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STUDIES ON THE MORPHOLOGICAL, PHYSIOLOGICAL, AND BIOCHEMICAL CHARACTERISTICS OF SEVEN POTATO VARIETIES (*SOLANUM TUBEROSUM* L.) UNDER THE PEDO-CLIMATIC CONDITIONS OF ARAD AREA, ROMANIA

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Abstract: Given the significant potential for the use of potatoes (*Solanum tuberosum* L.) in diverse economic sectors, including agriculture, gastronomy, the starch industry, and alcohol production, this study aims to analyze some mid-late and late potato varieties cultivated under the specific conditions of the Arad area (Romania). The objective is to implement optimal solutions for expanding cultivation areas and, consequently, increasing production capacity. A single-factor experiment was conducted with seven potato varieties cultivated under optimal technological conditions in four replicates as experimental variants, employing the following potato genotypes: V1 – Armonia; V2 – Cosiana; V3 – Coval; V4 – Foresta; V5 – Gared; V6 – Productiv; V7 – Desiree. The Desiree variety, which has been cultivated in the study area for the last twenty years, achieving good results, was used as a control variant. A series of qualitative indices were evaluated, such as: vegetation period, plant height, chlorophyll and dry matter content of leaves, tuber production, percentage content of water, starch, proteins, and lipids in tubers, as well as economic efficiency The interaction between the genotype and the pedo-climatic conditions generates a high degree of variability in the growth and development of the analyzed genotypes. The cultivation of certain potato varieties in the Arad area is economically viable, as indicated by the recorded data.

Keywords: *Solanum tuberosum* L., potato, morphology, biochemistry, productivity.

INTRODUCTION

The potato (*Solanum tuberosum* L.) is an annual plant native to South America, representing the fourth largest source of food energy after rice, wheat, and corn (Jităreanu et al., 2020; Zhang et al., 2024). It is cultivated in over 100 countries (Boivin et al., 2020) and, in addition to its use as a food source, it is also used in the chemical and cosmetics industries, among others, thanks to its eco-plasticity (Kennedy et al., 2019).

In recent years, the global cultivation of potatoes has reached approximately 49 million hectares, with a total production of 359 million tons in 2021. China, India, and Ukraine are the leading producers of this species (FAO, 2023; Kurek et al., 2023). Potato production is mainly concentrated in some (28) Member States of the European Union, which account for ¾ (77.8%) of the total area and ¾ (78.9%) of the total quantity of potatoes. Germany is the leading EU country with 10.6 million tons (18.8% of total EU production), followed by France (15.2%), the Netherlands (12.3%), Poland (11.5%), the United Kingdom (9.3%), Belgium (7.1%), and Romania (4.7%) (Levaj et al., 2023). Over the last decade, approximately 0.2 million hectares have been cultivated annually in Romania, with a production of around 2.68 million tons (Jităreanu et al., 2020).

Over the years, the potato has established itself as a global food crop (Xu et al., 2023), having been a food source for humans for over 6,000 years (Alamar et al., 2017). Currently, there is a shift in consumer preferences towards potatoes, with a dynamic growth in the market for convenience foods and processed products, which has led to the intensive use of potato processing, thus contributing to the increase in demand for fast food (Uferah et al., 2019; Kurek et al., 2023). It is estimated that annual potato consumption per capita worldwide ranges from 44 to 140 kg (Boivin et al., 2020), while in Romania it is around 100 kg (https://www.madr.ro/, 2020).

The potato stands out as a versatile and nutritionally complex crop (starch, protein, fiber, minerals, polyphenols, carotenoids, vitamins, minerals), functioning as an antioxidant, antibacterial, anti-inflammatory, anti-allergenic, blood pressure, and cholesterol regulator (Bártová et al., 2009; Xu et al., 2023). It is widely cultivated in various soil and climate conditions, including temperate, tropical, and even subtropical regions (Agrawal et al., 2024).

