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INTEGRATED IRRIGATION MANAGEMENT FOR POTATO UNDER THE PEDOCLIMATIC CONDITIONS OF WESTERN ROMANIA: THE ROLE OF SOIL PROPERTIES AND WATER QUALITY

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Abstract. *Potato (Solanum tuberosum L.) is highly sensitive to water stress, especially during critical growth stages such as tuber initiation and bulking. In Western Romania, increasing climatic variability, uneven rainfall distribution, and frequent drought periods during the growing season significantly impact both yield and tuber quality, making irrigation a key factor in sustainable production. This study evaluates the necessity of irrigation by examining potato water requirements in relation to regional climatic conditions, including temperature patterns, evapotranspiration, and precipitation dynamics. It also considers soil properties such as texture, structure, and water-holding capacity, which influence water availability and irrigation efficiency. In addition, irrigation water quality parameters, including salinity and pH, are analyzed due to their effects on soil condition, nutrient uptake, and crop performance. The results indicate that water deficits during critical phenological stages lead to reduced yields and compromised quality. Modern irrigation systems, such as sprinkler and drip methods, along with monitoring tools like soil moisture sensors, can significantly improve water use efficiency and crop response. Overall, irrigation is not merely supplementary but essential for achieving stable and high-quality potato production under current climatic conditions. Proper management of both soil and water resources is crucial for ensuring sustainability and resilience in Western Romania.*

Keywords*: potato, irrigation, soil properties, water quality, evapotranspiration, climate variability, Western Romania.*

INTRODUCTION

Potato (Solanum tuberosum L.) is one of the most important agricultural crops worldwide due to its high nutritional value, adaptability, and significant role in food security. The crop is characterized by relatively high-water requirements and increased sensitivity to water stress, mainly because of its shallow and poorly developed root system. Water deficits occurring during critical phenological stages such as tuber initiation, flowering, and tuber bulking may significantly reduce plant growth, tuber formation, yield, and quality parameters (Shock & Feibert, 2000; Onder et al., 2005).

In recent years, climate variability and increasing drought frequency have become major challenges for agricultural production systems, especially in regions with irregular precipitation distribution and elevated evapotranspiration rates. Western Romania is increasingly affected by climatic variability, prolonged drought periods, and irregular precipitation distribution during the vegetation season, conditions that significantly increase agricultural water demand and the necessity for sustainable irrigation management strategies (Food and Agriculture Organization, 2021; Gui-Bachner, 2025). Under such conditions, maintaining optimal soil moisture through efficient irrigation practices becomes essential for achieving stable and sustainable production (Food and Agriculture Organization, 2021; Ayas, 2013).

Among modern irrigation methods, drip irrigation is considered one of the most efficient systems due to its capacity to deliver water directly into the active root zone while minimizing losses caused by evaporation, runoff, and deep percolation. In addition to

improving water use efficiency, drip irrigation contributes to more uniform plant development, better nutrient uptake, and improved crop response during periods of insufficient rainfall. The efficiency of irrigation management is also influenced by soil properties such as texture, structure, and water-holding capacity, as well as irrigation water quality parameters including pH, salinity, and electrical conductivity (Lamm, 2007; Pereira, 2002).

The present study focuses on the potato variety Red Fantasy cultivated under drip irrigation conditions in Timișoara, Western Romania. The research evaluates the role of irrigation in maintaining favorable soil moisture conditions during critical BBCH growth stages and analyzes the relationship between climatic conditions, soil characteristics, water management, and crop development in the context of sustainable potato production.

MATERIALS AND METHODS

Study Area and Climatic Conditions

The experimental study was carried out within the Educational Resort for Young Naturalists located in Timișoara, Timiș County, Western Romania. The study area belongs to the Banat Plain, characterized by low-altitude relief, favorable agricultural conditions, and intensive field crop cultivation. Timișoara is situated at an average altitude of approximately 90 m above sea level and is influenced by a temperate-continental climate with sub-Mediterranean influences, resulting in warm summers and relatively mild winters.

