechnology*, v. *96*, p. 696-707, 2021. https://doi.org/10.1080/14620316.2021.1906761

Weiss, M.; Jacob, F.; Duveiller, G. (2020). Remote sensing for agricultural applications: A meta-review. *Remote sensing of environment*, v. *236*, e111402. https://doi.org/10.1016/j.rse.2019.111402

Yin, H., Cao, Y., Marelli, B., Zeng, X., Mason, A. J., & Cao, C. (2021). Soil sensors and plant wearables for smart and precision agriculture. *Advanced Materials*, *33*(20), 2007764

**https://metos.global/ro/

**https://www.specmeters.com