From an agro-phytotechnical and agro-economic point of view, potatoes require easy cultivation methods and relatively low costs, being a good precursor plant for most crops, making good use of fertile soils with loamy-sandy and sandy-loamy texture, non-saline, non-alkaline, naturally loose, rich in organic matter, with good drainage and aeration (Brezuleanu, 2009; Sandoiu, 2012Koko et al., 2020; Agrawal et al., 2024). This is an additional reason for our country to relaunch production

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by creating and zoning varieties on all types of agricultural land, especially under irrigation conditions (Jităreanu et al., 2020).

Given the significance of the *Solanum tuberosum* L. species and the prospects for increased consumption and crop expansion, along with the demand for varieties resistant to soil and climate change while maintaining productivity, we proposed the following experimental study, which we conducted in four repetitions using seven potato varieties. In this paper, we analyze a series of morphological, physiological, biochemical, and productivity parameters of the selected experimental variants under the Arad area's soil and climate conditions with the aim of evaluating the possibility of expanding this crop.

MATERIALS AND METHODS

The following materials were used in the experiments:

- Alluvial soil with loamy-clay texture: pH = 7.1 - 7.3; Humus = 3.4 - 3.8 %; Clay = 33-34 %; Depth to groundwater = 55 - 60 cm; Mobile Phosphorus = 13.44 mg/100 g soil; Total Nitrogen = 0.16 - 0.18 mg/100 g soil (Ungureanu, et al., 2021);

- plots of 42 m^2 area, L = 10 m, W = 4.2 m, 2.8 m wide buffer zone, 2.8 m between repetitions, and 0.7 m between variants (Jităreanu et al., 2020);

Soil tillage consisted of:

- autumn plowing at 28-30 cm depth, leveled and kept free of weeds until sowing;

- seedbed preparation with a cultivator equipped with arrow-type active parts at a depth of 14 cm;

- planting in the third decade of March, at a density of 50,000 tubers/ha, at a depth of 6-8 cm, and at a distance of 70 cm between rows;

Fertilization was carried out when preparing the seedbed with NPK complex fertilizer as follows: N = 120 kg/ha, P = 110 kg/ha, and K = 70 kg/ha;

A monofactorial experiment was conducted with seven *Solanum tuberosum* varieties under normal technology conditions in 4 replications.

The potato varieties used as experimental variants were V1 - Armonia, V2 – Cosiana, V3 - Coval, V4 - Foresta, V5 - Gared, V6 – Productiv, and V7 - Desiree (martor) (www.madr.ro/ISTIS, 2023);

Morphological, physiological, biochemical, productivity, and economic analyses were performed separately on samples taken from 15 plants representative of each genotype.

RESULTS AND DISCUSSIONS

The application of optimal cultivation technologies in potato farming (Ahmad et al., 2023) has highlighted the growth and development of the seven genotypes taken into study. Potato varieties cultivated in Romania are categorized based on their vegetation period as follows: early varieties (up to 90 days), semi-early varieties (90-110 days), semi-late varieties (110-130 days), and late varieties (over 130 days). The analyzed cultivars were from the mid-late and late varieties range and had a vegetation period close to that mentioned by the breeders of the respective genotypes, ranging from 110 days (for *Desiree*) to 126 days (for *Gared*).

The vegetation period closest to that of the control was found in the *Foresta* (111 days) and *Armonia* (113 days) varieties, while the furthest from that of the control was found in the *Productiv* (122 days) and *Gared* (126 days) varieties (Table 1).

The climatic conditions in the Arad area: temperature, precipitation, cloud cover, and relative humidity were within normal range values, and didn't show any major differences from the multiannual average.

The temperature during the potato growing season, i.e., March to August, was within normal limits, allowing for the growth of vegetative and reproductive organs in all potato varieties taken into study.

Precipitation was relatively sufficient during the growing season, but the reduced amount in the first ten days of each month of the growing season had a slightly negative influence on the studied varieties. After June 20th, there was a decrease in atmospheric humidity and a slight increase in temperature, which caused a decrease in hydric and thermal comfort with implications for plant growth and development..