In recent years, the climatic conditions of Western Romania have been increasingly affected by climate variability, especially through irregular precipitation distribution, elevated temperatures, and prolonged drought periods during the vegetation season. According to Croitoru et al. (2013), changes in precipitation extremes and the increasing frequency of drought events represent important limiting factors for agricultural productivity in Romania. Similar studies conducted for southeastern and western Europe indicate that increasing evapotranspiration and reduced soil water reserves are becoming major challenges for sustainable agricultural systems under climate change conditions (Spinoni, 2015).

The multiannual average air temperature in the Timișoara area is approximately 11.5–12.0 °C, while average annual precipitation ranges between 550 and 650 mm. However, precipitation during the potato growing season is frequently uneven, with reduced rainfall occurring during late spring and summer months when crop water demand reaches maximum values. During the vegetation period (April–September), average monthly temperatures frequently exceed 20 °C, contributing to accelerated soil moisture depletion and increased evapotranspiration rates. Under these conditions, potato crops become highly vulnerable to water stress, particularly during critical BBCH stages such as tuber initiation and tuber bulking (Obidiegwu, 2015).

Table 1.

Climatic conditions specific to the Timișoara area in Western Romania

Parameter	Value
Location	Timișoara, Western Romania
Altitude	~90 m
Climate type	Temperate-continental with sub-Mediterranean influences
Average annual temperature	11.5–12.0 °C
Average annual precipitation	550–650 mm

Vegetation period	April–September
Summer average temperatures	20–24 °C
Maximum summer temperatures	>35 °C possible
Main drought risk period	June–August
Estimated annual ETo	700–850 mm
Dominant climatic risk	Summer drought and heat stress

Biological Material and Experimental Design

The biological material used in the experiment was the potato variety Red Fantasy, a medium-early cultivar characterized by high marketable yield potential, good adaptability, and suitability for irrigated cultivation systems. The variety is recognized for its red skin, yellow flesh, and relatively good tolerance to environmental variability.

The experimental field had an approximate surface area of 1000 m² and was organized under drip irrigation conditions. The drip irrigation system was selected due to its capacity to deliver water directly into the active root zone, improving irrigation efficiency and reducing water losses caused by evaporation and surface runoff. Studies regarding drip irrigation systems in potato cultivation indicate that localized irrigation significantly improves water use efficiency and supports more uniform crop development under water-limited conditions (Ati, 2012; Elhani, 2019).

Figure 1. Pre-germinated Red Fantasy seed tubers prepared for planting

Figure 2. Early vegetative development of Red Fantasy potato under drip irrigation condition

The experimental analysis included:

- monitoring climatic conditions during the vegetation period;
- evaluation of irrigation water requirements;
- assessment of soil physical properties influencing water retention;
- analysis of irrigation water quality parameters.

Two experimental variants were monitored:

- V1 – drip-irrigated potato crop;
- V2 – control variant based exclusively on natural precipitation.

Soil Characteristics

The experimental field is located on agricultural soils typical for the Banat Plain, generally characterized by moderate fertility and medium water-holding capacity. Soil properties play an essential role in irrigation management because parameters such as texture, structure, infiltration rate, and field capacity directly influence water availability for crops and irrigation efficiency (Hillel D., 2003).

Soil investigations focused on determining:

- soil texture;
- soil structure;
- field capacity;
- water-holding capacity;
- infiltration characteristics.

The analyzed soils presented medium texture conditions with moderate permeability and relatively good moisture retention capacity. These properties are considered favorable for drip irrigation systems because they allow gradual water infiltration and relatively stable moisture conditions within the active root zone.

Drip Irrigation System

The experimental plot was equipped with a drip irrigation system designed to ensure uniform and controlled water distribution directly into the root zone of the potato plants.

The technical configuration included:

- water source;
- pumping and filtration unit;
- polyethylene (PEHD) distribution pipelines;
- drip irrigation lines;
- pressure control components.