An analysis of the climatic conditions in 2023 indicates that they were favorable for potato cultivation (Figure 1).

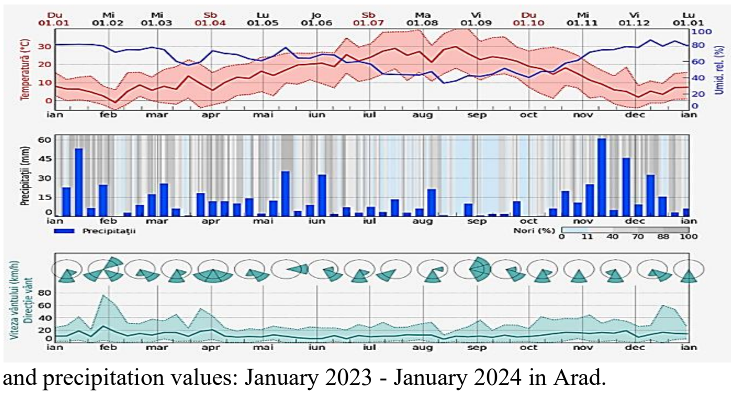

Fig. 1. Average temperature and precipitation values: January 2023 - January 2024 in Arad.
Source: https://www.meteoblue.com Weather Archive Arad.

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Table 1.
The influence of pedoclimatic conditions on the vegetation period of the varieties taken into study

No.	Variety	Vegetation period (days)	Difference to control lot (days)
1	*Armonia*	113	3
2	*Cosiana*	119	9
3	*Coval*	118	8
4	*Foresta*	111	1
5	*Gared*	126	15
6	*Productiv*	122	12
7	*Desiree* (control)	110	mt

It is well known that well-developed plants have advantages in terms of vegetative mass development, photosynthesis, respiration, resistance to diseases and pests, competition with weeds, and advantages that lead to high-quality macroproduction (Jităreanu, 2007). The seven genotypes studied responded well to the cultivation technology applied and to the soil and climate conditions in the area, with plant heights ranging from 84 cm for the *Foresta* variety to 97 cm for the *Gared* variety. Heights of over 90 cm were recorded for the *Coval* (90 cm), *Cosina* (92 cm), and *Productiv* (94 cm) varieties. The *Desiree* variety, which served as the control group, had a height of 88 cm, exceeding the *Foresta* variety by 4 cm and the *Armonia* variety (86 cm) by 2 cm (Table 2).

Table 2.
The influence of pedoclimatic conditions on the height of the varieties taken into study

No.	Variety	Plant size (cm)	Difference to control lot (cm)
1	Armonia	86	-2
2	*Cosiana*	92	4
3	*Coval*	90	2
4	*Foresta*	84	-4
5	*Gared*	97	9
6	*Productiv*	94	6
7	*Desiree* (control)	88	mt

Chlorophyll plays a fundamental role in the photochemical reactions of photosynthesis (Fortună et al., 2023), being considered the pigment responsible for the green color and for directing the metabolism and physiological state of plants, which induces the major importance of quantifying the total chlorophyll content in leaves (Jităreanu, 2007). Thus, low chlorophyll levels can signal nutritional deficiencies, hydric stress, or attacks by pathogens (Jităreanu, 2007).

Experimental analyses of potato leaves have revealed variable levels of chlorophyll "a" and "b." This variation is attributed to the distinct characteristics of the cultivated strain and the specific vegetation period during which the observations were conducted. The results of the quantification of the measurements taken 30 days after the plants sprouted indicate that the chlorophyll "a" content in potato leaves ranged from 14.9% in the *Desiree* and *Foresta* varieties to 15.8% in the *Coval* variety, with an average of 15.3%. After the vegetation period, we observed a significant decrease in the percentage content of chlorophyll "b" compared to chlorophyll "a," with values ranging from 4.9% in the *Armonia* variety to 5.3% in the *Productiv* variety, with an average of 5.1% (Table 3).