Water distribution was achieved through emitters positioned at regular intervals along cultivated rows. Modern irrigation management systems integrated with hydraulic modeling and digital monitoring technologies can significantly improve irrigation efficiency and optimize agricultural water consumption under variable climatic conditions (Gui-Bachner & Șmuleac, 2025).

The irrigation schedule was adapted according to climatic conditions, crop development stages, and estimated crop water requirements during the vegetation period.

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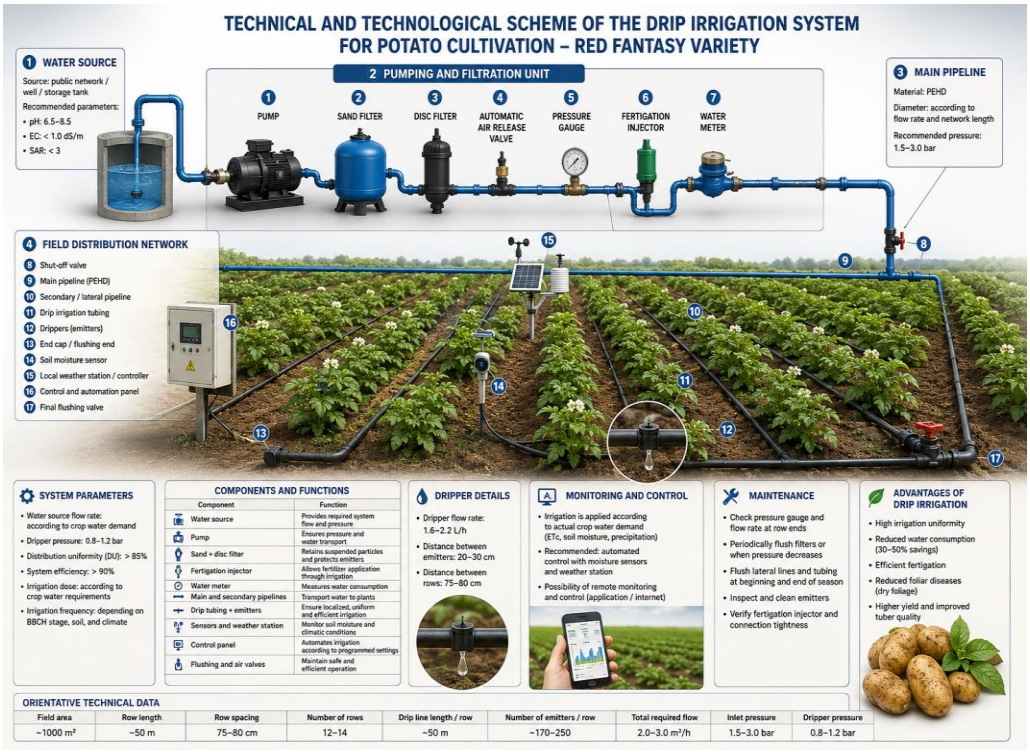

Figure 3. Complete diagram of the irrigation system installed in the field

Water Quality Analysis

Water quality represents an important factor influencing soil conditions, nutrient availability, and crop development under irrigated agricultural systems. Water quality evaluation included the determination of:

- pH;
- electrical conductivity (EC);
- salinity;
- dissolved mineral content.

Climatic Monitoring and Crop Water Requirements

Climatic monitoring during the experimental period included observation of:

- air temperature;
- precipitation regime;
- evapotranspiration dynamics;
- drought occurrence during the vegetation season.

The data obtained were comparatively analyzed between experimental variants during the monitored BBCH growth stages.

RESULTS AND DISCUSSION

The preliminary results obtained during the current vegetation period highlight the positive influence of drip irrigation on potato development under the pedoclimatic conditions of Western Romania. Compared to the control variant (natural precipitation only), the irrigated plots maintained a more stable soil moisture level throughout the critical BBCH growth stages, particularly during tuber initiation and tuber bulking (BBCH 30–69). These phenological stages are highly sensitive to water deficits, and insufficient water availability may negatively affect tuber formation and overall crop development.