Table 3.
The influence of pedoclimatic conditions on chlorophyll content in leaves of the varieties taken into study

No.	Variety	Vegetation days (no.)	Clorophyll (%)		Difference to control lot (%)	
			Clorophyll „a”	Clorophyll „b”	Clorophyll „a”	Clorophyll „b”
1	*Armonia*	30	15,1	4,9	0,2	-0,2
		40	16,5	5,4	0,2	-0,1
		50	17,8	5,7	0,3	-0,1
		60	17,2	5,5	0,5	-0,1
2	*Cosiana*	30	15,7	5,2	0,6	0,1
		40	16,9	5,6	0,6	0,1
		50	18,1	5,9	0,6	0,1
		60	17,5	5,4	0,7	0,2
3	*Coval*	30	15,8	5,0	0,9	-0,1
		40	17,2	5.4	0,9	-0,1
		50	18,4	5,8	0,9	0,0

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No.	Variety	Vegetation days (no.)	Clorophyll (%)		Difference to control lot (%)	
			Clorophyll „a”	Clorophyll „b”	Clorophyll „a”	Clorophyll „b”
		60	17,7	5,7	1,0	0,1
4	*Foresta*	30	14,9	5,0	0,0	-0,1
		40	16,3	5,5	0,0	0,0
		50	17,6	5,8	0,1	0,0
		60	16,9	5,6	0,2	0,0
5	*Gared*	30	15,2	5,2	0,3	0,1
		40	16,6	5,7	0,3	0,2
		50	17,2	6,1	0,3	0,3
		60	17,0	5,9	0,3	0,3
6	*Productiv*	30	15,7	5,3	0,8	0,2
		40	17,2	5,7	0,9	0,2
		50	18,4	6,0	0,9	0,2
		60	17,7	5,8	1,0	0,2
7	*Desiree* (control)	30	14,9	5,1	mt	mt
		40	16,3	5,5	mt	mt
		50	17,5	5,8	mt	mt
		60	16,7	5,6	mt	mt

It is known that the dry matter in potato leaves correlates with the totality of solid compounds remaining after water removal through complete drying (Ungureanu et al., 2020), and its content varies depending on the variety, the stage of plant development, and environmental conditions, influencing photosynthesis and resistance to abiotic stress (Jităreanu, 2007). The dry matter content of the leaves after 30 days of vegetation ranged from 13.7% for the *Gared* variety, 15.1% for the *Cosiana* variety, and 14.7% for the *Desiree* control plot. The *Armonia* variety had the lowest dry matter mass at 14.5%, which was 0.6% lower than the *Desiree* control. The *Cosiana* variety had the highest value at 15.7%, which was 0.6% higher than the control.

Sixty days after sprouting, the leaves showed values of up to 16.8% for the *Cosiana* variety, 16.4% for *Coval*, and 16.1% for *Desiree*. The *Armonia*, *Foresta*, and *Gared* varieties had lower values of 15.8% and 15.9% for the percentage of dry matter content (Table 4).

Table 4.

The influence of pedoclimatic conditions on the dry matter content in leaves of the varieties taken into study

No.	Variety	Vegetation days (no.)	Dry matter (%)	Difference to control lot (%)
1	*Armonia*	30	13,8	-0,9
		40	14,5	-0,6
		50	15,1	-0,4
		60	15,8	-0,3
2	*Cosiana*	30	15,1	0,4
		40	15,7	0,6
		50	16,2	0,6
		60	16,8	0,7
3	*Coval*	30	14,7	0,1
		40	15,2	0,1
		50	15,8	0,2
		60	16,4	0,3
4	*Foresta*	30	14,2	-0,5
		40	14,7	-0,3
		50	15,4	-0,2
		60	15,9	-0,2
5	*Gared*	30	13,7	-1,0
		40	14,6	-0,5
		50	15,3	-0,3
		60	15,9	-0,2
6	*Productiv*	30	14,1	-0,6
		40	14,8	-0,3
		50	15,5	-0,1
		60	16,0	-0,1
7	*Desiree* (control)	30	14,7	mt
		40	15,1	mt
		50	15,6	mt
		60	16,1	mt