The comparative analysis between the drip-irrigated variant and the control indicates superior vegetative growth and improved plant uniformity under controlled irrigation conditions. As illustrated in the BBCH comparative graph, the irrigated plants presented higher relative development indicators during the main growth stages, especially during flowering and tuber development. In contrast, the non-irrigated variant showed slower development and visible sensitivity to fluctuating soil moisture conditions caused by irregular precipitation distribution and increasing evapotranspiration during spring and early summer.

Drip irrigation helped maintain more consistent water availability directly within the root zone, reducing water losses through evaporation and improving overall irrigation efficiency. In addition, localized water application minimized excessive surface drying and supported more homogeneous crop development across the experimental field. The monitored soil moisture values suggest that irrigation can provide favorable conditions for optimal crop growth during periods with insufficient rainfall.

Although the experiment is still ongoing and final harvest data are not yet available, the current observations indicate that the irrigated variant has the potential to achieve improved tuber yield, better tuber uniformity, and enhanced crop stability compared to the control. Continued monitoring throughout the remaining vegetation stages and at harvest will allow a more precise evaluation of production differences and irrigation efficiency.

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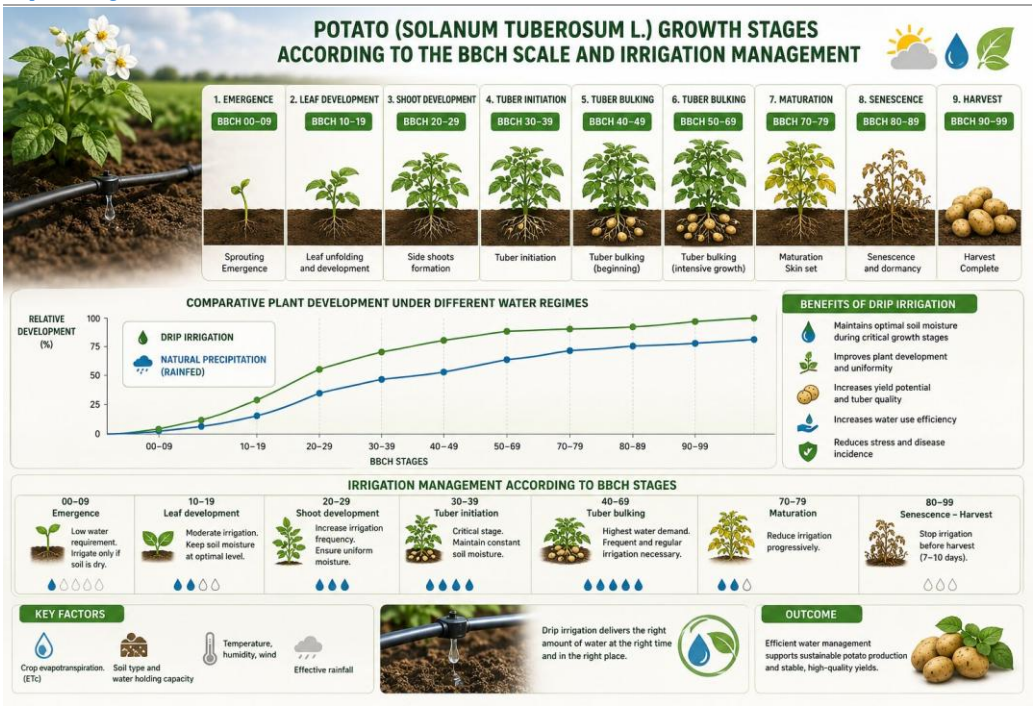

Figure 4. Potato growth stages under irrigation system

The obtained results confirm that drip irrigation represents an efficient and sustainable solution for potato cultivation in Western Romania, especially under current climate change tendencies characterized by increasing drought frequency and uneven precipitation distribution. Proper integration of irrigation management with soil characteristics and crop water requirements can significantly improve both productivity and resource use efficiency.

Irrigation Water Quality Analysis

The irrigation water analysis revealed physicochemical characteristics generally favorable for potato cultivation under drip irrigation conditions. The measured pH value of 7.4 indicated neutral to slightly alkaline water, a range considered suitable for most agricultural crops, including potato, without significant risks related to nutrient imbalance or soil acidification.