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Potato production is of significant importance in the food and economic sectors, playing a crucial role in global food, agriculture, and industry. Given the climate and soil conditions in the Arad area, potato plant growth and development were favorable, which is also reflected in the tuber production obtained from the studied varieties. The *Gared*, *Productiv*, and *Coval* varieties demonstrated the highest tuber production per unit area, with yields of 34.1 tons per hectare, 33.7 tons per hectare, and 33.3 tons per hectare, respectively. Lower tuber yields than the control variety *Desiree*, of 33.1 t/ha, were achieved with the varieties *Cosiana*, *Foresta*, and *Armonia*, with values of 30.2 t/ha, 30.9 t/ha, and 31.5 t/ha, respectively (Table 5).

Table 5.

The influence of pedoclimatic conditions on tuber production in the varieties taken into study

No.	Variety	Tuber production (t/ha)	Difference to control lot (t/ha)
1	*Armonia*	31,5	-1,6
2	*Cosiana*	30,2	-2,9
3	*Coval*	33,3	0,2
4	*Foresta*	30,9	-2,2
5	*Gared*	34,1	1,0
6	*Productiv*	33,7	0,6
7	*Desiree* (control)	33,1	mt

Moisture is an important factor in potatoes because it influences product quality during the drying process and processing, and is also associated with the shrinkage rate and potato colour (Muruganantham et al., 2023). The moisture content of the potato tubers studied ranged from 75% for the *Gared* variety to 79% for the *Armonia* and *Foresta* varieties, indicating their suitability for mass consumption. Varieties with a lower water content are recommended for processing. (Table 6).

Table 6.

The influence of pedoclimatic conditions on the moisture content in tubers of the varieties taken into study

No.	Variety	Humidity content (%)	Difference to control lot (%)
1	*Armonia*	79	1
2	*Cosiana*	77	-1
3	*Coval*	78	0
4	*Foresta*	79	1
5	*Gared*	75	-3
6	*Productiv*	76	-2
7	*Desiree* (control)	78	mt

Potatoes are rich in starch (60-90%), which is located in the tuber (Chorfa et al., 2022). Starch is also the main reserve carbohydrate that provides energy in tubers (Singh et al., 2023). The starch content in the potato tubers studied ranged from 16.9% in the *Foresta* variety to 19.8% in the *Gared* variety. The starch content in the tubers of the *Armonia*, *Cosiana*, and *Desiree* varieties was 17%, 17.2%, and 17.5%, respectively, and in the *Productiv* and *Coval* varieties, it was 18% and 18.6%, respectively (Table 7).

Table 7.

The influence of pedoclimatic conditions on the starch content in tubers of the varieties taken into study

No.	Variety	Starch content (%)	Difference to control lot (%)
1	*Armonia*	17,0	-0,5
2	*Cosiana*	17,2	-0,3
3	*Coval*	18,6	1.1
4	*Foresta*	16,9	-0,6
5	*Gared*	19,8	1,4
6	*Productiv*	18,0	0.5
7	*Desiree* (control)	17,5	mt

Potatoes contain a relatively small percentage of protein: 1–2.5%, but they are notable for their array of essential amino acids and peptides with antioxidant activity (Chang et al., 2020). The protein percentage in potato tubers in the tested varieties ranged from 1.9% in *Foresta* and *Armonia* to 2.3% in *Gared*. The control variety *Desiree* had a protein content of 2.1% in potato tubers, which was exceeded by the varieties *Coval* and *Cosiana* (Table 8).

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Table 8.
The influence of pedoclimatic conditions on the protein content in tubers of the varieties taken into study

No.	Variety	Protein content (%)	Difference to control lot (%)
1	*Armonia*	1,9	-0,2
2	*Cosiana*	2,2	0,1
3	*Coval*	2,1	0,0
4	*Foresta*	1,9	-0,2
5	*Gared*	2,3	0,2
6	*Productiv*	2,0	-0,1
7	*Desiree* (control)	2,1	mt

Potato tubers have a low content of essential lipids, ranging from 0.15 to 0.5% of fresh weight, but they may contain bioactive lipids with beneficial health effects (Levaj et al., 2023). The *Productiv* and *Cosiana* varieties exhibited the highest lipid content, with a value of 0.5%, while the *Armonia*, *Coval,* and *Desiree* varieties demonstrated the lowest content, with a value of 0.3%. However, this value represents an average percentage when compared to the range specified in the literature (Levaj et al., 2023) (Table 9).

Table 9.
The influence of pedoclimatic conditions on the percentage of lipids in tubers of the varieties taken into study

No.	Variety	Lipid content (%)	Difference to control lot (%)
1	*Armonia*	0,3	0,0
2	*Cosiana*	0,5	0,2
3	*Coval*	0,3	0,0
4	*Foresta*	0,4	0,1
5	*Gared*	0,4	0,1
6	*Productiv*	0,5	0,2
7	*Desiree* (control)	0,3	mt

Potatoes (*Solanum tuberosum* L.) are among the most significant annual crops from an economic perspective, distinguished by their high productivity, substantial yield per hectare, and consistent market demand. To ensure optimal returns, it is essential to invest in high-quality biological material and employ modern technology. This approach enables the maximization of profits, directly linked to effective resource management, disease prevention, and efficient production utilization (Daurov et al., 2024). Following the analysis of the potato varieties studied, from an economic point of view, the most suitable genotypes for use are *Gared* and *Productiv*, with a reported profit per unit area of 16,400 RON/ha and 16,000 RON/ha, respectively. At the opposite end of the spectrum are the *Cosiana* and *Foresta* varieties, with profits of 12,500 RON/ha and 13,200 RON/ha, respectively (Table 10).

In the future, further studies should provide an alternative to commercial cultivation not only of potatoes, but also of other economically important plants.

Table 10.
The influence of pedoclimatic conditions on the economic efficiency of the varieties taken into study

No.	Variety	Tuber production (t/ha)	Tuber production value (RON/ha)	Profit (RON/ha)	Difference to control lot (RON/ha)
1	*Armonia*	31,5	31.500	13.800	-1.600
2	*Cosiana*	30,2	30.200	12.500	-2.900
3	*Coval*	33,3	33.300	15.600	200
4	*Foresta*	30,9	30.900	13.200	-2200
5	*Gared*	34,1	34.100	16.400	1000
6	*Productiv*	33,7	33.700	16.000	600
7	*Desiree* (control)	33,1	33.100	15.400	mt

Price of potato tubers = 1.0 RON/kg; Price of potato tubers for sowing = 1.5 RON;
Production cost/ha = 17,700 RON; Profit = production value - production cost.

CONCLUSIONS

Analyzing the experimental data, it can be concluded that the *Gared*, *Productiv*, and *Coval* varieties are the most efficient in terms of tuber production and economic profit, with the *Cosiana* and *Foresta* varieties at the opposite end of the spectrum.

The recorded morphological, chemical, physiological, economic, and productivity values for the tested genotypes under the Arad area's pedoclimatic conditions indicate the successful cultivation of these varieties that would contribute to the sustainability of agriculture in the region.

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AUTHORS CONTRIBUTIONS

Conceptualization, O.C.U., E.U. and B.M.T.; methodology, O.C.U., I.O.S., E.U., M.E.F., B.M.T. and T.V.; data collection O.C.U., E.U., M.E.F., B.M.T.; data validation, O.C.U., I.O.S., E.U., M.E.F., B.M.T. and T.V.; data processing O.C.U., T.V.; writing—original draft preparation, O.C.U., I.V.U. and P.A.B.; writing—review and editing, V.B.B. and T.V.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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