An electrical conductivity (EC) value of 0.71 dS/m classified the water as low salinity, suggesting minimal risk of salt accumulation in the soil profile during irrigation. Similarly, the Sodium Adsorption Ratio (SAR) value of 2.5 indicated excellent suitability for irrigation use, with low potential for sodium-related soil structure degradation or reduced infiltration capacity.

Table 2.

Irrigation water quality parameters

Parameter	Measured Value	Interpretation
pH	7.4	Neutral–slightly alkaline
EC	0.71 dS/m	Low salinity
SAR	2.5	Excellent suitability
TDS	512 mg/L	Suitable
Nitrates	27 mg/L	Moderate presence
Iron (Fe)	0.26 mg/L	Occasionally elevated
Manganese (Mn)	0.084 mg/L	Low–moderate
Chlorides	67 mg/L	Acceptable

The total dissolved solids (TDS) concentration reached 512 mg/L, remaining within acceptable limits for agricultural irrigation systems. Nitrate concentration was measured at 27 mg/L, indicating a moderate presence of dissolved nitrogen compounds that may contribute partially to crop nutrient availability during the vegetation period. Iron (Fe) concentration reached 0.26 mg/L, representing slightly elevated values that may require periodic monitoring in long-term irrigation management, especially regarding potential emitter clogging within drip irrigation systems. Manganese (Mn) concentration remained within low to moderate limits, while chloride concentration (67 mg/L) was considered acceptable for potato cultivation and did not indicate salinity-related risks.

Overall, the analyzed irrigation water presented favorable quality parameters for drip irrigation application and sustainable potato cultivation under the pedoclimatic conditions of Western Romania. The obtained results indicate low salinity risk, suitable chemical composition, and good compatibility with localized irrigation systems used within the experimental field.

Soil Characteristics

The experimental field is located within the Banat Plain, Western Romania, an area predominantly characterized by chernozem and cambic chernozem soils developed under temperate-continental climatic conditions. These soils are generally recognized for their relatively high fertility, favorable structure, and moderate-to-good agricultural productivity potential.

Studies conducted in Western Romania indicate that chernozem soils from the Banat region commonly present medium-textured profiles, moderate permeability, and relatively good water retention capacity, properties considered favorable for irrigated agricultural systems (Caraba, 2024). The relatively high humus content and stable soil structure contribute to improved moisture storage and nutrient availability, important factors for potato cultivation under variable climatic conditions.

Table 3.

Soil characteristics specific to the Banat Plain experimental field

Parameter	Estimated Value	Interpretation
Soil type	Chernozem / Cambic Chernozem	Fertile agricultural soil
Texture	Clay-loam / Loam	Moderate permeability
Soil pH	6.8	Neutral–slightly alkaline
Humus content	4%	Moderate–good fertility
Bulk density	1.2 g/cm³	Favorable root development
Field capacity	24–32%	Moderate water retention
Wilting point	10–14%	Moderate drought sensitivity
Available water capacity	120–180 mm/m	Suitable for irrigation
Infiltration rate	Moderate	Favorable for drip irrigation

CONCLUSIONS

The preliminary results of the study highlight the importance of drip irrigation for potato cultivation under the pedoclimatic conditions of Western Romania. Climatic variability, irregular precipitation distribution, and elevated evapotranspiration during the vegetation period create significant water deficits that may negatively influence potato growth and development during critical BBCH stages.

The analyzed irrigation water presented favorable physicochemical characteristics for agricultural use, while the soil properties specific to the Banat Plain provided suitable conditions for efficient drip irrigation management. Compared to the control variant, the irrigated crop showed improved vegetative development, more stable soil moisture conditions, and reduced visible water stress symptoms during the monitored growth stages.

Although the experiment is still ongoing and final harvest data are not yet available, the current observations suggest that drip irrigation represents an efficient and sustainable solution for improving water use efficiency and supporting stable potato production under increasing drought risk conditions in Western Romania.

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